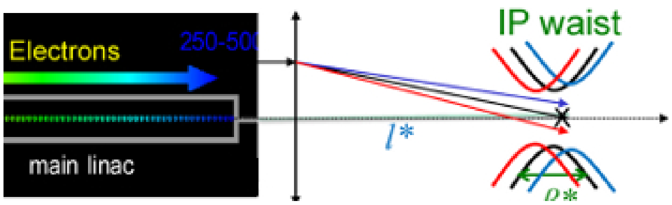
FEATURE

1-TeV beam shapes up

by Leah Hesla



Designing a 1-TeV upgrade of the ILC requires a suitable particle beam to go along with it. Scientists recently decided on the shape of the 1-TeV beam, and it has a shifted waist.

AROUND THE WORLD

From CERN Courier: The SuperB approach to high luminosity

The next-generation B factory to be built in Italy will reach new levels in luminosity by employing the innovative crab-waist scheme at the beam collision point. The SuperB concept represents a real breakthrough in collider design. The low-emittance ring has its roots in R&D for the International Linear Collider (ILC) and could be used as a system-test for the design of the ILC damping ring. The invention of the crab-waist final focus could also have an impact on the current generation of circular colliders.

Read more in *CERN Courier*

DIRECTOR'S CORNER

Baseline Technical Review for ILC superconducting RF systems

by Barry Barish

On 19 and 20 January 2012, the third Baseline Technical Review to finalise the *Technical Design Report* baseline was held at KEK laboratory in Japan. The meeting reviewed the proposed cavity gradient performance, cavity integration, and the main linac integration and interfaces to the ILC conventional facilities, including radiofrequency power, control and interfaces to conventional facilities. A special meeting on superconducting radiofrequency costs followed this meeting on 21 January.

IMAGE OF THE WEEK

BTR meeting groupies

Image: Nobu Toge

KEK hosted the third ILC Baseline Technical Review meeting last month. Read more about the main linac and superconducting radiofrequency technology decisions in this issue's Director's Corner.

IN THE NEWS

from *The Australian*
7 February 2012
UK: Celebrity physicist triggers boom
THE cult of the celebrity scientist has caused a marked rise in applications for physics degrees in Britain, with some leading universities reporting increases of up to per cent in what has been nicknamed the Brian Cox effect.

from *SLAC Today*
2 February 2012
BaBar Extends the Search for New Matter-Antimatter Asymmetries
The theoretical expectation, based on Kobayashi's and Maskawa's very successful theory, is that the positively charged B+ will undergo this decay about as frequently as the negatively charged B– meson.

from *Physics Today*
February 2012
A century of cosmic rays
Twenty years after puzzling atmospheric ionization led to the discovery of cosmic rays, their investigation opened up particle physics. Now they're providing a window on extragalactic astrophysics.

from *Scientific American Blogs*
31 January 2012
Life after Tevatron: Fermilab Still Kicking Even Though It Is No Longer Top Gun
But even though protons and antiprotons no longer course through the six-kilometer loop of the Tevatron, life at Fermilab goes on.

CALENDAR

UPCOMING EVENTS

3rd LC FORUM meeting
DESY, Hamburg
07- 09 February 2012

CALICE collaboration meeting
Shinshu University, Matsumoto, Japan
05- 07 March 2012

ILC Mechanical & Electrical Review and CFS Baseline Technical Review
CERN
21- 23 March 2012

UPCOMING SCHOOLS

Physics and Technology of Particle Accelerators (JUAS 2012)
Geneva, Switzerland
09 January- 16 March 2012

Excellence in Detectors and Instrumentation Technologies (EDIT 2012)
Fermilab, Batavia, IL, USA
13- 24 February 2012

View complete calendar

BLOGLINE

2 February 2012
physicsworld.com
Where should the International Linear Collider be built?

PREPRINTS

ARXIV PREPRINTS

1202.1075
Single Higgs boson production at a photon-photon collider: a 2HDM/MSSM comparison

1202.0764
Depolarization in the ILC Linac-to-Ring Positron Beamline

1202.0752
Polarized positrons for the ILC – update on simulations

1202.0751
Spin Tracking at the ILC Positron Source

1202.0660
Indirect sensitivity to Z's in high-energy e+e- collisions: a "standard" vs. "composite" study

1202.0624
Recent results of Micromegas sDHCAL with a new readout chip

1202.0507
Associated production of light gravitinos at future linear colliders

1202.0488
Neutralinos from Chargino Decays in the Complex MSSM

1202.0378
Parity violating Moller scattering asymmetry up to the two-loop level

1202.0080
QCD corrections to the $γγb\bar b$ production at the ILC

1201.6495
Design and R&D of very forward calorimeters for detectors at future e+e- collider

1201.6489
Multi-tau lepton signatures in leptophilic two Higgs doublet model at the ILC

1201.6345
The Higgs sector of the NMFV MSSM at the ILC

1201.6305
MSSM Higgs Bosons from Stop and Chargino Decays

1201.6173
Positrons sources and related activities for Future Linear Collider at LAL Orsay Laboratory

1201.6157
Mh in the MSSM-seesaw scenario with ILC precision

1201.6155
Calibration Issues for the CALICE 1m3 AHCAL

1201.6098
Performance of the CALICE Scintillator-Based ECAL Depending on the Temperature

FEATURE

1-TeV beam shapes up

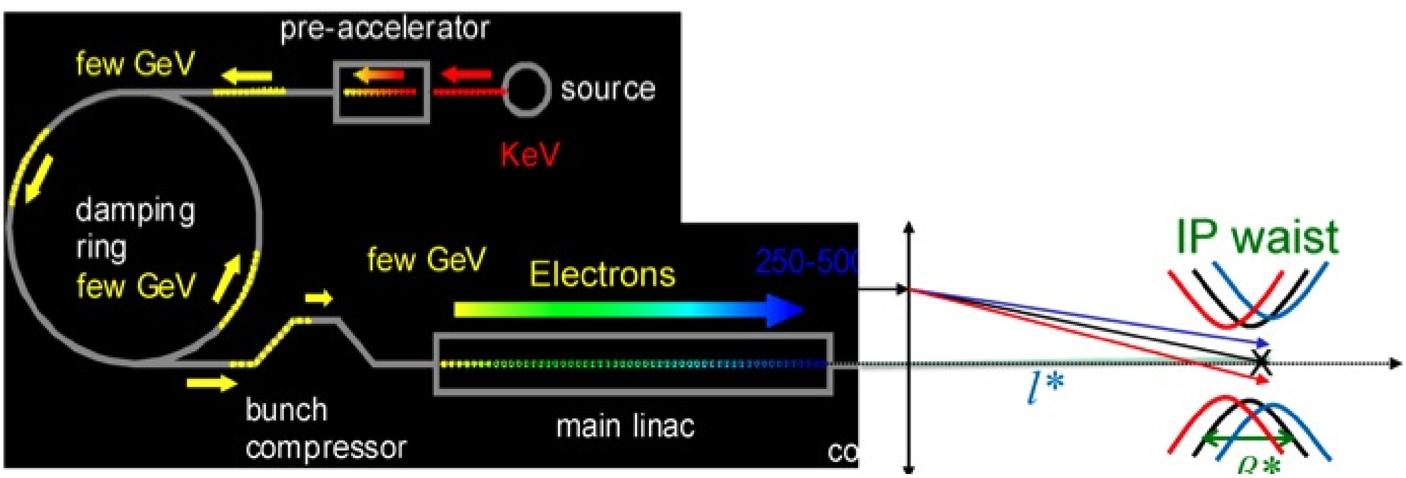
Leah Hesla | 9 February 2012

The popular understanding of a particle beam as a threadlike one-dimensional strand of energy isn't wrong, but from the point of view of accelerator scientists, it's a bit simplistic. Particle beams are nearly always carefully formed structures, especially in the space surrounding the point of their collision. Pinched here, stretched there, particle beams are crafted to squeeze the most luminosity and energy from their collisions.

Last month scientists decided on the best shape for an electron and a positron beam at the ILC with one teraelectronvolt (TeV) of centre-of-mass energy: its bunches are longer than initially designed and it has a shifted waist.

A particle beam's waist, or focus, is the narrowest point along its length, where the particles that had been flowing merrily along are then packed into a tiny, compact space. To generate a healthy number of collisions, scientists guide the beams so that the densest parts of the oppositely directed beams meet up with each other, increasing the likelihood that their constituent particles will collide head-on.

The goal is straightforward. The execution isn't.



The red and blue lines represent a shifted waist away from the original focus, in black. ILC scientists chose the shift represented by the red curve.

Over the past several months, ILC researchers have been manipulating the length, placement and timing of the 1-TeV-beam waist, stretching or contracting it like a wad of taffy into different sizes and shapes by playing with various magnetic strengths and orientations to get the highest luminosity, or the most head-on collision, for ILC studies.

"It's a physics-process-dependent balancing act," said Jim Brau, research directorate contact for the Americas. The act involves balancing luminosity and background noise.

Through simulations, ILD and SiD detector scientists found a worrisome source of post-collision background interference, low-energy electron-positron pairs. These pairs would be kicked away from the beam at such an angle that they would strike the edge of the detector, multiplying into even more background tracks and clouding sought-after signals with their careless flights.

It is of course to a study's advantage that, post-collision, the interesting particle signatures present themselves in the detector clearly, without unwanted noise obscuring events so hard-won by relentless and repeated shots at head-on collisions.

High luminosity is indeed hard-earned. To hit on the right waist placement for lots of collisions, ILC scientists considered several beam shapes, among them the travelling focus beam and the eventual winner, the shifted-waist beam.

In the shifted-waist scheme, the waist of both the electron and the positron beam would arrive not at the point of collision, which was the dynamic of the originally designed ILC beam, but just before the collision point. The shift of the beam's narrowest point away from the collision site by just a couple hundred micrometres was shown to increase the luminosity by 10 to 15 percent over the original proposal. However, the shifted-waist shape couldn't match the luminosity of its main competition in beam profile: its luminosity was about 5 to 10 percent less than that of the travelling focus scheme.

In the travelling focus scheme, one beam's focus moves along with that of the oncoming beam, creating a strong, inseparable attraction between the two. Though this beam shape is shown to make wonderfully luminous collisions, it's exceedingly difficult to achieve and requires devices that are still in the beginnings of the development stage.

CERN scientist Daniel Schulte suggested that the shifted-waist scheme could work for linear collider beams. Though shifted-waist has been understood for some time, it hasn't yet been put into practice by any particle physics project. Now that the ILC project is receiving its finishing touches and its researchers have a firmer handle on how all the parts come together, it is at the stage where even modest luminosity gains of about 10 percent are worth pursuing.

Having milked the beam for that last bit of luminosity, the ILC team wanted to avoid undercutting this gain with too much background noise. This meant creating a beam shape that would help kick the noisy electron-positron pairs back down the beam pipe so as not to disturb the detector.

Last autumn, Kaoru Yokoya, Global Design Effort Asian regional director, proposed stretching the beam's constituent particle bunches along their lengths and tightening their widths. He found that by lengthening the little bunches, he could reduce the kick-off angle of the renegade electron-positron pairs, redirecting them closer to the beam pipe and so away from the detector.

This bunch type carries a different risk – its longer shape amplifies the even the tiniest inadvertent initial up- or down-misplacement of the beam, leaving little room for error in the beam setup. Last month researchers agreed to a bunch length of 225 micrometres, finding a nice compromise between reduced background-pair angles and safe initial setup.

"Now it's possible to keep this very high luminosity but to calm the pairs down to a smaller cone that's compatible with the design of the detectors at 500 gigaelectronvolts," Brau said.

The ILC is fully designed for 500 GeV of collision energy, but the machine will also be able to be upgraded to deliver twice that, one TeV of energy. In designing a suitable beam with double the energy of the baseline design, scientists had to come up with a beam that the detectors, designed for the 500-GeV collider, could handle. Now that this latest step in the 1-TeV upgrade is finalised, researchers will likely adopt a similar beam profile for the 500-GeV technical design as well.

The beam specifications will be documented in the 2013 Detailed Baseline Design and the *Technical Design Report*.

1 TEV | **BEAM SIZE**

CERN Courier

Jan 25, 2012

The SuperB approach to high luminosity

The next-generation B factory to be built in Italy will reach new levels in luminosity by employing the innovative crab-waist scheme at the beam collision point.

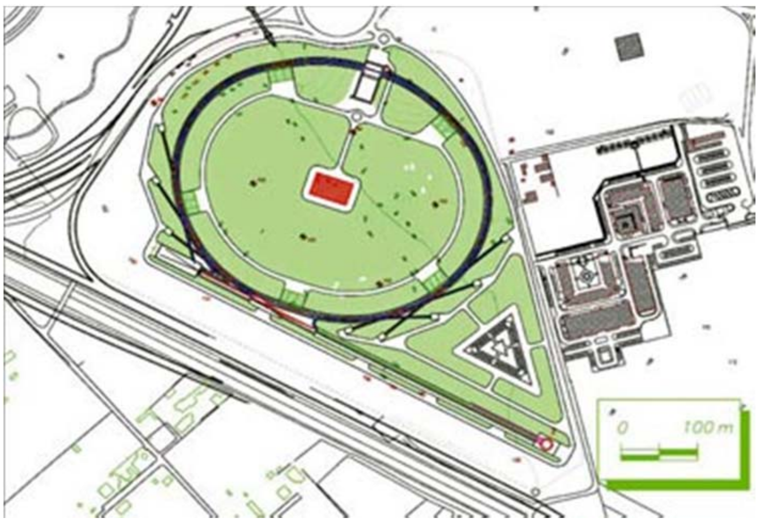


Fig. 1.

Résumé

SuperB et haute luminosité

En 2010, le gouvernement italien a donné le feu vert pour la construction du SuperB – « usine à B » de la prochaine génération – sur le campus Tor Vergata de l'Université de Rome. L'objectif est que le nouveau collisionneur électron–positon asymétrique délivre une luminosité de crête record de 10^{36} *cm*$^{-2}$ *s*$^{-1}$ *au moyen d'un dispositif innovant (« crab waist ») au point où les faisceaux entrent en collision. De la sorte, le SuperB pourra procéder à l'exploration indirecte d'une nouvelle physique par l'étude d'un grand nombre de désintégrations de particules B, D et τ et donner lieu à toute une série de nouvelles recherches.*

In 2010 the Italian government gave the green light for SuperB – a next-generation B factory based on an asymmetric electron–positron (e^+e^-) collider, which is to be constructed on the Tor Vergata campus of Rome University (figure 1). The intention is to deliver a peak luminosity of 10^{36} cm^{-2} s^{-1} to allow the indirect exploration of new effects in the physics of heavy quarks and flavours through studies of large samples of B, D and τ decays. Building on the wealth of results produced by the previous two B Factories, PEP-II and KEKB, and their associated detectors, BaBar and Belle, SuperB will produce an unprecedented amount of data and make accessible a range of new investigations.

The SuperB concept represents a real breakthrough in collider design. The low-emittance ring has its roots in R&D for the International Linear Collider (ILC) and could be used as a system-test for the design of the ILC damping ring. The invention of the crab-waist final focus could also have an impact on the current generation of circular colliders.

The SuperB e^+e^- collider will have two rings with a 1.25 km circumference, one for electrons at 4.18 GeV and one for positrons at 6.7 GeV. There will be one interaction point (IP) where the beams will be squeezed down to a vertical size of only 36 nm rms. The design results from a combination of knowledge acquired at the previous B factories as well as the concepts developed for linear colliders.

The innovative crab-waist principle, which has been successfully tested at Frascati's Φ factory – the DAΦNE e^+e^- collider – will allow SuperB to overcome some of the requirements that have proved problematic in previous e^+e^- collider designs, such as high beam currents and short bunches. While SuperB will have beam currents and bunch lengths similar to those of its predecessors, the use of smaller emittances and the crab-waist scheme for the collision region should produce a leap in luminosity from some 10^{34} cm^{-2} s^{-1} to an unprecedented level of 10^{36} cm^{-2} s^{-1}, without increasing the background levels in the experiments or the machine's power consumption.

High luminosity in particle colliders not only depends on high beam-intensity, it also requires a small horizontal beam size and horizontal emittance (a measure of the beam phase space) and a very small value for the vertical β function at the IP, β^*_y. (The β function in effect gives the envelope of the possible particle trajectories and has a parabolic behaviour around the IP.) However, β^*_y cannot be made much smaller than the bunch length without running into trouble with the "hourglass" effect, in which particles in the bunch-tails experience a much higher β^*_y and a loss in luminosity.

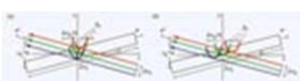


Fig. 2.

Unfortunately it is difficult to shorten the bunch length in a high-current ring without exciting instabilities and therefore paying in radio-frequency voltage. One way to overcome this is to make the beam crossing-angle relatively large and the horizontal beam size small, so that the region where the two colliding beams overlap is much smaller than the bunch length. In addition, in the crab-waist scheme, two sextupoles at suitable phase-advances from the IP are used to rotate the waist in the β function of one beam such that its minimum value is aligned along the trajectory of the other beam, so maximizing the number of collisions occurring at the minimum β (figure 2). This technique can substantially increase luminosity without having to decrease the bunch length. A crab-waist scheme was tested at the DAΦNE in 2008 allowing a peak luminosity three times higher than the previous record for similar currents in the two rings.

The combination of large crossing-angle and small beam sizes, emittances and beam angular divergences at the IP in the SuperB design will also be effective in decreasing the backgrounds present at the IP with respect to the previous B factories. A limited beam current also contributes to keeping these levels very low at SuperB. However, luminosity-related backgrounds are still relevant and impose serious shielding requirements.

The high luminosity of SuperB, representing an increase of nearly two orders of magnitude over the current generation of B factories, will allow exploration of the contributions of physics beyond the Standard Model to the decays of heavy quarks and heavy leptons. Indeed, new physics can affect rare B-decay modes through observables such as branching fractions, CP-violating asymmetries and kinematic distributions. These decays do not typically occur at tree level, so their rates are strongly suppressed in the Standard Model. Substantial variations in the rates and/or in angular distributions of final-state particles could result from the presence of new heavy particles in loop diagrams, providing clear evidence of new physics. Moreover, because the pattern of observable effects is highly model-dependent, measurements of several rare decay modes can provide information regarding the source of the new physics.

The SuperB data sample will contain unprecedented numbers of charm-quark and τ-lepton decays. Such data are of great interest, both in a capacity to improve the precision of existing measurements and in sensitivity to new physics. This interest extends beyond weak decays; the detailed exploration of new charmonium states is also an important objective. Limits on rare τ decays, particularly lepton-flavour-violating decays, already provide important constraints on models of new physics and SuperB may have the sensitivity to observe such decays. The accelerator design will allow for longitudinal polarization of the electron beam, making possible uniquely sensitive searches for a τ electric dipole moment, as well as for CP-violating τ decays.

Studies of CP-violating asymmetries are among the primary goals of SuperB. In addition to known sources of CP, new CP-violating phases arise naturally in many extensions of the Standard Model. These extra phases produce measurable effects in the weak decays of heavy-flavour particles. The detailed pattern of these effects, as well as of rare-decay branching fractions and kinematic distributions, will be made accessible by SuperB's high luminosity. Such studies will provide unique constraints in, for example, ascertaining the type of supersymmetry breaking or the kind of extra-dimensional model behind the new phenomena. A natural consequence of such detailed studies will be an improved knowledge of the unitarity triangle to the limit allowed by theoretical uncertainties.

In addition to pursuing important research in fundamental physics, SuperB is also taking up the challenge to combine it with a rich programme of applied physics: the synchrotron light emitted by the machine will have a high brightness and will be suitable for studies in life sciences and material science. Current proposals include: the creation and exploitation of beamlines for laser ablation on biomaterials (a technique that, by modifying the surface of the material with a laser, allows the creation of patterns of biological systems); femtochemistry studies (a field that includes the structural study of small numbers of molecules); and the development of new phase-contrast imaging techniques to improve the reconstruction of morphological information related to tissues and organs.

The construction of SuperB, which is funded by the Italian government and supported by a large international collaboration that includes scientists from Europe, the US and Canada, is planned to take about six years. The newly established "Nicola Cabibbo Laboratory" Consortium will provide the necessary infrastructure for the exploitation of the new accelerator. In November, the Consortium appointed Roberto Petronzio as director with an initial three-year mandate. The machine will reuse several components from PEP-II, such as the magnets, the magnet power-supplies, the RF system, the digital feedback-system and many vacuum components. This will reduce the cost and engineering effort needed to bring the project to fruition.

The exciting physics programme foreseen for SuperB can only be accomplished with a large sample of heavy-quark and heavy-lepton decays produced in the clean environment of an e^+e^- collider. The programme is complementary to that of an experiment such as LHCb at a hadron collider. Indeed, a "super" flavour factory such as SuperB will, perforce, be a partner together with experiments at the LHC, and eventually at an ILC, in ascertaining exactly what kind of new physics nature has in store.

About the author

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ilc newsline

DIRECTOR'S CORNER

Baseline Technical Review for ILC superconducting RF systems

Barry Barish | 9 February 2012

Atsuto Suzuki, KEK director general, addresses the superconducting radiofrequency Baseline Technical Review. Image: ILC

The final preparatory step in our process of defining the baseline for the *Technical Design Report* (TDR) is to carry out a set of four Baseline Technical Reviews (BTR) that concentrate on the large number of small technical decisions that remain to be defined for the TDR baseline. We previously made a set of top-level changes from the ILC reference design through a formal change process in order to better optimise performance, cost and risk. The large number of remaining smaller technical decisions is the responsibility of the Global Design Effort (GDE) project managers, who are leading a set of four open BTR meetings to help draw a consensus.

The first BTR was focussed on the positron source and damping rings, while the second was on accelerator systems. The third BTR, focussed on ILC main linac and superconducting radiofrequency (SRF) systems, was held at KEK on 19 and 20 January in order to define the outstanding issues for our central technology. The main linac is a primary cost driver for the ILC, therefore these technical decisions must be made with a strong eye on cost impacts.

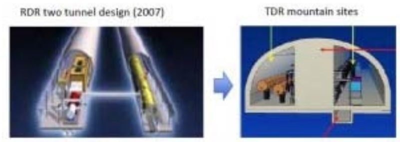
The approach of the GDE project managers towards these decisions has been to first evaluate designs for technical feasibility and performance that satisfy the ILC technical requirements, make sure they are consistent with plug-compatibility at interfaces, and then make the most cost-effective design choices for the TDR baseline.

Some of the more important technical decisions for the KEK BTR included the following:

Atsuto Suzuki, KEK director general, addresses the superconducting radiofrequency Baseline Technical Review. Image: ILC

- In the area of main linac integration, there was a question of whether an extra 400 metres of tunnel (with or without utilities) should be included in the TDR baseline. The purpose would be to ensure that the capability of reaching 500 GeV was maintained, a measure that comes with consequences in timing issues and costs. This issue was analysed and discussed at length at the BTR meeting, leading to a decision to increase the length by only about 150 metres and to instrument the tunnel to increase the energy safety margin by at least 1 percent for both proposed high-level RF schemes.
- A new question addressed whether the main linac design could accommodate a slight tilt. This is a site-dependent issue regarding future expansion of the tunnel to 50 kilometres for the 1-TeV option. In order to cross a river for the Japanese southern site, the main linac must either be sited deeper (significantly increasing the required lengths of access tunnels), or a slight tilt must be accommodated. Technically, the proposed tilt does not appear to introduce any serious problems.

- The high-level RF being considered for mountainous sites has been a distributed system consisting of about four thousand 800-kilowatt klystrons. However, based primarily on cost considerations, a new tunnel shape ("**kamaboko**") has been proposed that is capable of accommodating the original reference design high-level RF system. This tunnel concept has a shielding wall between the main linac and klystron gallery that would enable servicing as in the original two-tunnel scheme.
- The cryomodule configuration in the reference design consisted of three cryomodule sets containing a cryomodule with nine cavities, followed by one with eight cavities plus a quadrupole in the middle, followed again by a third with nine cavities. Alternatives to this configuration have been being considered, but the final conclusion is to stay with the RDR configuration.
- For cavity performance, a new recipe has been adopted: (1st pass: 60% and 2nd pass: 70%) having a gradient of 31.5 megavolts per metre +/- 20%, while adopting a statistical approach to cavity degradation.



A new tunnel shape for mountainous sites. The enabling reference design high-level RF concept has been adopted

Overall, the Baseline Technical Review process for completing the details of the TDR baseline has been working well and we are proceeding on schedule. We will carry out a final BTR, focused mainly on the conventional facilities, on 22 and 23 March at CERN.

I should make one important caveat as to whether we are truly finalising all aspects of the TDR baseline by the BTR process. We do not yet have detailed costing for the TDR subsystems, so the present decisions are based on our best present estimates of the cost impacts. We do not expect big surprises, but some adjustments in the design may be necessary once we are able to make reliable evaluations of the TDR costs over the coming months.

BASELINE TECHNICAL REVIEW | **BTR** | **KEK** | **SRF** | **SUPERCONDUCTING RF** | **TDR** | **TECHNICAL DESIGN REPORT**