Deken This is Jean Deken speaking with Marty Breidenbach on Thursday July 18th, 2019, about the history of the SL D project. And we're looking at the October 2001 presentation Marty gave on the history of SLD.[1]

Breidenbach [00:03:15] I put this together for the final collaboration meeting.

Deken [00:03:25] Before we actually start with the presentation, I wanted to ask you about the sort of prehistory of the SLD project. Why was it undertaken? Was there a particular impetus behind it?

Breidenbach [00:03:46] Yes. Burt [Richter] was getting SLC going, and the intention was to move Mark II yet again. Mark II began at SPEAR, went to PEP, and then they were going to move it to SLC. A few of us thought that Mark II was a woefully inadequate detector for SLC. Even to this day one can argue about whether that was really true, but that's certainly what we believed. We struck out on our own to build a collaboration and a proposal and a detector, which was SLD. The beginnings were most definitely due to a judgment of the technical inadequacy of Mark II.

Deken [00:04:58] What were the inadequacies that you were trying to overcome?

Breidenbach [00:05:03] We wanted a much better vertex detector which we thought would be crucial. David Leith thought it was an opportunity to add real particle identification and we wanted a much, much better tracker and calorimeter, and I think we accomplished essentially all of that.

Deken [00:05:23]Were you looking over your shoulder at any other projects internationally?

Breidenbach [00:05:33] At the beginning, not at all.

Breidenbach [00:05:37] But it was around that time that Burton spent a year at CERN, and he got them started on what became LEP, and then LEP most definitely became very real competition for us. If one believed the propaganda of that time coming from SLAC, mainly from Burt, we would be fine. We would be ready. We would have comparable luminosity; we would be turning on at a comparable time, and we would have polarization. In the beginning we certainly were not worried. However, as things evolved, we were much later than expected. There was a great heroic effort and a totally different story of making SLC work, and you should talk to Nan [Phinney] about that.

Deken [00:06:33] Yes, I intend to.[2]

Breidenbach [00:06:36] She was the center of that effort after a major reorganization. We were late, the luminosity was low, but we did have polarization. Still, there was a lot of trouble getting the polarization going. There's a whole long set of things that I can talk about, and Nan can talk about SLC the machine.

Deken [00:07:04]. OK so let's just talk about SLD then. So, you've got a slide up here for the six stages.
Breidenbach [00:07:15] Yes, that was a way of thinking about it. (I should put in as an aside that I really haven't thought about this talk probably in in 20 years.)

[1] PowerPoint presentation: SLC_History_Breidenbach_20022005 (SLAC AHRO collection)
[2] See Nan Phinney interview with David Zierler of AIP, July 16, 2020

Breidenbach [00:07:41We had been looking for international cooperation and much broader national participation, but it started very small. So, as you can see, [slide 3] around '82 we wrote a Letter of Intent. We had Caltech, Johns Hopkins, MIT and SLAC of course, and University of Washington. At that time, the conventional wisdom was that you could make fantastically good hadron calorimetry by having uranium as part of the structure. It was called "compensating calorimetry" and that was initially in our thinking, but beam tests and a great analysis by Jim Brau led us to get rid of that. We had a superconducting solenoid which would have been a very good thing to have both for physics performance and operating costs, but to be blunt, I think DOE [Department of Energy] screwed up yet again.

Deken [00:09:15] Oh, OK.

Breidenbach [00:09:16] They didn't believe our cost estimates. Burton wasn't being very helpful. We got into trouble when it finally came to real approval., We had this original extremely naive cost estimate of some 30 million dollars. There was some struggle within the broader SLAC user community about whether it should be a new detector, and whether we should use a tracker based on the new TPC concept. In 1983, Wit Busza from MIT…

Breidenbach [00:10:10] gave a talk to the Experimental Physics Advisory Committee convincing them to approve us. There were the canonical wars between SLAC and Fermilab, that we were 'stealing dollars out of D Zero's mouth.'

Deken [00:10:35] So the main cast of characters at SLAC was you Harvey Lynch, Charlie Prescott, Blair Ratcliffe... Who else at SLAC?

Breidenbach [00:11:00] David Leith was an original player.

Deken [00:11:04] OK.

Breidenbach [00:11:06] To be properly scholarly, we should find the L.O.I,

Deken [00:11:13] OK.

Breidenbach [00:11:13]
Deken [00:11:18] I've got it... SLD Design Report at SLAC, R 0273.

Breidenbach [00:11:32] So the Design Report is a much more polished document and came later. And the LOI was exactly what an LOI was in those days. It was a long letter, and you didn't need a truck to move it around, as you do these days.

Deken [00:11:52] Okay. I'd like to see a copy of that if you've got it.

Breidenbach [00:11:55] I'm certain that it’s around my office.

Deken [00:12:02] So that's the letter of intent stage.

Breidenbach [00:12:08] That's right. This is a somewhat bizarre view of the detector on a logarithmic scale so you can see what's inside (which would normally be a little dot at the center) We knew then that there would be a CCD vertex detector. That's kind of interesting

in and of itself: CCDs for vertex detectors were way ahead of the state of the art. We had in the collaboration Chris Damerell from Rutherford Lab.

Deken [00:12:47] Okay.

Breidenbach [00:12:47] The first one was VXD 1, followed by VXD 2, and in the end -- jumping way ahead of this story, we had VXD 3 which, with all due modesty, was and is the best vertex detector ever built.

Deken [00:13:09] Oh? Okay…

Breidenbach [00:13:10] In terms of vertexing performance. Admittedly, we didn't have to deal with the rates and radiation that the LHC does. That goes right up front. But in terms of precision performance, nobody's challenged it.

Deken [00:13:29] Interesting.

Breidenbach [00:13:32], The next slide is this telex [slide4].

Deken [00:13:52] Is there a date on this telex?

Breidenbach [00:14:12]. Here it is from Stanford California May 16th, 1983.

Deken [00:14:17] OK. See I see it now.

BREIDENBACH [00:14:20] This was sent to Chris [Damerell]. This was the collaboration building after we had a base at SLAC to begin to be serious.

Deken [00:14:45] So Damerell and his colleagues were the people that you wanted to help build the vertex detector?

Breidenbach [00:14:53] That is correct.

Deken [00:14:53] OK. And they were the experts on that? At that time?

Breidenbach [00:15:00] They had a complete hammerlock on the CCD technology which was the right way to go. Yes.

Deken [00:15:10] And what was their reaction to this telex? Do you remember?

Breidenbach [00:15:13] I don't remember precisely

Deken [00:15:34] But they came on board the collaboration ultimately

Breidenbach [00:15:37] Absolutely. They came on board and then I had Italian friends who joined us. This is Marcello Piccolo and his wife and friends. They became a strong part of the collaboration and then David Leith had collaborators he had worked with before in Japan who joined, and he knew the Canadians. So that was our international set.

Deken [00:16:09] OK.

Breidenbach [00:16:09] By modern standards, tiny, but by SLAC standards of the day,

enormous

Deken [00:16:16] OK.

Breidenbach [00:16:17] Then came the design report [slide 5] which you had mentioned, and that's it's number [SLAC-273]. This was a much more serious document. We still had the superconducting coil and still had the uranium, but by now we were up to 120 people and 26 groups. [SLAC Director] Panofsky had decided that he wanted an outside co-spokesman for this, and so he, more or less by himself, asked Charlie Baltay to join me, and this was incredibly felicitous. Charlie and I barely knew each other at the beginning but we became extremely close friends. I mean our families are friends to this day.

Deken [00:17:11] Wow.

Breidenbach [00:17:12] Nan and I are the godparents of one of Charlie's granddaughters.

Deken [00:17:23] Oh, wow.

Breidenbach [00:17:24] It became a super good friendship. It was again a little bit unusual because there were other examples of co-spokespeople at, for example, at Fermilab, at CDF, to be blunt, who fought tooth and nail.

Deken [00:17:40] Interesting!

Breidenbach [00:17:41] We just decided that it would be much better for everything if we weren't competing. The key to that was total openness. There wasn't e-mail yet, maybe that was fortunate. SLAC gave me a phone card. I don't know what Columbia did for Charlie, but we spent on average more than an hour on the phone every day.

Deken [00:18:09] Oh, wow.

Breidenbach [00:18:11] We talked and talked and talked. And that was key to this level of cooperation.

Deken [00:18:18] So he was not local? Or was he local part of the time?

Breidenbach [00:18:22] He was at Columbia.

Deken [00:18:24] And he stayed at Columbia?

Breidenbach [00:18:26] No.

Deken [00:18:26] No.

Breidenbach [00:18:27] He moved. I won't have the exact date.

Deken [00:18:30] OK.

Breidenbach [00:18:31] It was about ten years in: his third son was killed in an automobile accident. He liked to say that it was his wife Ginny who really needed a change of scenery. I don't believe it for a second: it was Charlie who needed the change of scenery. And they went to Yale.

Deken [00:18:59] Wow. But he was not on site at SLAC?

Breidenbach [00:19:06] He actually took several sabbaticals at SLAC. We were getting into a routine of having so-called "SLD Weeks." The SLD Weeks were key to this. We would take a full week once a month and go through various collaboration activities including a meeting for all the collaborators who were on site. People weren't expected to travel for that. But we had an Advisory Group of about a dozen people who were expected to travel for that. So, Chris Damerell typically came, Charlie [Baltay] came, David Hitlin who was at Caltech.

Breidenbach [00:20:05] would come up for all of these. We met on Thursday afternoons until sometime in the evening when everybody got hungry, and then we would go out for dinner together, relax, and perhaps have a little too much beer...

Deken [00:20:27] [laughs].

Breidenbach [00:20:27] This was a key part of making this organization work -- I'm quite serious.

Deken [00:20:32] No, I understand.

Breidenbach [00:20:33] And then anything unfinished, we'd try to resolve on the following Friday, starting in the morning, and it went on until we were done. There's a side story: early on, once Charlie was aboard, Pief called us in and explained what responsibility and authority meant. It was 'the authority for this experiment is with the co-spokespeople. It is not with any committee you may set up or anyone else might setup. If you guys screw up never dream of, coming to me and saying there's a problem, we didn't really want to do this, but the committee voted this way.'

Deken [00:21:29] Yeah, yeah.

Breidenbach [00:21:30] He just didn't want to hear that. That, to some extent, was an offshoot of the mess with the TPC [Time Projection Chamber].

Deken [00:21:41] Oh, OK.

Breidenbach [00:21:42] At PEP, which had a disaster. Their whole superconducting magnet imploded.

Deken [00:21:51] I didn't know that.

Breidenbach [00:21:53]. It was a design error. And then there was a lot of buck passing, and Pief wanted to make sure that was no buck passing would happen again.

Deken [00:22:03] OK.

Breidenbach [00:22:04] He told us that in no uncertain terms, and then, in typical Pief-style, there was a memo to files. He also sent us a letter, because he was really concerned about responsibility being delegated. You can delegate people to work of course but...

Deken [00:22:34] Right.

Breidenbach [00:22:35] we owned it.

Deken [00:22:38] The buck stopped with you.

Breidenbach [00:22:39] That is why the advisory group was called the advisory group. They didn't make decisions. They didn't vote. We never had a vote. We discussed things. That was accepted and I would say it worked rather well.

Deken [00:22:58] So, he was burned by what had happened at the TPC and he wanted to make sure that you guys did not fall into that same hole.

Breidenbach [00:23:06] Right…

Deken [00:23:08]. So, you guys knew that you were responsible.

Breidenbach [00:23:15] He made it so clear that it was unmistakable. And it's something I still remember to this day and it's still something I find very much wrong with the way that modern projects are run, because they're full of all these damn committees. They are not necessarily part of the project, but usually part of the host lab. They have completely diluted responsibility because they're busy making decisions. Once the committees start making decisions for you and telling you what to do and what not to do, the spokespersons are off the hook...

Deken [00:23:55] Sure.

Breidenbach [00:23:58] And, I think that's crazy.

Deken [00:23:59] Yeah.

Breidenbach [00:24:01] As a side comment, I was on one of those committees for Fermilab - the so-called LBNC, the Long Baseline Neutrino Committee… This was a committee of the Fermilab director, a perfectly nice guy. I like Nigel, but what this committee was doing was playing nanny to the DUNE experiment. DUNE had submitted a segment of a design report (now design reports are thousands of pages long and there are many sections). This section was pure unadulterated garbage, but they gave it to this committee to look at. And everyone just thought it was 'oh OK we just tell them that it needs a lot of work' and we go on. And I was aghast...

Deken [00:24:53] Really.

Breidenbach [00:24:55] Yes. I mean how can you do this? How could the spokesman let such a piece of crap out into the world? After stewing about this for a couple of months I resigned: I just didn't want to have any more to do with it.

Deken [00:25:09]. OK.

Breidenbach [00:25:11] OK. So, then some technical things… [returning to review of collaboration presentation]

Deken [00:25:17] OK. This is slide 6. OK.

Breidenbach [00:25:22] Do you remember Ed Temple?

Deken [00:25:24] No.

Breidenbach [00:25:26] Ed was the first guy to head what's become the DOE Office of Construction Management and Temple was the predecessor to Danny Lehman.

Deken [00:25:41] He was before my time then.

Breidenbach [00:25:46] Temple was. But you were contemporary with Danny Lehman, right?

Deken [00:25:49] With Lehman, sure.

Breidenbach [00:25:50] In the years after this, I've learned to question Temple's judgment even more. He didn't like the superconducting coil cost estimates, even though they were pretty serious by that time. Burton wanted to cut the budget that we had, and he wanted more contingency. Charlie and I had an interesting situation with General Dynamics. Their view was if the coil was going to be built in the US, General Dynamics was going to do it. Charlie and Bob Bell and I flew down to San Diego to visit them. Did you know Bob Bell?

Deken [00:26:45] I did. Yes.

Breidenbach [00:26:47] So Bob was our project engineer...that's another story. These conversations, Jean, are wonderful because I can go off on all these tangents.

Deken [00:26:55] Absolutely.

Breidenbach [00:26:57] The only time I really got Pief mad at me was when I stole Bob Bell. I seduced Bob Bell away from the SLC project and onto SLD. Bob loved the project and he liked working with us. Pief really got mad, but we made up. The three of us went down to General Dynamics for them to show us their facility and discuss their approach to such a project. We got into a mess talking to their 'Vice President for Extracting Dollars from Government.' They wanted a cost-plus contract. I explained that we only did fixed price, and this went back and forth. I explained that he was probably used to working with DOD or Defense people in DOE, and in the science side of DOE you only can have a fixed price. So, then this guy puts his foot up on a table and looks at us and says 'OK, you want fixed price, you can have fixed price no problem. But the coil is gonna be down here in San Diego and you want it up there in Menlo Park and I can assure you before it gets to Menlo Park, you'll pay us what we want, and our lawyers are better than your lawyers.' So, We went home. And then Charlie Prescott suggested, 'Screw the superconducting coil, just build an aluminum coil.' He also had some great ideas on how to make the drift chamber even better.

Deken [00:28:51] Mm hmm.

Breidenbach [00:28:52] We were then essentially back at the momentum resolution we had started from. It was interesting. There was essentially no technical risk with an aluminum coil, but it was a power pig. That's what SLAC bought. There were a lot of operating costs with that thing, but that's what Burt wanted. And that was the coil.

Deken [00:29:22] OK. [scrolls to Slide 6]

Breidenbach [00:29:23]… The quote on the slide is from the design report about the calorimeter., We planned to use and develop the method from CERN where fission in depleted uranium is used to compensate for the energy that disappears in an ordinary metal like lead when the nucleus is broken by a nuclear interaction. This had pretty much reached the level of accepted dogma, and we began to get depleted uranium at SLAC. And Jean, you may remember, some reporter found out that we were shipping in depleted uranium. I was called and I was more naive in talking to reporters at that time. There was a headline in The Mercury [San Jose Mercury News] 'SLAC physicist says Uranium is minimally radioactive'. I still have that around. [Slide 7]

Deken [00:30:49] Yeah.

Breidenbach [00:30:51] The heroes of this story were Jim Brau and Tony Gabriel, who were running detailed simulations of how this calorimetry process worked, and they began to raise serious doubts. However, they were doing a computer calculation and the compensation was pretty much a 'well-accepted fact.' So.

Deken [00:31:25] But their simulation was contradicting the well-accepted fact?

Breidenbach [00:31:32] Yes.

Deken [00:31:33] OK.

Breidenbach [00:31:35] So we wanted to do tests and they eventually got done but we had to make a decision. After much discussion and worry, what formally happened is Baltay and I said, 'we are not going to do uranium.' In hindsight, that was absolutely the right answer. I'm very glad we did that. D0 [D Zero experiment] got it wrong: they used uranium. In fact, we may have sent them a little bit of the uranium that we had left, and it was painful. Uranium doesn't do you that much good and it's not that expensive but it's hard to work with. You go crazy with safety. The stuff is not very dangerous, but it's hard to machine. The metal is not a problem, but the dust is. You don't want to inhale it.

Deken [00:32:30] Yeah.

Breidenbach [00:32:31] Then there was getting money out of the system. Things were a little different then. Formally, the money was equipment money which came to SLAC, and the Director doled it out. It was not project money coming from Washington to the project. SLAC got money and Burton gave us what he wanted.

Deken [00:33:07]… Let's go back to the money for a second. What was the financial situation in the early ‘80s? Was the lab budget pretty tight?

Breidenbach [00:33:19] It was fairly tight, and much tighter than it was 10 years ago. Burton, bless his heart, had low-balled SLC, so there wasn't a lot of money.

Deken [00:34:24] OK.

Breidenbach [00:34:26] So then things got started. We went out worldwide for bids on the iron structure and worldwide was indeed worldwide. This was a big purchase for SLAC, and they had all this very formal bidding procedure. Once this process started, we

weren't allowed to talk to anyone, and it's all done very correctly. We learned that the Japanese do not work like we do. They sure as hell talk to each other.

Deken [00:35:17] Oh, interesting.

Breidenbach [00:35:17] They decided, in Japan, that Kawasaki would put in the 'serious bid' and all the other big Japanese players, Toshiba, and a few others, would just put in 'courtesy bids.'.

Deken [00:35:39] Oh, interesting.

Breidenbach [00:35:40] The others were substantially higher, so it was obvious that Kawasaki was the Japanese winner. It was clear that it was way lower than anything from the US.

Deken [00:36:00] Interesting.

Breidenbach [00:36:01] SLAC was still antsy, and they went to DOE asking if was okay to have a Japanese bidder on about six million dollars. And DOE said 'you know, there's a "Buy American Act" and if they're 6 percent lower -- go ahead.'

Deken [00:36:26] Oh, okay.

Breidenbach [00:36:27] It was great. Working with Kawasaki was truly wonderful.

Deken [00:36:36] Oh good.

Breidenbach [00:36:37] They assembled it at their plant. Bob Bell took this picture [Slide 9].

Deken [00:36:47] Oh, okay.

Breidenbach [00:36:48] This was a test assembly [Slide 10]. Then they put it on the ship, Ruth Lykes [Slide 11]. Charlie, Nan [Phinney], and I got to the Marin Headlands at 4:00 in the morning to take this picture of SLD's ship coming in under the Golden Gate. This is it being assembled in the pit [Slide 12]. They sent along an engineer to advise on the assembly.

Deken [00:37:25] Did the engineer speak good English?

Breidenbach [00:37:28] Yes. Almost all of them spoke pretty reasonable English and the whole process with them was very nice.

Deken [00:37:41] Oh great.

Breidenbach [00:37:42] There are a couple of examples: when they were welding these door structures together, they had a problem with warping, and so they telexed us and said, 'there is a problem, these plates are warping, would it be alright if they put some spacers in?' And we said, we'd have to check to make sure the chambers that go there would fit. We checked; we sent back a note saying OK. And they sent back a note saying, 'Never mind, we ground it all apart. We did it again. We did it right. We don't want any spacers.' This was typical of the way they behaved. When the ship was unloaded, there

was a pallet with these big cans on it. I had no idea what this was. It didn't make any sense. And it turned out they had sent 100 gallons of touch-up paint.

Deken [00:38:39] Oh wow.

Breidenbach [00:38:41] That wasn't in the contract anywhere. It was just very nice. That took care of the iron. At the same time, we got talked in to doing the machining of the central drift chamber endplates at SLAC [Slide 13]. We had gone outside for bids as well. Kawasaki had given us a price we thought was high and a schedule we thought was pretty long and SLAC said: 'Oh no, we can do it just fine.' We bought SLAC a big rotary table which they didn't have, and which was necessary for them to do the machining. And it was done at SLAC. In the end the product was fine, but it cost more than Kawasaki, and took longer than Kawasaki.

Deken [00:39:41] Oh, really?

Breidenbach [00:39:42] So we learned yet another lesson.

Deken [00:39:45] If you had factored in the shipping from Kawasaki, would it have been comparable?

Breidenbach [00:39:58] Kawasaki bid the work FOB SLAC, so all delivery charges were included.

Deken [00:40:05] OK.

Breidenbach [00:40:06] It's part of their job to deliver it to us and they contract with the local heavy drayage to get the thing here. It was not our problem to get it through customs. it's not our problem to deliver it from the port, they had to do all of that.

Breidenbach [00:40:31] Yes, it was a very clean cost and schedule comparison.

Deken [00:40:34] Wow.

Breidenbach [00:40:36] This is the drift chamber [Slide 14]. I thought these were rather pretty pictures.

Deken [00:40:44] Those are great pictures.

Breidenbach [00:40:47] These are the guys stringing the drift chamber [Slide 15].

Deken [00:40:55] Who is that looking at it at the camera?

Breidenbach [00:40:58] I can guarantee you I'm not going to remember.

Deken [00:41:03] I just thought if you knew off the top of your head...

Breidenbach [00:41:08] If you want to find out, I can ask Peter Rowson. He typically has a memory that's really wonderful for this.

Deken [00:41:14] OK. I'll ask him then.

Breidenbach [00:41:16] This is a view of the thing when it's assembled.

Deken [00:41:25] Slide 16.

Breidenbach [00:41:26] Yes.

Deken [00:41:28] How long did it take to assemble?

Breidenbach [00:41:31] It was about two years.

Breidenbach [00:41:39] There was Mike Farrow, who I'm pretty sure was then at MIT. He found a better wire. And then there was a wire break. It took two weeks to remove that wire. That was the story with that.

Deken [00:42:08] Slide 17.

Breidenbach [00:42:08] These are the shielding for the triplets. They were called "Pacmen," because they came together and “ate” the beam line[3].

Deken [00:42:15] OK.

Breidenbach [00:42:16] There was a different attitude at SLAC then towards safety. We were not responsible for subcontractors -- totally outside people working on the site. The way it worked then was that their safety was their problem.

Deken [00:42:41] Okay

Breidenbach [00:42:41] That's totally 100 percent changed.

Deken [00:42:43] Hmm.

Breidenbach [00:42:47] We can argue whether that's reasonable or not. That's the way it was then. There was an injury with a sub who was welding on the innards of the Pacmen before they were filled with concrete. He fell off a ladder and into the rebar and messed up an ankle pretty badly.

Deken [00:43:06] Oh man.

Breidenbach [00:43:08] [Slide 18] This is the aluminum coil being wound at Mitsubishi: Bill Ash was the physicist leading that. This is obviously Bob Bell with the white hair.

Deken [00:43:25] OK.

Breidenbach [00:43:25] And this may be Bill Ash from the back. And at this point, SLAC wasn’t frightened of a Japanese procurement. It was obvious that Mitsubishi was the winner internally in Japan. They got to produce the real bid and they won. Here is the coil coming into Redwood City [Slide 19]… It went by ship from Japan to Oakland, by barge from Oakland to the port of Redwood City, and then it was put on this very long double gooseneck trailer truck. There's another picture of it here [Slide 20]. Here it is on El Camino. It is big.

[3] They look like pieces from the “Pac-Man” maze-action video game popular at the time

Deken [00:44:14] Yes. Yes.

Breidenbach [00:44:15] This was a Mitsubishi activity. They contracted with Sheedy to move this thing. Here it is on 280 [Slide 21]. We only took one lane of 280, but there were these other cars in the convoy. We basically shut down 280.

Deken [00:44:37] Wow.

Breidenbach [00:44:40] It all worked. Here's the coil going into SLD [Slide22]. You should note that the ironworkers are walking along relatively high up.

Deken [00:44:53] Yeah.

Breidenbach [00:44:54] Without any.

Deken [00:44:56] No harness....no safety harness

Breidenbach [00:44:56] No safety anything in those days.

Deken [00:44:58] Yeah.

Breidenbach [00:44:59] We hired iron workers who did high iron, and they didn’t do safety belts. To this day I don't know if somebody is working on a skyscraper, do they wear safety belts?

Deken [00:45:11] I think the high iron workers don't wear safety gear.

Breidenbach [00:45:19] They certainly didn't at SLAC, and that was an interesting safety challenge that I had early on. We had a wonderful tech who was, it turned out with a little bit of observation, not comfortable with these heights, but it was a challenge to his manhood, 'if they could do it, he could do it.' So, I had to take him aside and tell him that he was totally forbidden to do that, and if I saw him anywhere at all dangerous without complete fall protection, he was out of here. That worked OK. But that was one of the problems you had to watch out for with these guys. Excesses of testosterone with the crew!

Deken [00:46:20] Ah, gotcha.

Breidenbach [00:46:20] The calorimeter cryostat was also made by Kawasaki [Slide 23]. It was a big liquid argon cryostat. We didn't screw up and try to have it made anywhere else.

Deken [00:46:31] Was this the same delivery?

Breidenbach [00:46:34] This was another time and contract.

Deken [00:46:35] Oh, ok.

Breidenbach [00:46:36] It also went to Redwood City. It was a little bit bigger than the coil with all its packaging, and they had to lift the electric lines and in a few places the lines came down.

Deken [00:46:54] Oh my.

Breidenbach [00:46:56] It wasn't nearly as heavy as the coil. The calorimeter came as two separate packages. This is a component of the calorimeter in the pit in building 750 [Slide 24].

Deken [00:47:14] Is this aluminum?

Breidenbach [00:47:16] Yes.

Deken [00:47:18] OK. (And Slide 24).

Breidenbach [00:47:22] This is being put onto a structure which had been designed by Knut Skarpaas the father... The Knut we have now is the eighth

Deken [00:47:38] Knut Skarpaas VII, okay.

Breidenbach [00:47:40] Both Knuts were just amazing. Knut the father had exceptional organizational talents. He was calm and could guide people and do big things and was just amazing. Knut VIII is every bit as inventive, but he is more of a very high powered individual.

Breidenbach [00:48:34] Knut the father is such a super guy and it's unfortunate that he's now in very bad health. [4]

Breidenbach [00:48:46] I don't know if I have more pictures of this, but what he did was a real tour de force. You can see some of it in the background.

Deken [00:48:59] OK so this Slide 25.

Breidenbach [00:49:01] This is the assembly platform, and this big yellow thing is what manipulates individual modules. It was just an amazing bit of big machinery that he put together to be able to put this thing together: it was all thought through in advance.

Deken [00:49:16] Wow.

Breidenbach [00:49:19] This is indeed Knut VII [Slide 26]. Here is his gadget picking up one of the modules. Some of the modules were made here, but most were made at Caltech.

Deken [00:49:40] Slide 27.

Breidenbach [00:49:40] Here it is almost done.
Deken [00:49:47] Ok

Breidenbach [00:49:49] This is it done [Slide 28].

Deken [00:49:55] Was that rotated as they were putting the modules in?

[4] Knut Skarpaas VII died in 2020

Breidenbach [00:50:00]. No.

Deken [00:50:03] No?

Breidenbach [00:50:03] It's pretty heavy to rotate.

Deken [00:50:08] The barrel LAC?

Breidenbach [00:50:10] This tool was made so it could insert modules from underneath.

Deken [00:50:16] Clever.

Breidenbach [00:50:17] It could insert modules from any angle. No, it did not rotate.

Deken [00:50:20] OK.

Breidenbach [00:50:21] These stands went up and down for people access.

Deken [00:50:35] OK.

Breidenbach [00:50:36] People were on this platform and also on the other side. The tool delivered modules in the correct orientation to where the people were so they could bolt them in and wire them.

Deken [00:50:45] OK.

Breidenbach [00:50:46] ... Here it is getting ready to go into the detector coil. [Slide 29]. It's on this first section of the "Big Beam". There's a mating section that extends through the coil and is supported at the far end. It was a big thread the needle sort of thing. [Slide 30] Everything worked pretty smoothly. it weighed 500 tons, so the crane was utterly irrelevant. The crane does 100 tons, and this was 500 tons.

Deken [00:51:24] So what was the crane there for?

Breidenbach [00:51:28] For putting all the pieces together. The crane was fine for handling these pieces, and the crane limits were very much part of the design. The Big Beam pieces weigh no more than 100 tons.

Deken [00:51:41] OK.

Breidenbach [00:51:41] Here is Rafe [Schindler, Slide 31] who was in charge of putting the calorimeter together. He's trying not to look too nervous as it goes in...

Deken [00:51:58] As it goes in, what is it wrapped in?

Breidenbach [00:52:02] Super insulation. This is the heavy part and it's filled with liquid argon. This is the vacuum chamber which goes over it, and in between is the super insulation which decreases the radiation losses. That way we don't use as much liquid nitrogen to keep it cold.

Deken [00:52:32].OK.

Breidenbach [00:52:35] The outer cylinder goes in first. This is the coil which is already in place that was lowered down into the iron yoke with the crane. This is the outer vacuum cylinder. This is the inner cylinder wrapped with super insulation as it's going in. And here it's in.

Deken [00:52:55] OK.

Breidenbach [00:52:57] And here we have a bunch of more relaxed people [Slide 32].

Deken [00:53:00] Now that it's in you can relax a little.

Breidenbach [00:53:04] Yes

Deken [00:53:04] That draping that's behind all of you in this Slide 32, that's the super insulation also?

Breidenbach [00:53:15] No, that's just plastic sheeting to keep it clean.

Deken [00:53:19] OK.

Breidenbach [00:53:21] The vacuum area should be kept as clean as possible. It's high vacuum, but not ultra-high vacuum. You try to avoid something like a fly getting inside. It would be hard to pump down a physical bug.

Deken [00:53:45] Yeah.

Breidenbach [00:53:46] It's annoying but not a disaster for this kind of vacuum. It would be a disaster for ultra-high vacuum

Deken [00:53:53]. OK.

Breidenbach [00:53:56] Not everything was perfect. There was an argon leak.

Deken [00:54:01] Slide 33.

Breidenbach [00:54:02] It was a challenge to fix, but this welder was really good. We also learned the hard way that the cryostat cylinders were made from a somewhat exotic aluminum alloy. The first time the cooling loops were welded to it they didn't get good welds. We also learned that one should always X-ray these things and make sure that the welds look good.

Deken [00:54:42] Mm hmm.

Breidenbach [00:54:44] This endcap calorimeter was made at Columbia. That's what Charlie Baltay and gang were working on. Along with Mike Shaevitz.

Deken [00:55:00] Slide 34.

Breidenbach [00:55:06] This was the Colombia contribution. And this is the Warm Iron Calorimeter [WIC]. The detectors were made at MIT and Wisconsin and Italy. [Slide 35]

Deken [00:55:25] MIT and Italy?

Breidenbach [00:55:25] That was a big deal and a little contentious. A lot of the stuff here is being tested [Slide 36]. This is one of the barrel sections being trucked in [Slide 37]. Here they are stacked up in the drive outside Building 750.

Deken [00:55:53] Slide 38, 39

Breidenbach [00:56:02] This is the back before the calorimeter was inserted .

Deken [00:56:09] OK.

Breidenbach [00:56:10] We're going back and forth in time a little bit. One of the little problems we had is that the Warm Iron Calorimeter electronics took up more space than we thought. These spacer blocks were just to keep the door from flexing in too much, and they bear against the core iron. We cut these slots in the rest of the iron. That was annoying but we did it.

Deken[00:56:34] And it worked?

Breidenbach [00:56:37] It worked. These are the endcap particle identification systems.

Deken [00:56:43] Slide 40.

Breidenbach [00:56:43] They are the endcap Cerenkov Ring Imaging Detectors. They were built by Uriel Nauenberg at the University of Colorado.

Deken [00:57:00] OK.

Breidenbach [00:57:01] This is a view of the inside of the CRID [Slide 41]. You can't really see too much - it was hard to get a good picture. Jaroslav Va'vra was the inventor of CRID, and was very involved in the design, construction, and testing it. This is one of the sensor test rigs, and it was the so-called "sewer pipe." [Slide 42] And.

Deken [00:57:20] Was it really a sewer pipe?

Breidenbach [00:57:22] No.

Breidenbach [00:57:27] Here's another picture of the innards of the CRID.

Deken [00:57:30] Slide 43.

Breidenbach [00:57:30] It's kind of pretty. It's still sitting there, to this day. So, a side story again is, SLD is there. Altogether it weighs about 4000 tons.

Deken [00:57:44] Oh my.

Breidenbach [00:57:45] The last person who had the slightest clue of how to take it apart is me, and maybe Martin Nordby remembers a little bit. They've sent the computer that's needed to open the doors to computer heaven to make space. I don't think it is going anywhere from where it is right now.

Deken [00:58:14] Goodness.

Breidenbach [00:58:15] If children come to see this place in 50 years, I'm pretty sure it'll still be there.

Breidenbach [00:58:27] This view has the calorimeter in place [Slide 44]. This is another one of Knut VII's clever ideas. This is a stainless oblong hoop that we used to call the "rubber band" which goes around the inner cylinder, so there are two on each end, and go to big cams in the top steel. They are what's taking the 500-ton load. In an earthquake, it can only sway a little bit because of way it's held, if it tries to rock this way it has to go up, and it can only do that a little bit. They control the transverse motion in an earthquake. There are four of these shock absorbers on each side, which go against the door and resist earthquake longitudinal motion. The earthquake systems got tested during Loma Prieta[5] and they worked fine: one of them squirted a little oil. They were engineered by our Canadian colleagues. They are technically a big deal because they have to hold the inner cold mass when it moves, but during normal operation, they can't be a heat leak. You can't just have something big pushed against the cold mass, So it's quite tricky. They wanted to test them with a real transient load. The story is that they were given an opportunity to use Boeing's 747 shock absorber test facility.

Deken [01:00:20] Oh.

Breidenbach [01:00:23]. Now, small parts.

Deken [01:00:26] Slide 45.

Breidenbach [01:00:27] The University of Oregon built this high precision luminosity monitor. It had small silicon pixels, certainly small for then. It was the first to use silicon with tungsten radiators, and that is now used all over the place.

Deken [01:00:52] Interesting.

Breidenbach [01:00:55] This is the young Gunther Haller [Slide 46].

Deken [01:00:57] OK.

Breidenbach [01:00:59] I hired Gunther to rescue the Drift Chamber electronics, but then he basically got involved in everything. There are the calorimeter electronics mounted directly to the calorimeter.

Deken [01:01:44] Okay.

Breidenbach [01:01:45] [Slide 47]. For the 1980s, this was way the hell ahead of its time.

Deken [01:01:53] And this was designed by who?

Breidenbach [01:01:56] It was certainly at SLAC. Gunther was involved.

Deken [01:02:14] But it was a SLAC design?

[5] Loma Prieta earthquake, October 17, 1989, 5:04 p.m.

Breidenbach [01:02:17] No question: And it was unusual because it put the preamplifiers right up against the calorimeter cryostat. This is a test board, and this is the actual electronics.

Deken [01:02:38] Okay.

Breidenbach [01:02:39] The preamps went right up against the detector. There were no intermediate cable plants. We got rid of cables, and the so-called CDU, the Calorimetry Data Unit, recorded signals from the preamp and then digitized them. From here only optical fibers came out. It was way the hell ahead of its time.

Deken [01:03:02] Wow. OK.

Breidenbach [01:03:05] We used a modular data acquisition system called Fast Bus. This may have been its first and last major use. We had a board fire [Slide 48]. We recovered but it was a bit exciting. These were the full set of Fast Bus racks in a room on top of the detector. This is J.J. Russell, our data acquisition architect.

Deken [01:03:29] OK.

Breidenbach [01:03:29] He is still at SLAC.

Deken [01:03:31] This is Slide 49.

Breidenbach [01:03:32] This is Mike Huffer, who is also still here. [mentioned in caption, not pictured]

Breidenbach [01:03:43] And this is Joanne Bogart. [mentioned in caption, not pictured]

Deken [01:03:49] OK.

Breidenbach [01:03:51] JoAnne is also still at SLAC. This is where they started out.

Breidenbach [01:04:09] Now a new story [Slide 50]. We decided to put in superconducting focusing quads. The quadrupoles themselves were built for us at Fermilab. They knew how to do it. We, SLD, and not even SLC, were going to put together these superconducting quads for SLC.

Deken [01:04:45] Yeah.

Breidenbach [01:04:46] This is Bill Burgess, and these are two cryo techs. We had recruited Bill from CERN, but I think he just wanted to come to California. He knew the latest and greatest in cryogenics and helium technology from CERN. And we had the eminent guru of cryogenics Bob Watt. Did you overlap with Bob Watt?

Deken [01:05:17] I have heard of him, but I never overlapped with him.

Breidenbach [01:05:22] Bob came to SLAC from LBL, when they had big hydrogen bubble chambers.

Deken [01:05:31] I think that's right.

Breidenbach [01:05:33] He had a style which I would say you can't do anymore, and you really couldn't even do in SLD days. He wanted to be “ultra-super” conservative. And then just in case that didn't work, he wanted a complete alternate conservative system, and if that didn't work there would be another alternate conservative system.

Deken [01:06:03] So he had a system and two backups?

Breidenbach [01:06:08] It was very conservative!

Deken [01:06:10] Yeah. Okay.

Breidenbach [01:06:10] Bill arrived, and he said, 'You don't need any of that. There's a trivial way of doing it, we'll do it with this flexible helium line, and you don't need any of that crap with a little bit of computing and a control system. We can do it for 5 percent of the cost of what Bob Watt was talking about’. So, we had the helium wars.

Deken [01:06:46] OK.

Breidenbach [01:06:47] Watt wrote a very formal letter to Burt [Richter] saying what Burgess was proposing wouldn’t work. Watt was the great old man of cryogenics.

Deken [01:07:04] Right.

Breidenbach [01:07:05] Burgess was a young guy at that time. And we were all relatively young, perhaps 40.

Deken [01:07:12] Yeah.

Breidenbach [01:07:12] It took a lot of guts to go up against Watt, and Burt did what might be the coward's way out. He convened a committee to look at this and they more or less said 'well we don't see any reason why the Burgess method won't work.' So, it got punted to Charlie and me, "Pief style," and we said, 'OK Burgess, go ahead.' I don't think Watt ever talked to us again.

Deken [01:07:48] Oh my.

Breidenbach [01:07:50]

Deken [01:07:50] Was Burton Richter the director at that point?

Breidenbach [01:07:56] Yes, he became the director shortly after SLD got going.

Deken [01:08:01] OK.

Breidenbach [01:08:03] I don't remember the exact date, but we were certainly dealing with Burt at this point.

Deken [01:08:07] OK.

Breidenbach [01:08:10] Bill Ash. You knew Bill, right. [Slide 50]

Deken [01:08:13] No, Bill was gone before I came to SLAC. I came in ‘96.

Breidenbach [01:08:21] Jean, somehow, I think you've been here forever, but ‘96 doesn't really count as forever.

Deken [01:08:25] No it doesn't, does it?

Breidenbach [01:08:27] Bill Ash was an utterly marvelous guy, good friend, and super physicist. He was leading this effort. And in ‘94, he died of cancer.

Deken [01:08:56] Slide 51.

Breidenbach [01:08:57] VXD3.Again, we had our problems with Burt. This was such an obvious thing to do, to build a superb vertex detector, but he was still having money problems. This wasn't very expensive; it was a few million dollars. There was a meeting of the EPAC [Experimental Program Advisory Committee]. We wanted to make a proposal for this and pitch its unique capabilities. Burton had said that we couldn’t make a pitch to the EPAC.

Deken [01:10:05] Uh-Huh.

Breidenbach [01:10:06] So, do you know the Magritte painting of a pipe which has a title on it which in French is ‘this is not a pipe’?

Deken [01:10:18] Yes, yes.

Breidenbach [01:10:20] So I began that part of my talk with that picture of ‘this is not a pipe’. And the following is not a proposal!

Deken [01:10:34] [laughs].

Breidenbach [01:10:34] When Burton realized what was going on, he started yelling at me and stormed out of the room.

Deken [01:10:42] Oh my!

Breidenbach [01:10:44] Another one of my dubious accomplishments. We were sure that if Burton would just listen, he'd be convinced. Unfortunately, it was impossible to get him to listen. He was mad at me, etc. So we went to Sid Drell, who was consistently wonderful always.

Deken [01:11:09] Indeed. Indeed.

Breidenbach [01:11:09] We talked to him, and Sid took on the job of convincing Burton that this made complete sense. He succeeded. We put together a pretty big collaboration for the time. It was a lot of work to build this thing. Various components were zipping back and forth all the time, so FedEx was important.

Deken [01:11:40] Uh-Huh.

Breidenbach [01:11:42] And it eventually got done!

Deken [01:11:46] If you go back to Slide 51. Give me a sense of the scale. Is that the size of the palm of a human hand? Is that smaller?

Breidenbach [01:11:57] It's a big beer can.

Deken [01:12:03] A big beer can, okay.

Breidenbach [01:12:04] The place where this is located today, right now, is in my office.

Breidenbach [01:12:09] You can come by and see it.

Deken [01:12:19] Oh great. This is Slide 52

Breidenbach [01:12:20] Here it's wrapped up inside all of the cables.

Deken [01:12:24] Okay.

Breidenbach [01:12:25] The connections are being made here. It's hidden behind the cables. This was the most delicate part of the assembly where the two halves are mated around the beam pipe. The whole assembly team was afraid of actually doing the mating. There was no real tooling built to do the mating. So, this is me. I had to show how you can be calm and put it together.

Deken [01:12:46] I see. This is Slide 53 and you're the person at the left.

Breidenbach [01:12:52] Yes. I'm putting it together and everybody else is watching and making sure that I don't hit anything on the way in.

Deken [01:13:00] Because if you hit anything what would happen?

Breidenbach [01:13:03] You could break the CCDs. They are quite fragile.

Deken [01:13:08] OK.

Breidenbach [01:13:10] Here it is inside the cryostat ready to go.

Deken [01:13:14] Slide 54.

Breidenbach [01:13:14] It's a complicated assembly, but it’s ready to go in.

Deken [01:13:21] Slide 55.

Breidenbach [01:13:34] So onto natural disasters. It was during Christmas break of 1991. Nobody was around.

Deken [01:13:50] Oh.

Breidenbach [01:13:51] We had a 100-year freeze. Essentially any plumbing which was exposed to the outside that didn't have flowing water burst. SLD had no damage, but the rest of SLAC was pretty amazing. Every klystron in the linac had glass flow meters. I think they were almost all broken. Lots of plumbing burst.

Deken [01:14:23] Oh, my!

Breidenbach [01:14:25] These are burst parts from fire sprinkler systems. This is a heat exchanger broken apart. It was quite amazing to be watching. Nan [Phinney] and I had gone into SLAC. We were driving around, and we'd hear a "kapow" and there'd be a geyser.

Deken [01:14:46] Oh my!

Breidenbach [01:14:47] It took a while to get that fixed. Then there was the

Deken [01:14:54] Slide 56.

Breidenbach [01:14:54] ... Loma Prieta [earthquake]. There's a bit more of a story here too.

Deken [01:15:00] OK.

Breidenbach [01:15:01] This beam's sole purpose was the backing for the two lower shock absorbers. It was only a safety measure that was intended to be in place when the detector door] was open. We had gone quite a while without these beams in place, largely because they were in the way of other installations and because we had not gotten around to it. I pretty much lost it at some point and insisted that those beams were going in that week. And then a few days later Loma Prieta hit. The crew thought I had special connections.

Deken [01:15:50] That you had some sort of special powers?

Breidenbach [01:15:53] Yes!

Deken [01:15:53] Yeah.

Breidenbach [01:15:54] So they worked when Loma Prieta struck. There were people working on the detector, and there were people up in (what were then called) man-lifts there. It was frightening, but no one was hurt. We were having an Advisory Group meeting in my office at the time. You could see ceiling tiles coming down and chairs falling over.

Deken [01:16:13] Yeah.

Breidenbach [01:16:14] My file cabinet drawers opened and the whole cabinet tipped forward. .

Deken [01:16:16] Did you all go under the table when it was hitting?

Breidenbach [01:16:18] No.

Breidenbach [01:16:21] We learned in the next few hours how big a deal it was and how much damage was done in San Francisco. Nan and I had tickets for some concert that night in the city. After our first round of inspection at SLAC, we thought there was no serious damage, and we could still go to our concert. But then we heard more. It was clear that every event was canceled. SLC was really OK. There was a misalignment which took a while to get fixed, but no real structural damage.

Deken [01:17:06] So this is slide 57, social issues.

Breidenbach [01:17:09] Social issues… Our software group was... "Competitive," and that's being a little bit mild.

Deken [01:17:27] Competitive with each other?

Breidenbach [01:17:29] With each other.

Deken [01:17:30] Got you.

Breidenbach [01:17:31] The essentially perfect real-time code that talked to Fastbus was professional, but the people who wrote more of the off-line software were amateurs. This was an opinion held by the Fastbus software engineering people. It caused a lot of management difficulties.

Deken [01:18:01] Were these all SLAC employees?

Breidenbach [01:18:05] Yes, mostly SLAC employees.

Deken [01:18:06] Mostly SLAC.

Breidenbach [01:18:08] For organization, we were a “collaboration,” which meant that we worked together. I don't remember the argument for collaboration versus confederation.

Breidenbach [01:18:51] OK so we had a lot of collaboration meetings. That was fine.

Deken [01:18:58] So Caltech had the best food huh? [Slide 58].

Breidenbach [01:19:00] That's right. That was clear. That was Dave. And.

Deken [01:19:07] Slide Fifty-nine.

Breidenbach [01:19:08] We peaked at one hundred and eighty people and a modern collaboration. At LHC the collaboration sizes are three thousand people.

Deken [01:19:17] Gee whiz.

Breidenbach [01:19:19] So.

Deken [01:19:19] It's quite a difference.

Breidenbach [01:19:21] It's pretty amazing.

Deken [01:19:22] Yeah.

Deken [01:18:35] Okay.

Breidenbach [01:18:37] Then we had the emperor's visit[6].

Deken [01:18:44] Yeah. There are a lot of famous pictures of when the emperor and empress came.

Breidenbach [01:19:22] This shows some of the preparations for the emperor's visit. This is the Control Room and Data Assembly Room.

Deken [01:19:34] Slide 60. So, what did you do with all those monitors and computers?

Breidenbach [01:19:38] We actually pushed half the room away, condensed the computer area and made a fairly large room available. There were potted plants and Oriental rugs… Here on slide 61, the plan was that they were going to come down to the floor of the Collider Hall using the elevator.

Deken [01:20:02] The pit where the where the detector actually sat?

Breidenbach [01:20:05] Yes.

Deken [01:20:06] OK.

Breidenbach [01:20:07] Here's Burt [Richter] leading the way. [Slide 61]

Breidenbach [01:20:36] Mike Huffer was the designated elevator driver. The elevator was on Fire Department Mode…
Deken [01:21:01] okay.

Breidenbach [01:21:02] Which means that you can't summon it at all. It's completely controlled from inside the elevator.

Deken [01:21:09] Right.

Breidenbach [01:21:10] If he is in the elevator and presses down, it goes down. It totally ignores the outside buttons until the Fire Mode is turned off with the key inside the elevator…

Deken [01:21:19] Right.

Breidenbach [01:21:19] So Mike sees the entourage of limousines start to come and he jumps in the elevator and comes down to where I'm waiting on the pit floor. And he comes running over and says, "They're coming, they're coming." And as he says that behind him one sees the elevator door closing. And that was it.

Deken [01:21:47] Oh. No.

[6] Emperor Akihito and Empress Michiko of Japan, June 23, 1994, visit to SLAC

Breidenbach [01:21:47] Yes. The elevator door was closed. There was no opening it. We could not ask the emperor and empress to descend stairs: that wouldn't do.

Deken [01:22:01] No, no, no.

Breidenbach [01:22:03] So we had to fake it all on the grade-level floor, which is what you're seeing in this slide.

Deken [01:22:13] OH NO.

Breidenbach [01:22:15] That was one of our favorite stories of the visit.

Deken [01:22:20] So then the emperor and the empress never got down into the pit.

Breidenbach [01:22:23] That is true.

Deken [01:22:25] Oh my.

Deken [01:22:33] This is Slide 62.

Breidenbach [01:22:34] I don't know if you know Phil?

Deken [01:22:36] No.

Breidenbach [01:22:37] This is Phil Burrows. Phil is one of our Brit collaborators. He's still a good friend. This is Charlie Baltay's son.

Breidenbach [01:22:47] Michael was working as an engineer on SSRL at the time.

BREIDENBACH [01:22:55]. I don't know who this is.

Deken [01:23:01] So the red ribbons were just part of the...?

Breidenbach [01:23:04] I think they were for identification.

Breidenbach [01:23:06] The Secret Service was there. This is Slide 63. This is what the scene looked like.

Deken [01:23:11] OK.

Breidenbach [01:23:12] Lots of limos, and television is broadcasting from their trucks.

Deken [01:23:15] OK.

Breidenbach [01:23:16] There's a lot of security around. Which is the lead-in to the next slide. These are security people.

Deken [01:23:26] OK.

Breidenbach [01:23:34] It's Gil Shapiro.

Deken [01:23:41] Gil Shapiro. OK.

Breidenbach [01:23:43] This is Gil Shapiro and Mike Woods. So where were they? They had wanted to get a really good picture of the emperor and empress and they were hiding behind the bushes someplace. This area had all been cleared of people by Secret Service, but they were hiding, and didn't get found. And then they did get found with their cameras hiding behind the bush. After the entourage had departed, I'm summoned to the front of the building. There was a bunch of these guys in black suits with Gil and Mike in handcuffs.

Deken [01:24:25] In handcuffs?

Breidenbach [01:24:26] In handcuffs, saying " Do you know these guys?" The temptation to say "no, never saw them before" was enormous.

Deken [01:24:36] I'll bet.

Breidenbach [01:24:37] But no, I say ‘they're mine.’

Deken [01:24:40] Yes.

Breidenbach [01:24:41] "What did they do?" The idiots were hidden behind some bush with their cameras.

Breidenbach [01:25:00] After the visit there was a picture of everyone who was around on SLD, and you're supposed to see that everyone has a coat and tie.

Deken [01:25:10] They're all dressed up, Yeah.

Breidenbach [01:25:12] And this is what the crowd normally looks like.

Deken [01:25:15] That's slide 65 and 66.

Breidenbach [01:25:17] That's right.

Deken [01:25:18] Okay. So, to back up for a second. What was the occasion of the emperor and empress’s visit? Did they specifically want to come because you had had components made in Japan?

Breidenbach [01:25:31] Part of it was that we had a significant Japanese collaborators… Certainly, that wasn't enough for them to come…

Deken [01:26:06] Slide 67.

Breidenbach [01:26:08] These were our expectations for 1989. The luminosity that we had earlier was about 10^27, and we wanted 10^28. Nan [Phinney] and company pulled it off.

Deken [01:26:38] Slide 68.

Breidenbach [01:27:02] This is the Z estimates for the day. We were way beyond what we were expecting.

Deken [01:27:15] Slide 68.

Breidenbach [01:27:16] And then the positron target failed.... The end of SLC and SLD was the best performing week, day, hour, and minute. It really was a fitting way to go out.

Deken [01:27:44] Hmm.

Breidenbach [01:27:45] The analogy that I used talking to the operators later was I consider it an America's Cup race. You're rounding the final mark and the keel falls off.

Deken [01:27:58] Oh my.

Breidenbach [01:27:59] …and you capsize.

Deken [01:27:59] Yeah.

Breidenbach [01:28:00] That was my analogy… And that is the end of the slides.

Deken [01:28:08] Let me just check my list of questions here.

Deken [01:28:18] How in terms of the success of SLD: what was happening at CERN with LEP ? Was there a competition between the two? Was one more successful than the other?

Breidenbach [01:28:42] The issue boils down to who is doing the most important, "Bleeding Edge" physics with the Z. As things turned out, for those analyses which required lots of luminosity, we could not compete. We did not have that kind of luminosity. But we had two things that were critical. We had polarization and we had VXD3, and on those they couldn't compete.

Deken [01:29:22] Okay.

Breidenbach [01:29:22] With the polarization, we were able to do measurements of the so-called weak-mixing angle, which is fundamental in electro-weak theory. It's also known as the Weinberg angle. This leads to a prediction, given the mass of the top quark which came from Fermilab, to the mass of the Higgs. In the early 90s, I would say we knew the mass of the Higgs and there was an attempt by LEP-2 to reach it. They came very close. LEP provided a lower limit, and we provided an upper limit and so we knew pretty well where it was. Then there was what I would call a lot of crap from LHC when they're starting up saying we don't know where it is, it could be anywhere. They searched all over. When they finally found the Higgs, it was precisely where it was supposed to be. I even won my largest ever physics bet!

Deken [01:30:43] A-ha!

Breidenbach [01:30:43] So that was a big thing, entirely based on polarization. There was a lot of detailed B physics that we could do. That was supplanted by the B factories and by

BaBar and Belle. I would say SLD was way ahead of its time, and that was courtesy of VXD3. We did pretty damn respectably where the vertex detector or and or the polarization was important.

Deken [01:31:20] OK, another question that I have: You're a much smaller collaboration then than LHC or even BaBar and Belle.

Breidenbach [01:31:31] That's right.

Deken [01:31:31] How was communication and how were communications and publications managed within the collaboration?

Breidenbach [01:31:43] We had "SLD weeks" every month and also full collaboration meetings. The collaborators were not required to come every month, but they were strongly encouraged to come to the collaboration meetings, and everyone did. They typically were held at some reasonably pleasant location.

Deken [01:32:18] How often?

Breidenbach [01:32:20] We tried to do them offsite, because it kept people from running off to their desks or having some horribly important meeting.

Deken [01:32:29] Yeah.

Breidenbach [01:32:30] I think that worked well and that's where papers were discussed. With 150 people who had any level of interest in a paper, it wasn't that hard.

Deken [01:32:44] Sure. And how often were the collaboration meetings held?

Breidenbach [01:33:00] We'd try to do two a year. When there was a lot of data to discuss, it was twice a year.

Deken [01:33:12] How was authorship arranged? Everybody was on all papers?

Breidenbach [01:33:23] It was a bit complicated. Everybody was on all papers if you were still part of the collaboration. If you left, you were on for a year after you left.

Deken [01:33:36] OK.

Breidenbach [01:33:38] For collaboration management, we had the Advisory Group which was the really important part. We also had a Collaboration Council consisting of the P.I. from each university The responsibilities of the P. I.'s, of the council, were primarily to decide on admission of new collaborators; and to determine publication policy. For example, they decided how long you had to be a member of the collaboration before your name went on a paper, and how long after you left. In principle they had the power to remove spokespeople but that never happened.

Deken [01:34:46] Oh, okay…

Breidenbach [01:34:47] The membership on the Advisory Group was absolutely not representative of the institutions. They were simply the people we had chosen to lead the major subsystems plus a few more wise people. So, it wasn't representative at all. The

way we met with the collaboration every SLD week helped a lot. Charlie and I produced agendas for the advisory group meeting -- fairly formal agendas -- but we shared them in an open meeting with the collaboration. Everyone was welcome. It was typically about 40 people. We went over the agenda and asked for input, so the Advisory Group heard from the collaboration before its meeting. It was a very nice way for everyone to contribute, since trying to get tricky stuff done with a large group wouldn't work.

Deken [01:35:57] OK. Then the next question I have is, how did you manage coordination with the SLC group. I assume they functioned fairly separately but there was had to be some kind of connection?

Breidenbach [01:36:17] That's a very dangerous question. I was living with the person who was running SLC! [Nan Phinney.]

Deken [01:36:26] OK so.

Breidenbach [01:36:30] I don't think there were any regularly scheduled meetings. SLC had a meeting which started at 8:00 AM every day.

Deken [01:36:51] OK.

Breidenbach [01:36:51] 7 days per week!

Deken [01:36:52] OK.

Breidenbach [01:36:53] Burt came to that very regularly, and it was an opportunity mostly to talk about issues with the machine. There was time to discuss interface issues between SLC and SLD.

Deken [01:37:12] Okay.

Breidenbach [01:37:13] And then, we had a daily 8:30 meeting at SLD where we went over the issues of the day.

Deken [01:37:20] Okay, okay.

Breidenbach [01:37:22] Those meetings helped a lot for tactical coordination and some strategic stuff. More ad hoc, there were strategy groups that Burt formed. Nan [Phinney] led some of them and you should talk to Nan directly about how that worked out.

Deken [01:37:46] I want to set up a set of interviews with her too, once you and I are done. So, Burt was intimately involved all along?

Breidenbach [01:38:01] Well....

Deken [01:38:02] Or not?

Breidenbach [01:38:02] Hmmm…

Deken [01:38:05] Only dipped in occasionally?

Breidenbach [01:38:20] Burton had delegated the real leadership of SLC the machine to Rae Steining. Did you know him?

Deken [01:38:34] I've heard the name… usually said as a.negative...

Breidenbach [01:38:37] Rae Steining was sort of a weird guy. He was plenty smart. And he had a style of management which Nan described as “Attila the Hun." Management was through fear and intimidation.

Deken [01:38:55] Yeah.

Breidenbach [01:38:56] It didn't work all that well because most of the technical staff adopted tactics of staying out of his way, 'Keep your head under the table and he won't know you're there, so he won't cut off your head.' It was amazing to me. When I talked to him, we would have these discussions about how he wanted to knock off this person and that person. It was the kind of fantasy that anyone in a leadership position would know as pure fantasy.

Deken [01:39:37] Sure.

Breidenbach [01:39:38] But with Rae it wasn't fantasy.

Deken [01:39:40] It wasn't? Oh my.

Breidenbach [01:39:41] And it took me a long time to figure out that he wasn't just musing about how nice he would be if he could do this. He really tried to do it.

Deken [01:39:50] So he wasn't just letting off steam?

Breidenbach [01:39:52] No. So, things degenerated. And then there was this famous DOE review: things were not going well, and the committee heard a lot of the crap that was going on. They had a lot of extra information given to them during the breaks by the usual suspects, but (you're talking to one and you will talk to another) and they eventually came to the conclusion that SLAC really had a mess. It came down to the committee deciding that they would tell Burton that he had a big problem. Do you know Frank Sciulli from Columbia?

Deken [01:40:56] I don't. I've heard the name.

Breidenbach [01:40:58] So Frank was on the committee and apparently nobody wanted to be the one to quietly give this news to Burt, but Sciulli drew the short straw. He agreed to talk to Burt, but it was on the condition that he never had to come back to another DOE review at SLAC ever again.

Deken [01:41:25] [laughs].

Breidenbach [01:41:25] And that's true.

Deken [01:41:26] Yeah?

Breidenbach [01:41:27] Sciulli got to tell Burt that the opinion of the committee was that Rae should go or he should go. And so, Rae left the next day. This was 1988…

Deken [01:41:47] Mm hmm.

Breidenbach [01:41:47] August 1, 1988. And he was gone, never to be seen at SLAC again.

Deken [01:41:53] Mm hmm.

Breidenbach [01:41:55] At this point Burt personally took over. Now he really had to pay attention. He asked me to take over controls which was a mess. Even though I was doing SLD fulltime! I asked Terry Schalk to take over the software part of controls which also was a mess. A lot of us had two hats. Burt was Director while he was running SLC, and that's how SLC got pulled back together. And then Nan [Phinney] got pulled in.

Deken [01:42:48] OK.

Deken [01:43:05] Interesting... So, I think that's all my questions....

Breidenbach [01:43:08] Jean, did I tell you this remark from John Jaros after Burton died?

Deken [01:43:18] No.

Breidenbach [01:43:22] It was from John: "everyone loved Dick Taylor; everyone respected Burton Richter."

Deken [01:43:32] Interesting.

Breidenbach [01:43:33] Yeah.

Deken [01:43:36] After Burton died, I was contacted by the Communications Office and they asked me to set up a 'Burt Stories' web site, like I had done for Pief [Panofsky] and for Dick [Taylor] and for Sid [Drell]. And I said "Really?" And they were like 'Oh yeah, absolutely.' So, I said ‘OK.’ And I've gotten exactly two Burt Richter stories and Andy Freeberg sent me an email and said, 'You know, I can't understand: why hasn't anybody you know sent their Burt Stories?’ and I said, "Andy, do you know the old saying 'de mortibus nil nisi bonum'?"

Breidenbach [01:44:29] 'Don't speak ill of...'

Deken [01:44:32] And he said he had to look it up, but he said "really?" And I said, 'You're too new, Andy, but you know, I don't think there are many Burt stories people really want to share.’

Breidenbach [01:44:46] That's right!

Breidenbach [01:44:50] I went as far out with Ken Chang in The *New York Times* obit as I dared.[7]

Deken [01:44:58] I mean I'll tell you a couple of my Burt stories but…

[7] Chang, Ken. Burton Richter, A Nobel Winner for Plumbing Matter, Dies at 87. New York Times, July 23, 2018

Deken [01:45:17] I was brand-new at SLAC when there was a ceremony. I think it might have been a dedication for PEPII. And there was a big convocation on the green and there were some folding chairs, but most of us were standing. I realized that [Edward] Teller[8] was sitting in one of the folding chairs and I recognized him from photos I'd seen in the news and in history books.

Deken [01:46:16] So, Burt gets up and says, ‘welcome everybody’ and he looks directly at Teller, and he says something to the effect of 'I'd like to welcome everyone here today except Ed Teller. I don't know what the hell you're doing here.' I remember my jaw dropped. And Teller just kind of waved his cane at Burt, and kind of grinned at him. And then Burt went on with his remarks, and I'm looking around like 'is anybody else appalled by that?' And nobody seemed to be batting an eye. And that was kind of my introduction to...

Breidenbach [01:46:58] What an introduction! I don't remember that - I probably was not there.

Deken [01:47:01] Yeah.

Breidenbach [01:47:02] I tended to avoid PEPII.

Deken [01:47:07] I just was stunned, and nobody else was batting an eye like, 'oh, that's just another day at the lab with Burt Richter.'

Deken [01:47:26] Yep. So those are all of my questions, I think. I think this is a good session we can we can wrap it up it's been one hundred and seven minutes.

[8] Hungarian American physicist, “father of the hydrogen bomb”