Collider R&D : Status and Plans

Olivier Napoly,
CEA-Saclay
for the R&D Board

Outline

- The R&D Board
- R&D Goals and Actions
- R&D Regional Funding Instruments
- Status of R&D after the MAC Review at Fermilab (26-27 April 2007)
  http://ilcagenda.linearcollider.org/conferenceDisplay.py?confId=1388
- Summary

The R&D Board

- *Bill Willis (Chairman)*
- *Chris Damerell*
- *Eckhard Elsen*
- *Terry Garvey, Olivier Napoly (the freshman)*
- *Hitoshi Hayano*
- *Toshiyasu Higo*
- *Tom Himel*
- *Lutz Lilje*
- *Hasan Padamsee*
- *Marc Ross*
- *Andy Wolski*

The R&D Board : Mandate

- **Assess and Provide guidance for the overall R&D program**
  - **suggest priorities for baseline and alternatives**
  - **the** *balance between accelerator and detector*
- **Develop a proposal-driven R&D plans.**
  - **define goals and milestones**
  - *evaluate resources*
- **Conduct tracking and reviews**
  - **identify gaps of duplications in coverage**
  - **resource or technical issues**

Topics not or lately addressed by the R&D Board [O.N]

The R&D Board : Actions

The R&D Board has

- Built a long "ideal" R&D list for the Baseline and Alternates , including prioritization and WBS
- Advised DoE, KEK and PPARC R&D programs
- Established a number of **Task Forces** to address the creation of collaborative R&D plans for cavity gradient, damping rings, BDS, sources, …
- Reported to RDB MAC Review, on 26-27 April
- Written down the R&D Status chapter for the RDR [E. Elsen, ed.]

R&D Goals [O.N]

1. R&D for securing the ILC engineering (e.g. : cold tuners, HOM dampers, Horizontal Klystrons, Linac RF Controls and Protection System, …)
   - The XFEL starts officially on 5 June
   - The XFEL gives itself 15 months R&S for securing engineering before the calls for tender for most of the components
   - The XFEL will define a **reference** for the technical solutions : ILC will improve on them
2. R&D in support of RDR Cost vs. Risk Mitigation (e.g. gradient, damping rings, positrons, BDS, MDI, …)
   - The EDR priorities
3. R&D for ILC higher performance or lower cost (e.g. new shapes, HOM-BPM,…)
   - R&D in support of new and radical ideas
4. Long Term R&D for ILC upgrades (energy and luminosity)
   - The S-ILC scenario (??)

R&D : Baseline vs. Alternates [O.N]

- The **Phase Space of ILC Parameters** (nominal, low P, High L, etc...) has been introduced by the GDE to reduce risk.
- Baseline and Alternate concepts explore the **Phase Space of ILC** Accelerator and Technical **Solutions**
- **MAC** suggests to set **R&D priorities** on criteria like: “(relative) cost savings, risk mitigation, availability, increase of performance margin, operational efficiency, operation cost savings, coupling to other R&D projects, regional balance and R&D opportunity”

  $\rightarrow$ more “transparent” process, but a lot of work !

Regional Funding Instruments

- Americas
- Asia
- Europe

Americas Funding Instrument : ART

Americas Regional Team labs

ANL-Rod Gerig

BNL-Brett Parker

Fermilab-Bob Kephart, Shekar Mishra, Sergei Nagaitsev

Cornell LEPP- Hasan Padamsee, Mark Palmer

Jefferson Lab -Bob Rimmer, Warren Funk

LLNL -Jeff Gronberg

LBNL -Mike Zisman

SLAC -Tor Raubenheimer, Nan Phinney, Tom Himel

TRIUMF -Shane Koscielniak

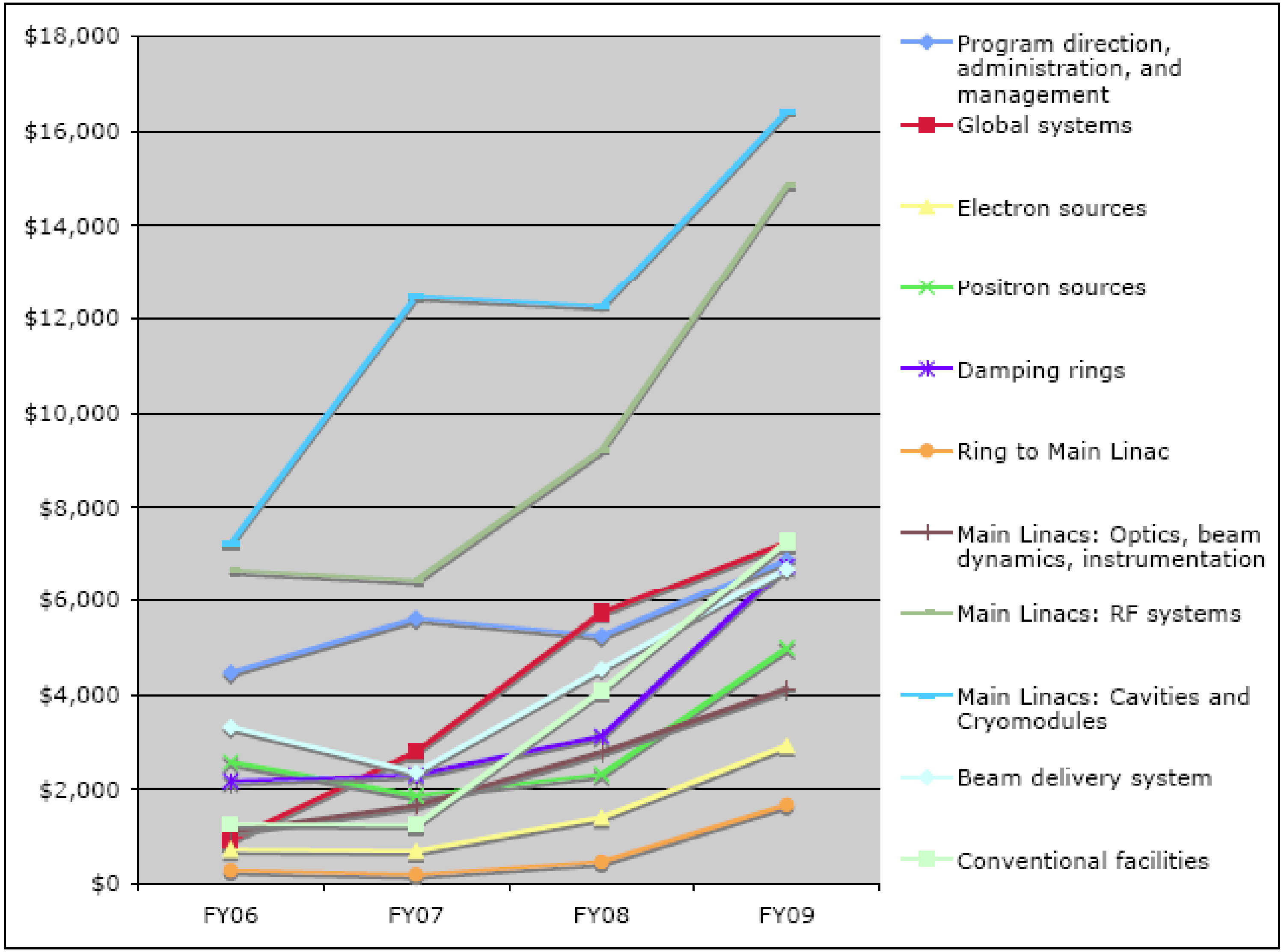
Universities- Project Leaders

Americas Funding Instrument : ART

ART Total:

33 M$ FY06
42 M$ FY07
53 M$ FY08

including
~30% M&S



Asia Funding Instruments

- KEK final FY07 budget decided in April, starts Apr.1
- KEK R&D plans includes
  - ATF Damping Ring
  - ATF2 BDS

ATF2

~ 3.8 M€

~ 4.6 M$

~ 3 M$

  - STF for Linac SRF technology (delayed by short budget)

Asia Funding Instruments

Rich R&D program developing in:

- China: IHEP, NSF-C
  - Large grain Nb cavity (Ningxia)
  - Cryomodules
  - Beam dynamics (damping rings)
  - ~ 0.3 M$ M&S
- India : RRCAT, BARC, IUAC
  - Cavity technology
  - RF power technology
- Korea: KNU, PAL, PNU, POSTECH
  - SRF Ichiro Cavity
  - Beam Position Monitors
  - Beam dynamics (damping rings, bunch compressor)
  - ~ 0.5 M$ M&S

EU Funding Instruments

- National Agencies:
  - STFC in UK
  - IN2P3 + CEA + ANR in France
  - INFN + Universities in Italy
  - Helmholtz Association (incl. DESY)
- CERN (+ White paper + Hosts)
- XFEL Project
  - Accelerator contributions in Germany, France, Italy
- European Commission FP6 and FP7 (2007-100
  - FP6 and FP7 for EU countries + CERN + Switzerland

⇒ **A new type of EU scientist is needed : the "fund-trotter"**

EU Funding Instrument : FP6

ESGARD : an advisory board with a mandate from ECFA, representing the EU Funding Agencies for Accelerator R&D

FP6 : projects ends officially in 2007, will continue until 2008 with little fresh money

- **CARE/SRF** : SC Cavities processing and ancillaries $\subset$ "EDR Technical Systems"
- **CARE/NED** : Nb3Sn high current conductor for SC Magnets (primarily for S-LHC)
- **EUROTeV** : ILC Beam lines $\subset$ "EDR Accelerator Systems"
- **EUROFEL** : Cryo Module Test Bench $\subset$ "EDR Technical Systems"

EU Funding Instruments: FP7

CNI Preparation Phase call (selection: July'07, start: late'07)

- ***SLHC*** (L. Evans, CERN)

CERN, CEA, CIEMAT, RAL

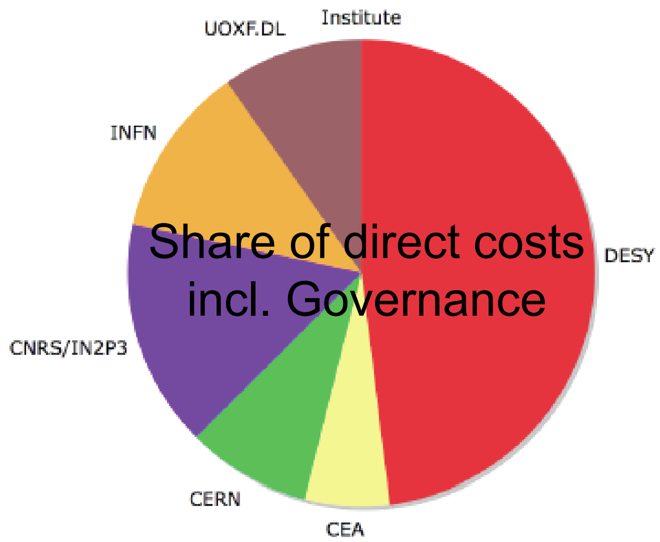
Includes 2.4 M€ incl. 1.2 M€ from EC to build a large aperture (**Ø130 mm**) high gradient (**~150 T/m**) **NbTi Quadrupole** (one 1m and one full length prototype)

→ relevant to BDS Alternate Schemes

- ***ILC HiGrade*** (E. Elsen, DESY)

7.4 M€ total incl. 4.1M€ from EC, on Technical Systems :

30 cavities with Eacc > 35 MV/m



EU Funding Instruments: FP7

Integrated Activity call (selection: July'08, start: late 2008)

Proto-IA on **SRF-Accelerating Systems** incl. five "JRA":

1. High Gradient Cavities
   - Single crystal, EP process, Advanced RF surface studies
2. Prototype cavities
   - Crab cavities, SCRF Gun with GaAs photocathode, …
3. Thin Films
   - High Tc A15 superconductors, Vacuum arc coating, …
4. Accelerator and Beam Studies
   - FLASH experiments : LLRF, HOM Beam Monitoring, …
5. RF Test Infrastructures
   - CERN + Ile de France + Cockcroft Inst. + …

EU Funding Instruments: FP7

Integrated Activity call (selection: July'08, start: late 2008)

- Proto-IA on **SRF-Accelerating Systems** ~45 M€ direct costs, including 15 M€ from EC.
- Two other Proto-IA on **High Intensity Proton Collider** (SLHC + SPL) and **Novel Accelerating Systems** (CLIC + Plasma + FFAG + Compton Positron) both aim at 45 M€.
- The FP7/IA EC contribution should be around 15-25 M€ $\Rightarrow$ EU laboratories may have to de-scope the project by a factor 2-3, or increase their contribution to a much higher level than EC.
- Alignment with GDE needs should be optimized by EU-GDE (P. Burrows)

EU Funding Instruments

- XFEL major investment (850 M€) for EU countries + …: at large, a big step forward for the ILC technology
- Excluding XFEL synergy: EU budget evaluated to
  250 FTE + 6 M€ /year M&S
- Overall **FLAT or DECREASING funding profile** for ILC R&D due to the termination of the 1st UK LC-ABD and FP6 programs
- Russian Laboratories (JINR + Budker Inst.) increasing involvement in ILC technology

R&D Task Forces

For producing collaborative R&D plans

- S0 : Cavity Gradient
- S1 : Cryomodule Operating Gradient
- S2 : Cryomodule String Test
- S3 : Damping Rings
- S4 : Beam Delivery System
- S5 : Positron Source
- S6 : Control systems
- S7 : RF Power Source

S0 : Cavity Gradient – Goal

- Goal : in a sufficiently large sample of 9 cell cavities (> 30) :
  1. **Provide 80% yield of cavities with Eacc > 35 MV/m at $Q_0 = 10^{10}$ in vertical tests**
  2. **Provide 95% yield after another processing cycle on cavities which failed the 1st acceptance test**

then , Goto S1

S0 : Cavity Gradient – Plan

To separate cavity preparation and production issues

1. Single-cell R&D

- **Establishing more reliable final preparation parameters.**
  - Focus on the final rinse after EP before HPR.
    - E.g. Ultrasound, Short EP (or HF rinse), H_2O_2

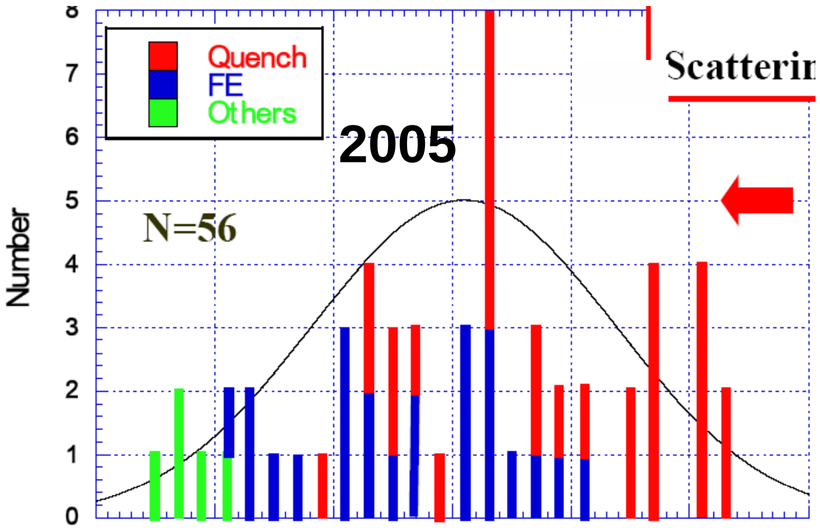
2. Tight-loop

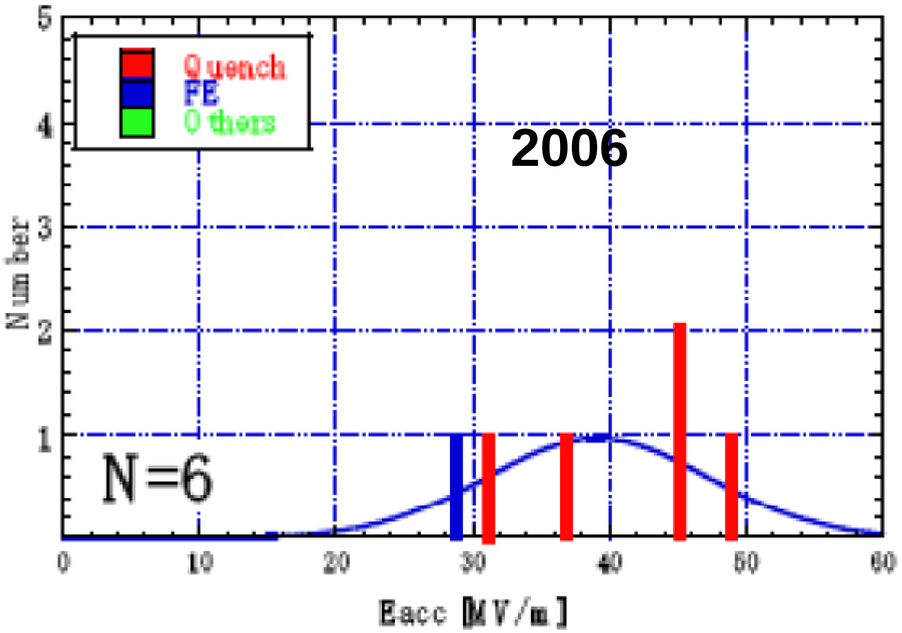
- **International multi-cell cavity exchange**
  1. Comparison of regional differences in preparation and testing
  2. Use single-cell results and implement on 9-cell cavities.

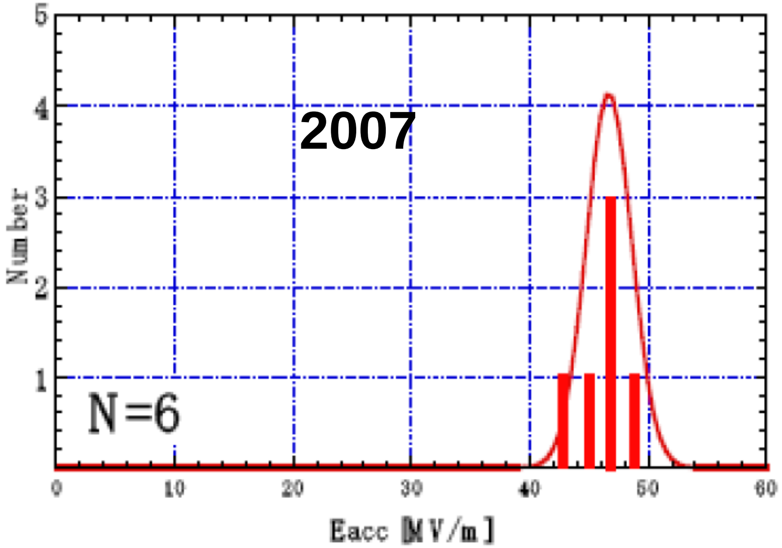
3. Production-like effort

- **Monitor ongoing productions**
  - Especially XFEL production
  - Use qualified and new vendors
- **Use improved preparation process for an ultimate batch of cavities (cf. FP7-CNI-PP ILC HiGrade)**

S0 : Cavity Gradient – Results







KEK single cell results:

2005 – just learning

2006 – standard recipe

2007 – add final 3 µm fresh acid EP

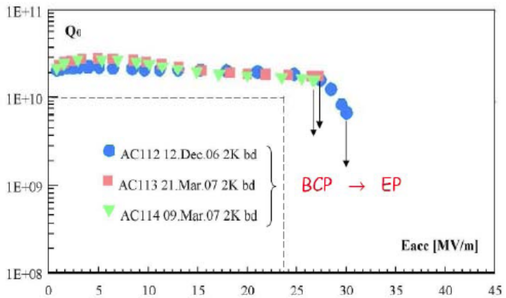
Note: multi-cells harder than singles

S0 : Cavity Gradient – R&D Results

Large Grain Material: Multi-Cells (XFEL option)

Option : Large Grain cavities / BCP

Heraeus /Accel (three cavities)



Less fabrication steps (lower cost)

no forging-rolling

disk from ingot

(less material pollution)

High RRR ~ 500

(avoid HT to ↗ K)

Probably higher gradients after Electropolishing (coming tests)

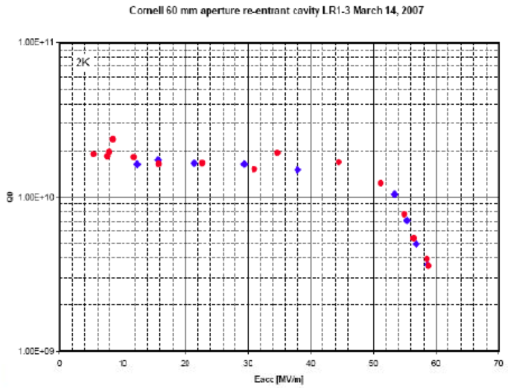
60mm-Aperture Re-Entrant Cavity

Best Eacc = 59 MV/m

Cornell-KEK Collaboration

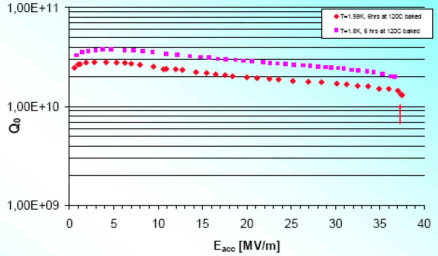
RE-LR1-3

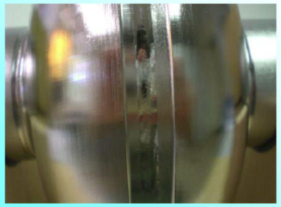
H. Padamsee et al.



DESY - JLab

DESY single crystal cavity 1AC8 build from Heraeus disc by rolling at RWTH, deep drawing and EB welding at ACCEL





Q(Eacc) curve after only 112 μm BCP and in situ baking 120°C for 6 hrs.

Preparation and RF tests of P.Kneisel, JLab

W. Singer, TTC Meeting at FNAL, April 23-26, 2007

S1 : Cryomodule Operating Gradient

- Goal :
  - Achieve > 31.5 MeV/m average operational accelerating gradient in 3 cryomodules, with cavities accepted in the low power test should achieve 35 MV/m at $Q_0 = 10^{10}$
  - Auxiliary systems like fast tuners should all work.
  - It needs not be the final cryomodule design

then , Goto S2

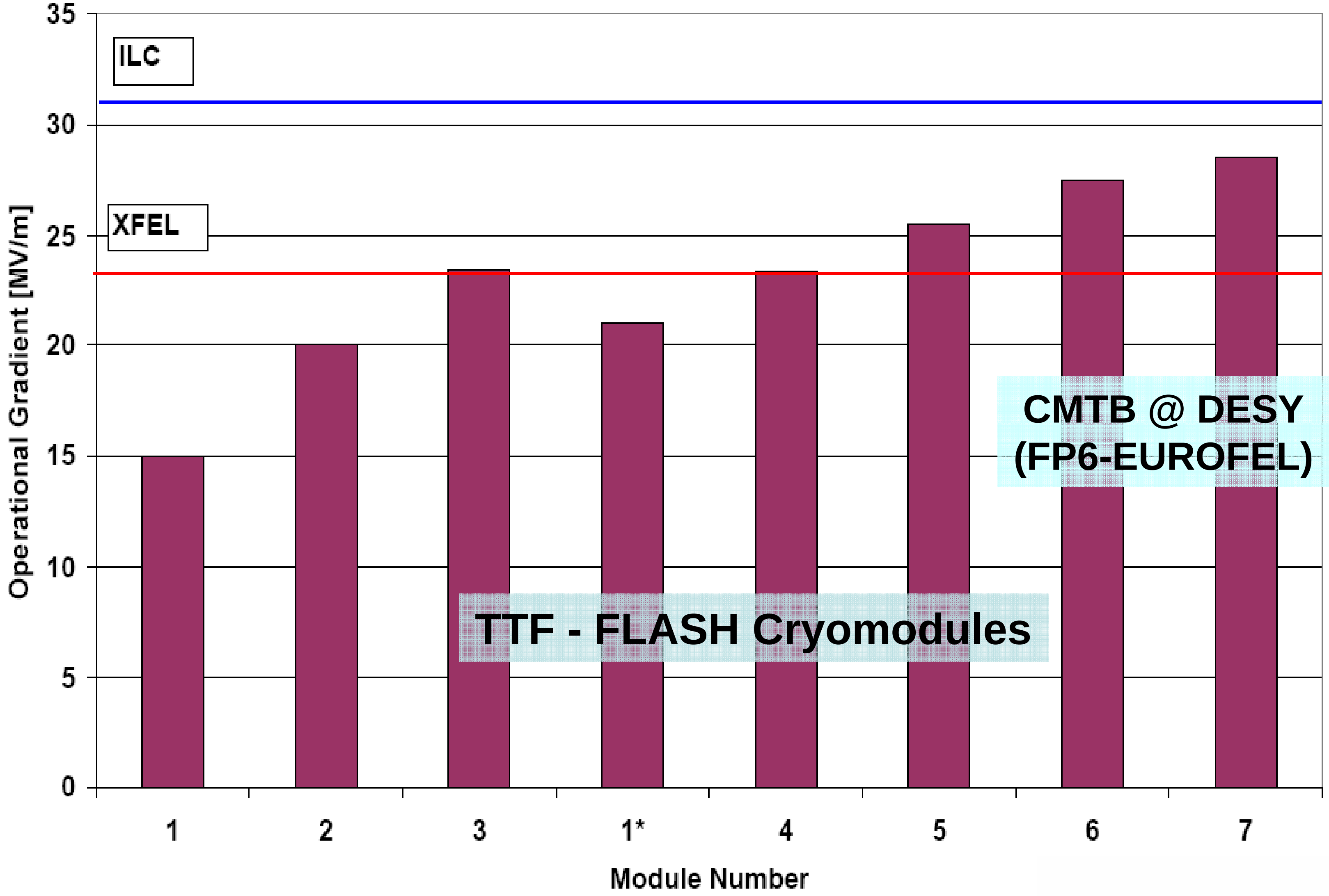
S1 : Cryomodule Test – Plan

Enough good cavities for the cryomodules are expected from the S0 cavity gradient program.

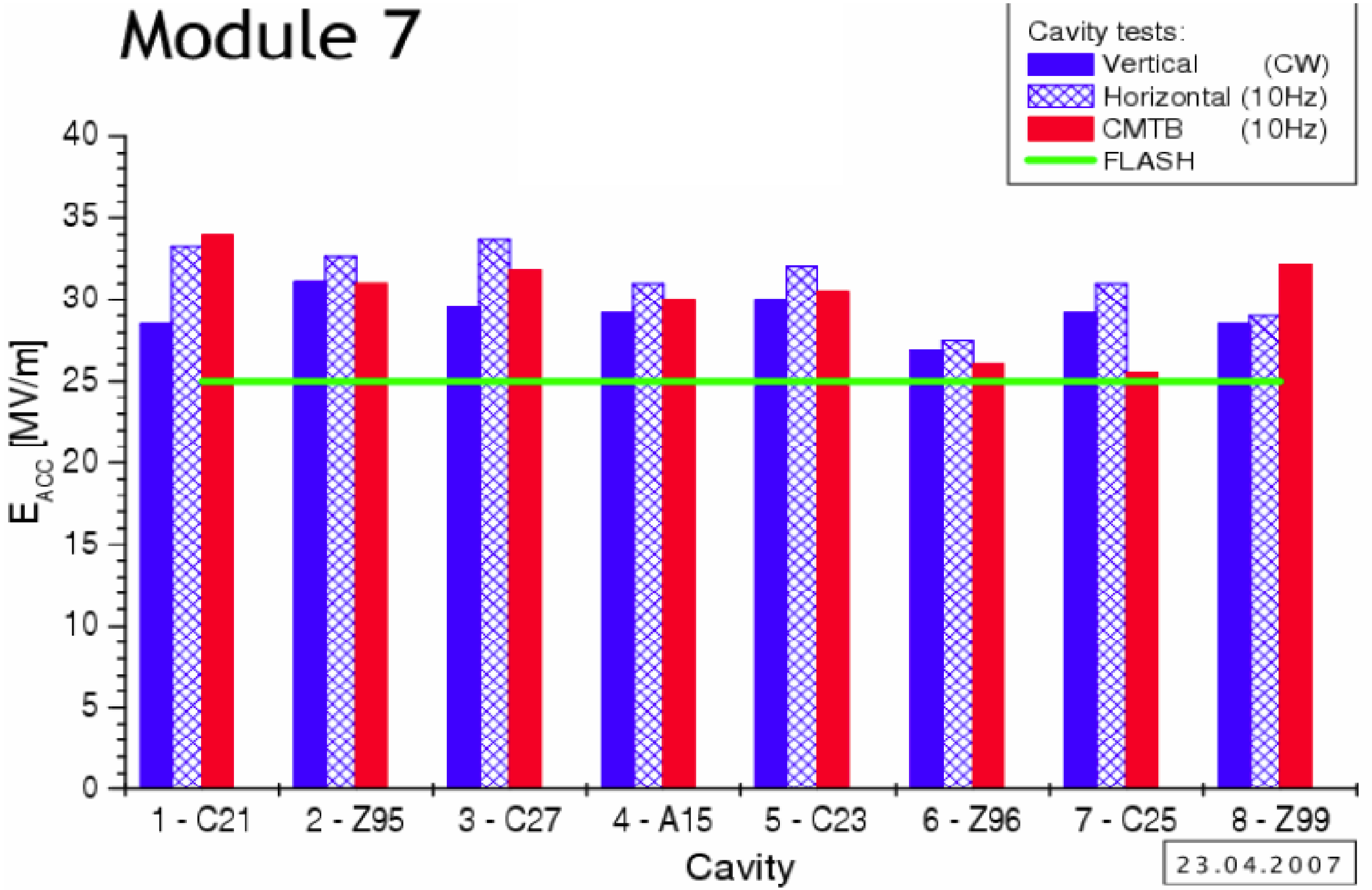
Module assembly plans:

- **DESY**
  - 2007: M7: tested now
  - 2007: M8: Probably no slow-down to select best cavities
  - 2007: M9 to FNAL
  - 2008: M10 – could select best cavities from several regions
- **US**
  - 2007: Assemble a kit of parts from DESY to get first assembly experience at FNAL
  - 2008: assemble 2 cryomodules from US produced parts.
    Second may be made by selecting the best available cavities.
  - 2009: build 2 more cryomodules
- **KEK**
  - 2009-10: Build, test, 3 cryomodules

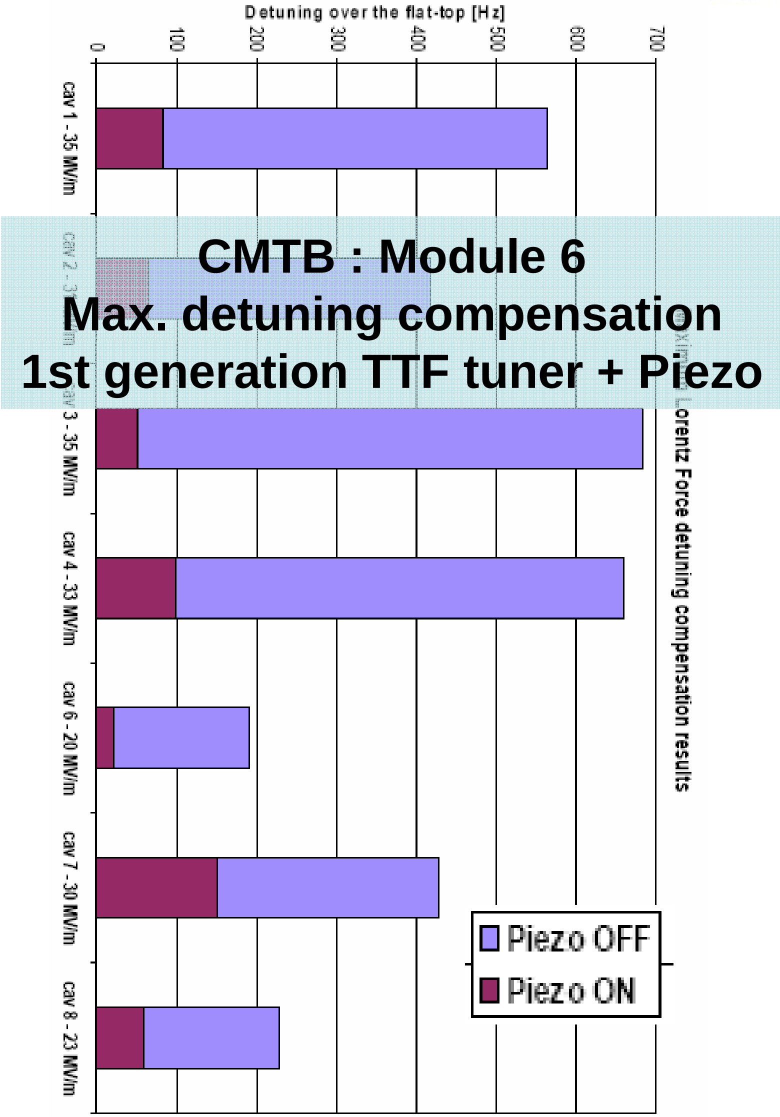
S1 : Cryomodule Test – Results

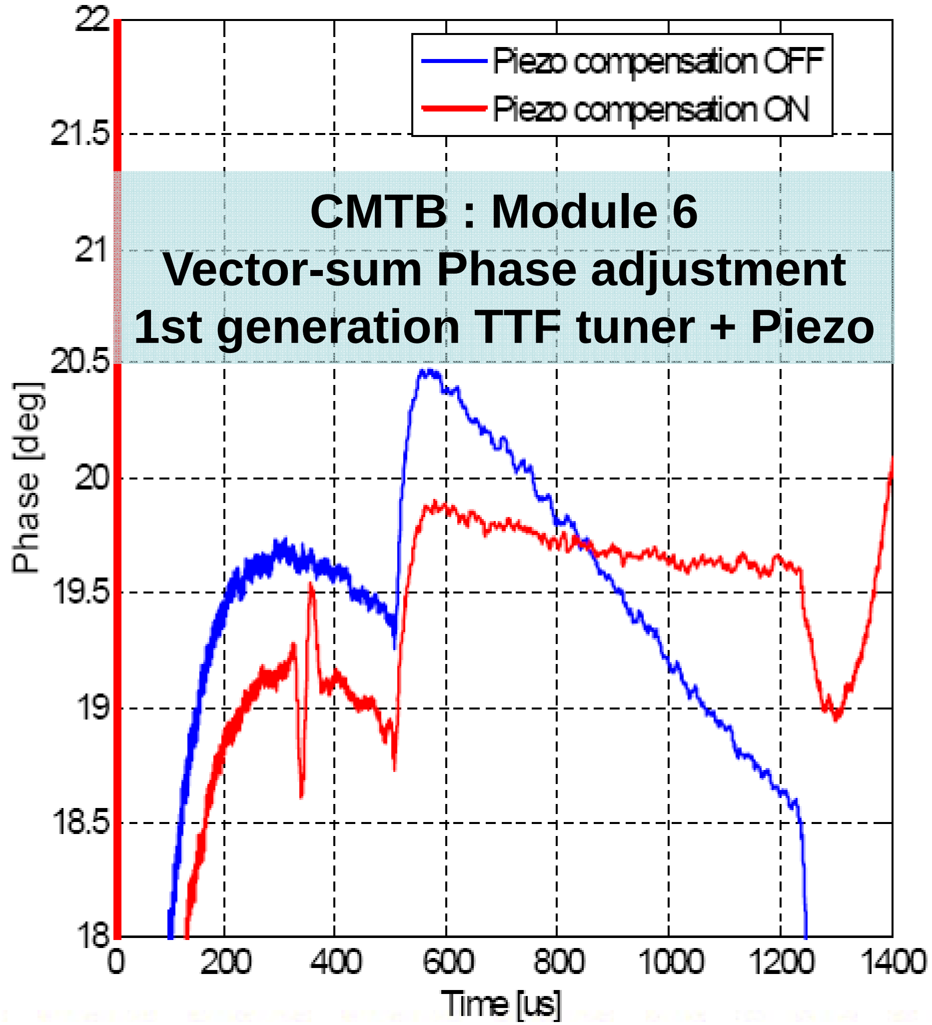


S1 : Cryomodule Test – Results



S1 : Cryomodule Test – Results





S2 – Cryomodule string test – Goal

- Build 1 RF unit (3 cryomodules + 1 Klystron) to fully check :
  - **What gradient spread can be handled by LLRF system.**
  - **For heating due to high frequency HOMs.**
  - **Amplitude and phase stability.**
  - **Static and dynamic heat loads.**
- To partially check:
  - **Reliability**
  - **Dark current**
  - **For degradation or other weaknesses**
- The ILC cryomodule (26 cavities) is enough different than that of the TTF that a new system test is warranted.

S2 : Cryomodule string test – Plan

- Use cryomodules built for module tests and for industrialization.
- Build 1 RF unit at KEK and 1 RF at Fermilab.
- Full – to spec – RF unit should work before 1% of the final industrial production of ILC cryomodules is complete (1 GILCU) to avoid discovering a design flaw.
- There will be a larger second phase string test to verify quality of the modules going into the ILC.

S3 : Damping Rings

S3 Task Force spelled out an exhaustive R&D plan and associated WBS based on the WP :

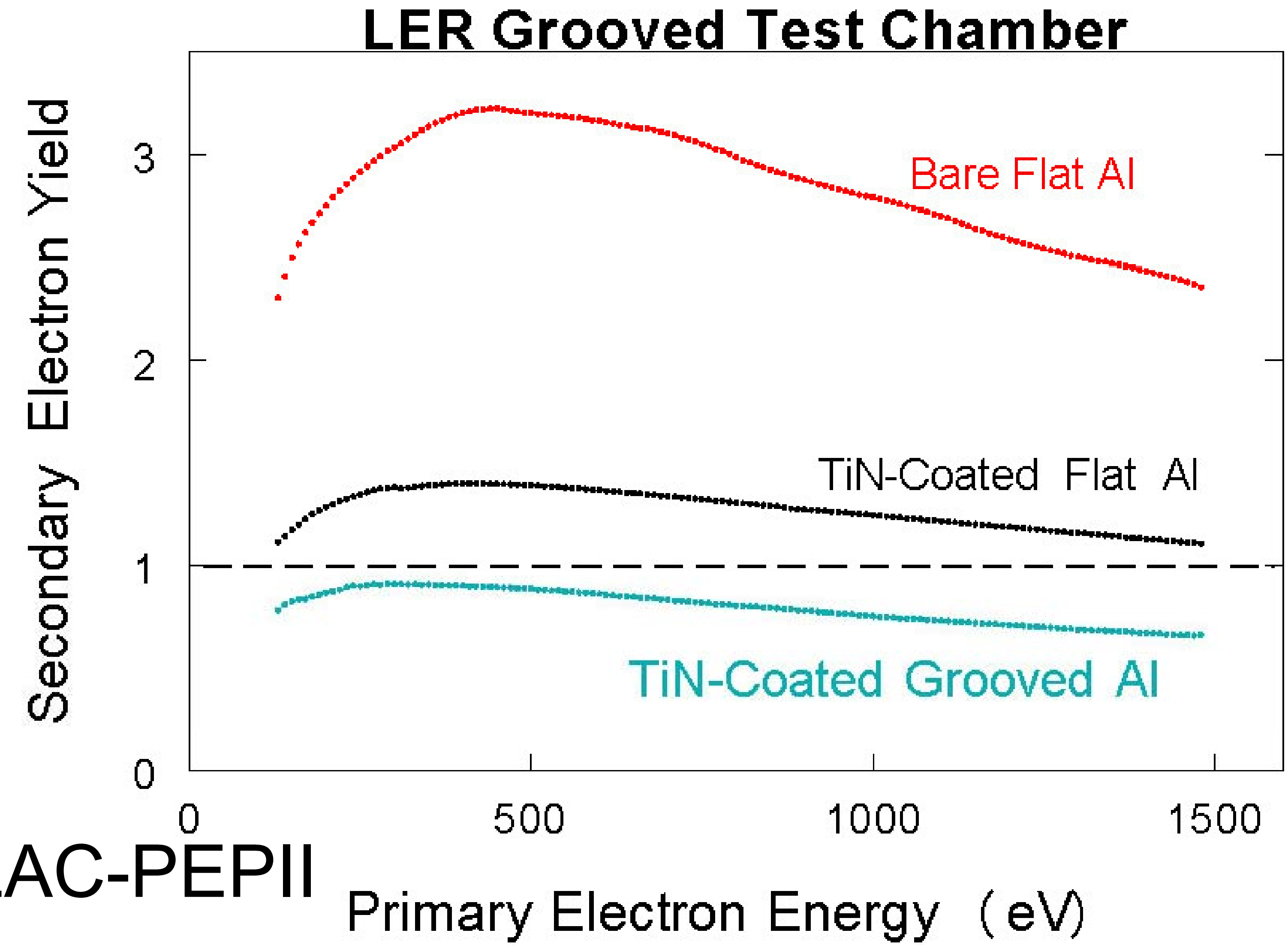
- Lattice Design
- Low-Emittance Tuning
- Impedance-Driven Single-Bunch Instabilities
- Electron Cloud
- Ion Effects
- Fast Injection/Extraction Kickers

- Most important issue is **Electron Cloud** :
  - Risk : blow-up e+ beam emittance
  - Cost : a second e+ damping ring (200 MILCU)

S3: DR e- cloud – Goals

- Very high priority Objectives
  - **Characterize electron-cloud build-up**
    - Do simulations in dipoles, wigglers and quadrupoles
    - Compare with measurements at PEP-II, KEKB, CesrTA, HCX (LBNL)
  - **Develop electron-cloud suppression techniques**
    - Test vacuum pipe coatings, grooved chambers, and clearing electrodes effect on e- cloud buildup
    - Do above in ILC style wigglers with low emittance beam to minimize the extrapolation to the ILC.
  - **Determine electron-cloud instability thresholds**
    - Characterize the electron cloud instability by measurements in existing facilities, including (for example) **CesrTA** or **KEKB** operating with ultra-low emittances.
    - Benchmark the simulation codes against experimental data

S3 : E Cloud – Results



SLAC-PEPII

S3: DR e- cloud – Test Facilities

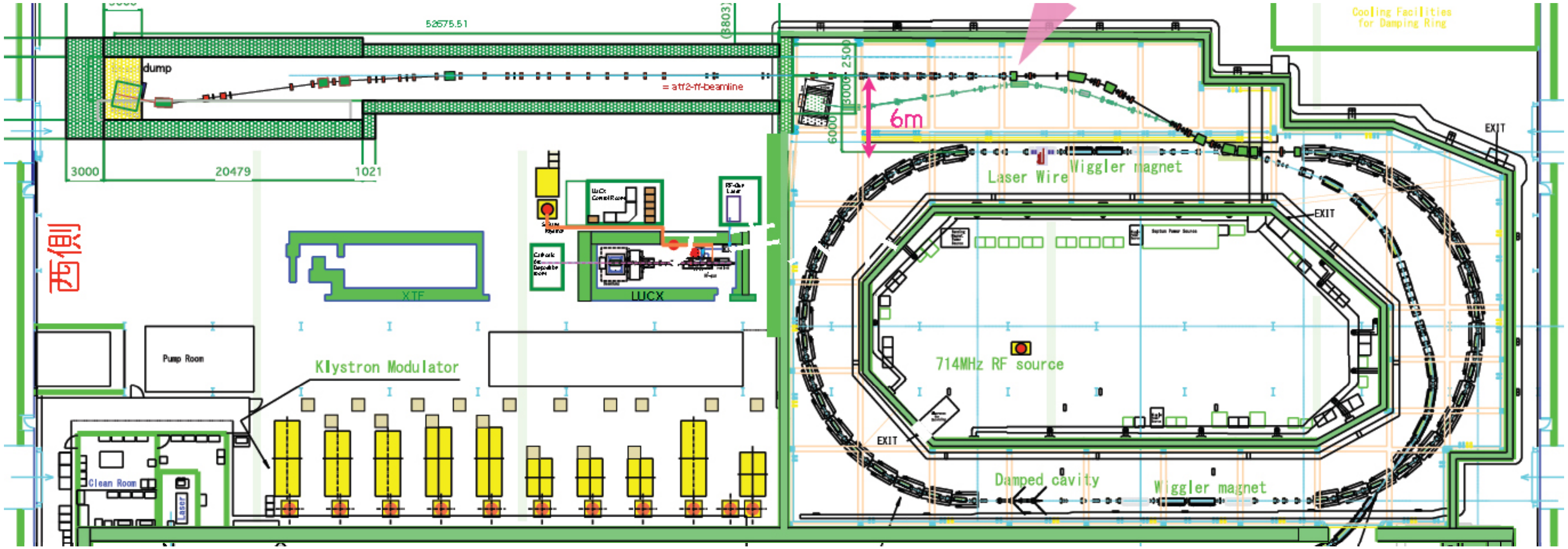
- CesrTA
  - The development of CESR into CesrTA would allow electron cloud studies at a dedicated test facility, operating in a parameter regime directly relevant for the ILC damping rings.
  - Requires relocation of wigglers to allow tuning for low natural emittance; upgrade of instrumentation for tuning for low vertical emittance; installation of instrumented test chambers in wigglers
- KEKB
  - KEKB LER could be tuned for ~ 1 nm emittance by reducing the energy from 3.5 GeV to 2.3 GeV.
  - For the next two years, the priority for KEKB will be to continue to provide luminosity for BELLE, but recent interest in a SuperB factory motivates further research.
- HERA-DR
  - More than just a test facility: the development of HERA into HERA-DR (> 2009) would actually provide one of the damping rings for the ILC

S4 : BDS System Test – Goal

- Build ATF2, a scaled BDS prototype at KEK to test:
  - **Optics design including never before done local chromatic correction**
  - **Keeping a beam small (35 nm), stable to a few nm for days at a time, and reproducible**
  - **Laser wires**
  - **Intra-train feedback**
  - **Nano BPM's**
  - **High availability power supplies**
  - **Tuning algorithms**

S4 : BDS System Test – Plan

- ATF2 is already under construction by a multi-regional collaboration.
- Will be commissioned in 2009 with optics tests done in 2010



S4 : ATF2 System Test

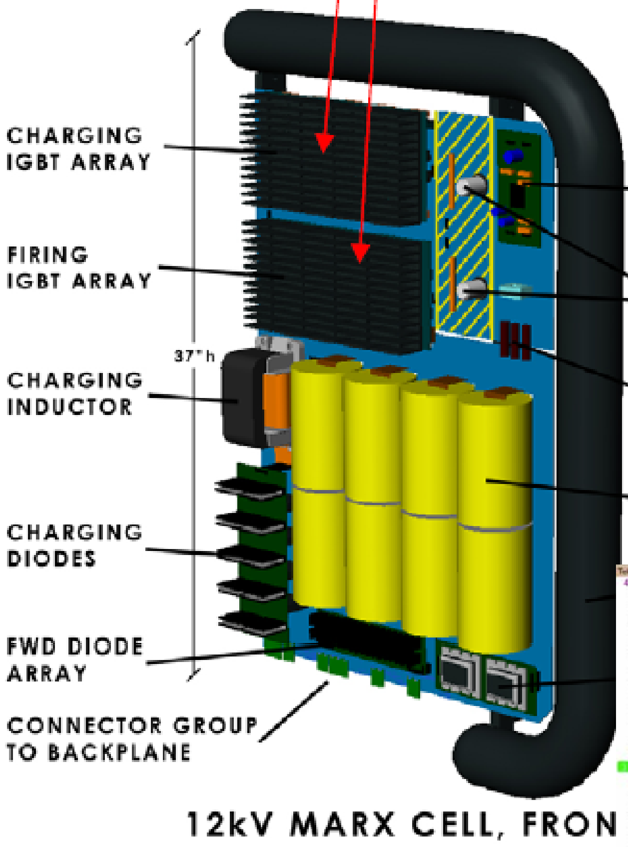
- Cost is ~5 MILCU
- This is generic test to qualify the **FF optics** and the 14mrad IR FD quadrupoles (stability)
- It does not check the impact of IR specific features:
  - **Impact of Solenoid at 14 mrad**
  - **Robustness of the Crab correction at 14 mrad**
  - **Reliability of electrostatic separators for Head-on IR, which relies on LHC-type FD quadrupoles**
  - **Reliability of extraction magnets for 2 mrad IR, which relies on S-LHC type FD quadrupoles**
  - **….**
- Other major issues : crab RF cavity, push-pull, beam dumps, …

S7 : High Power RF – Goals

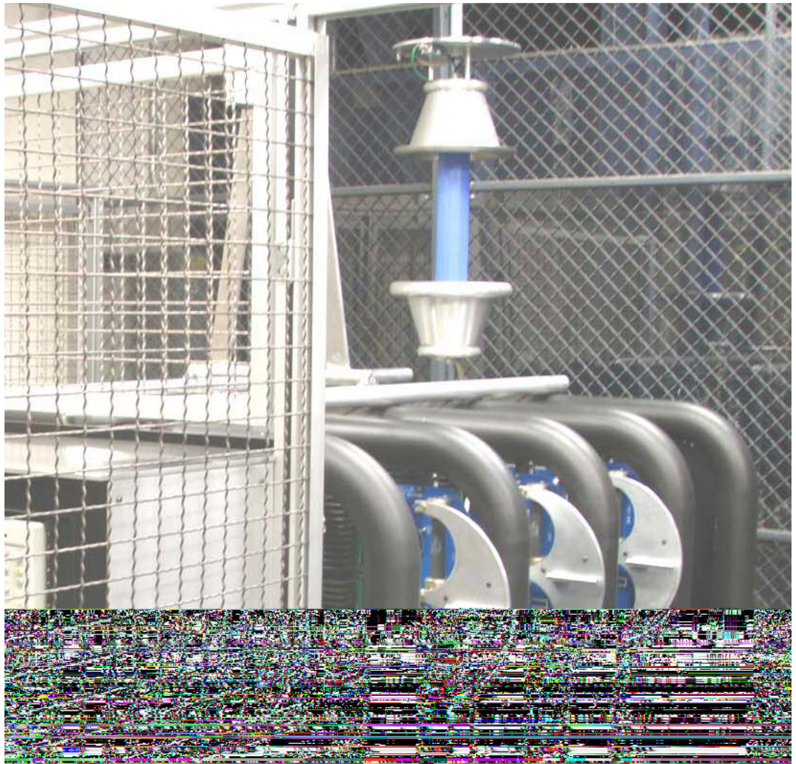
- The baseline HPRF design is mature and has very little risk.
  - **Thales and Toshiba klystrons on specs**
  - **Horizontal klystrons being worked our for XFEL**
- The R&D concentrates on cost reduction
  - **A Marx modulator to replace the bouncer modulator**
  - **Modified RF distribution system**
  - **Sheet-beam klystron to replace multi-beam klystron**
- If all are used, the HPRF cost is cut in half.

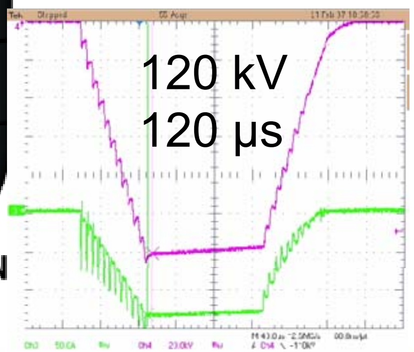
S7 : Marx Modulator

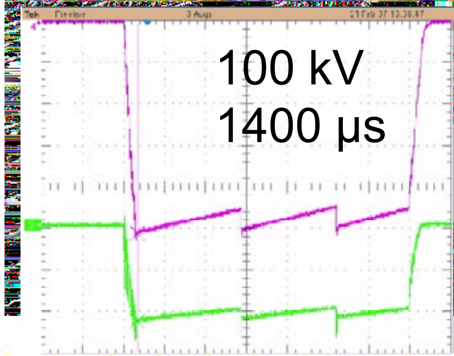
4+1 Redundant Switch Arrays
for charge, discharge



SLAC



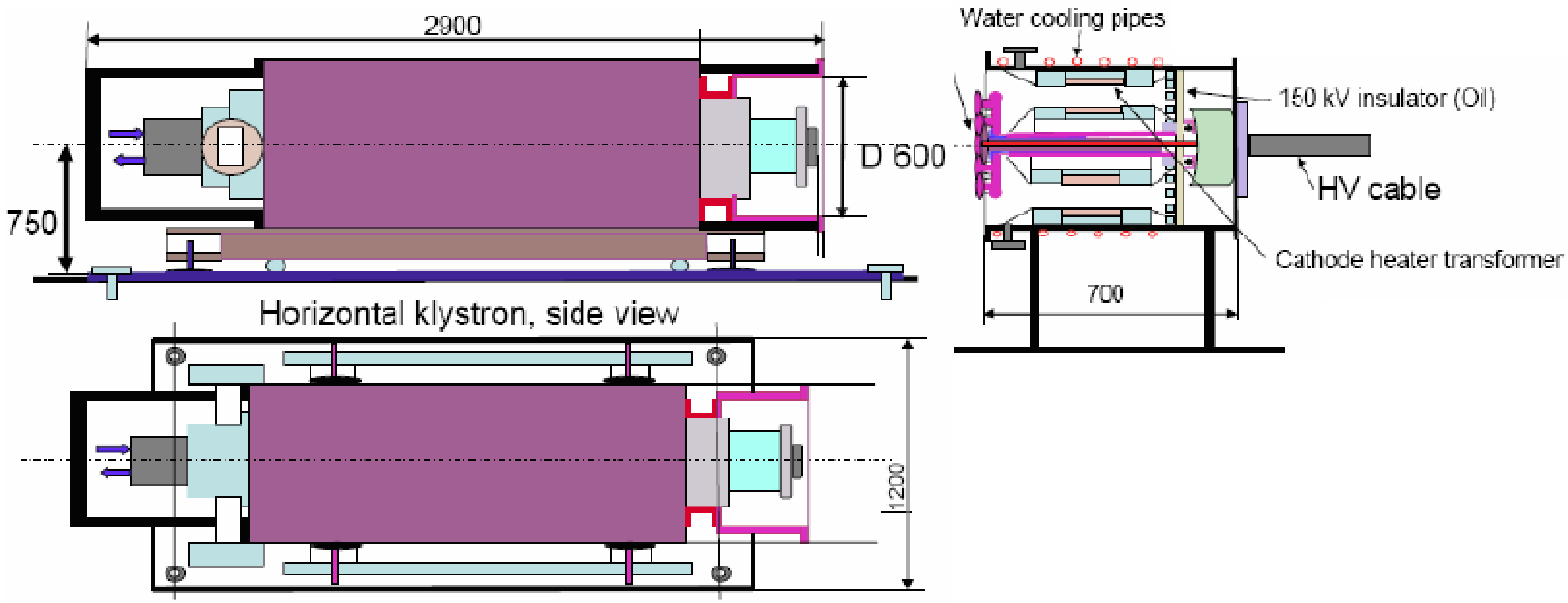




S7 : Sheet Beam Klystron

Horizontal MBK for XFEL

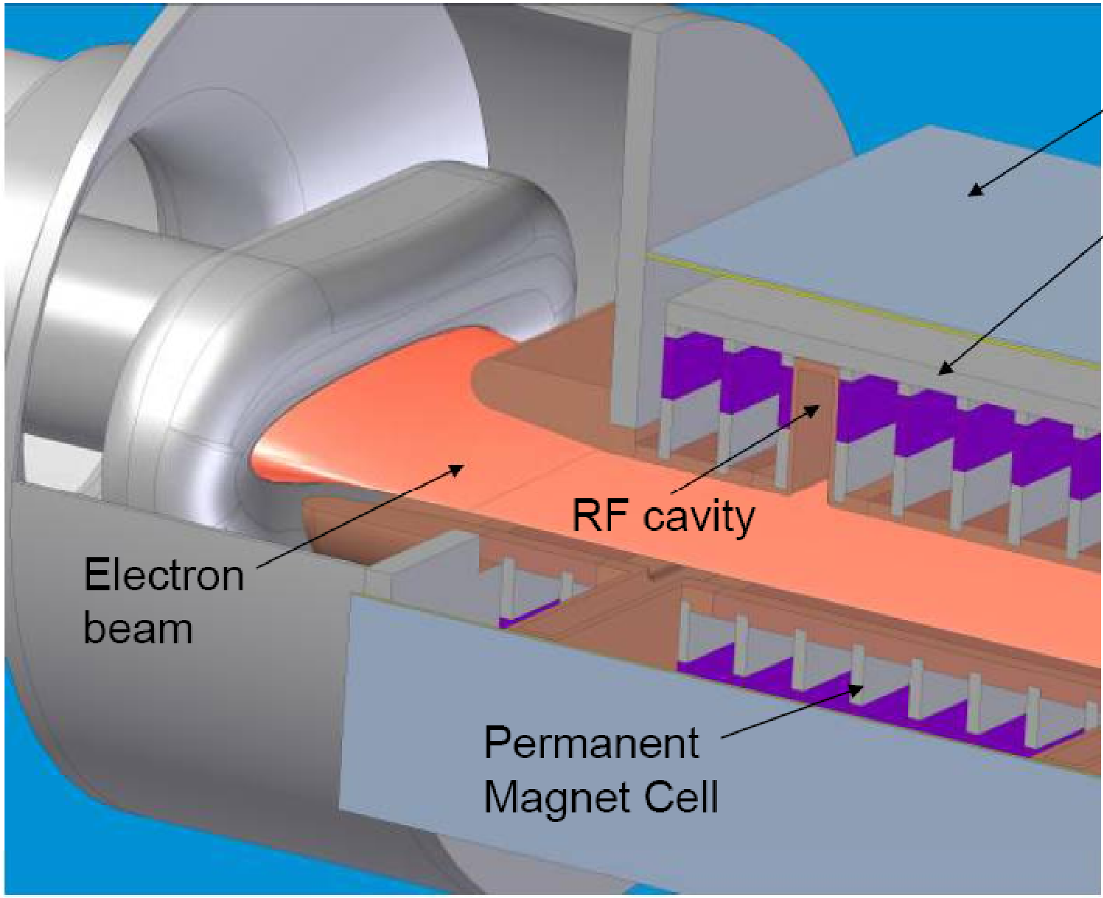
Expect the first horizontal MBK in 03/08. DESY is currently working with three companies to design the klystron interface to the transformer tank



Top view

S7 : Sheet Beam Klystron

The elliptical beam is focused in a periodic permanent magnet stack that is interspersed with rf cavities



Lead shielding

Magnetically shielded from outside world

Have done:

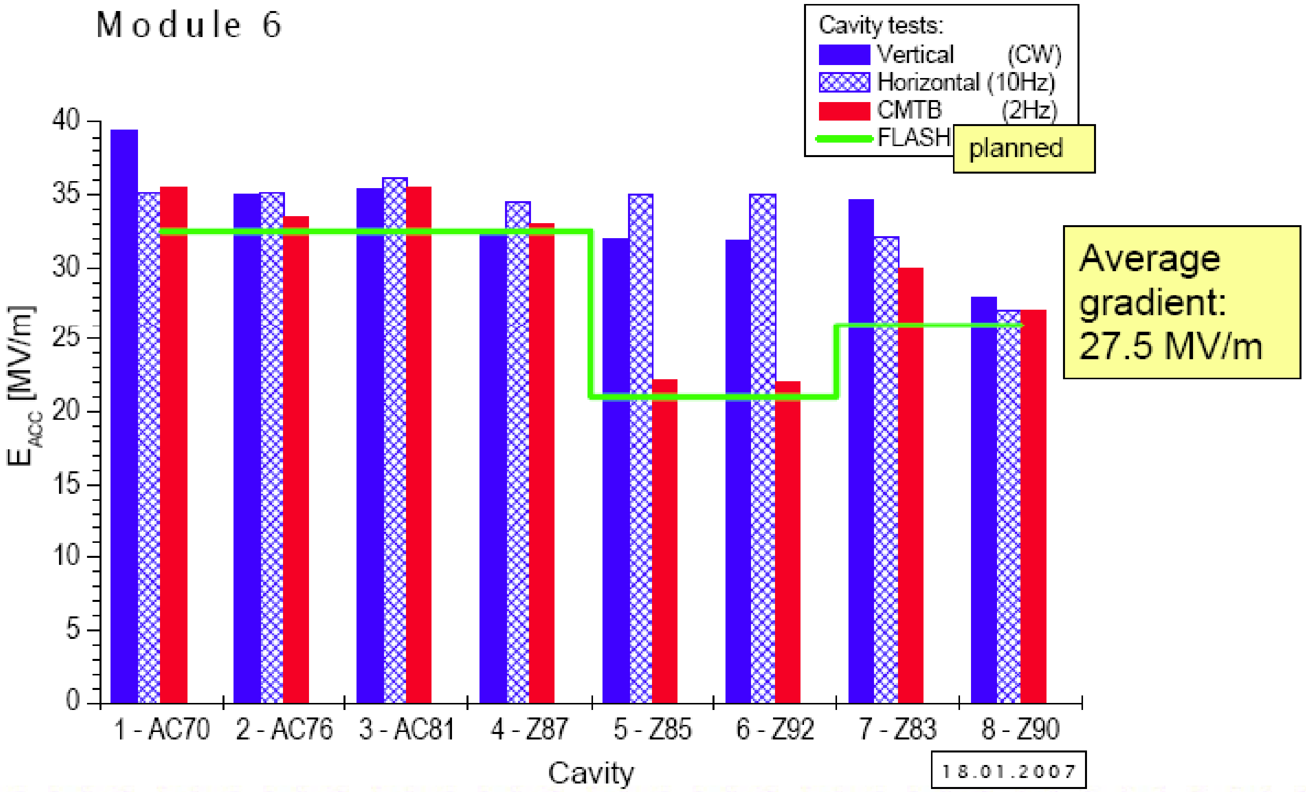
3D Gun simulations of a 130 A, 40:1 aspect ratio elliptical beam traversing 30 period structures.

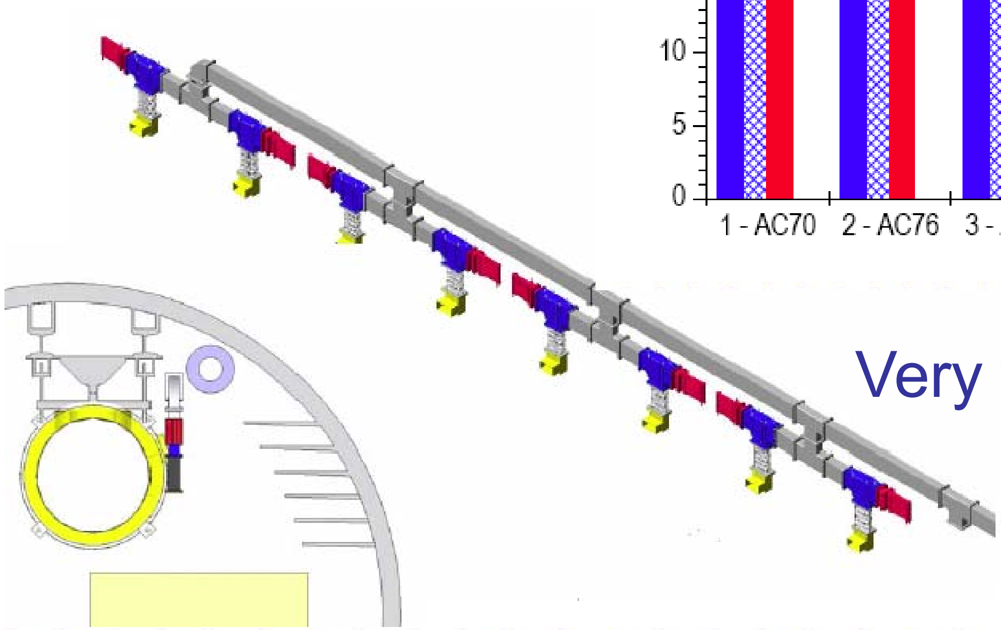
3D PIC Code simulations of rf interaction with the beam.

Test foreseen in Summer 2008

S7 : RF Distribution System

DESY designed an RF distribution by pairs of cavities, with phase shifters : eliminates the “weak cavity” limit

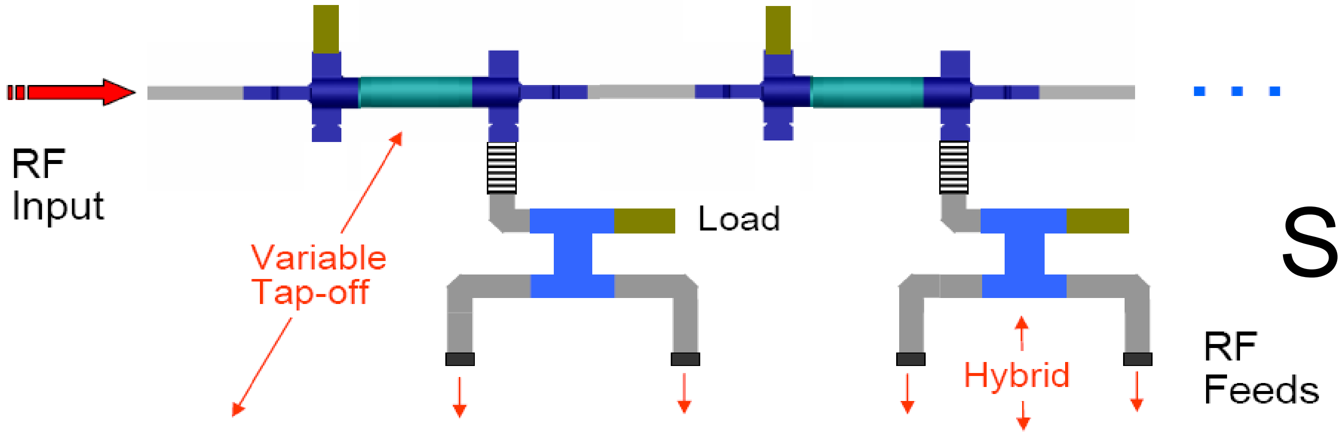




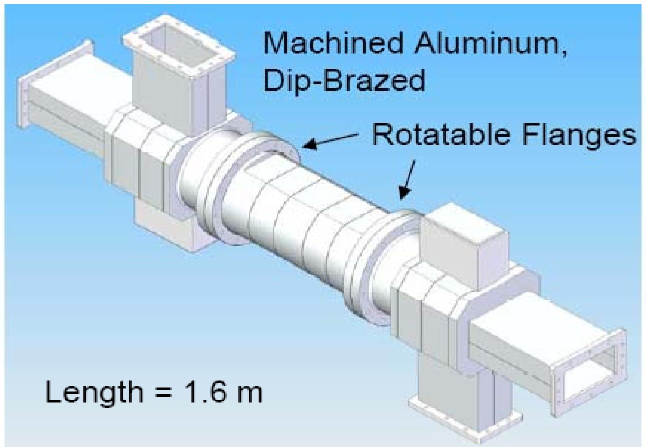
Very well suited to M6 performance !!

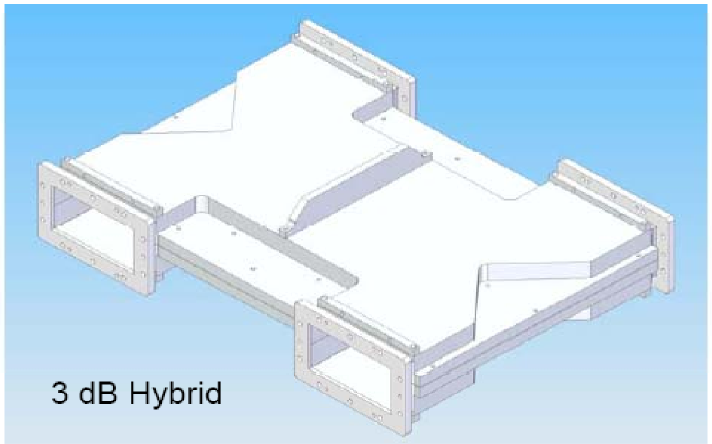
S7 : RF Distribution System

RF Distribution System without Circulators but with Variable Tap-offs (VTOs)



SLAC





Summary

- The RDB has started to work effectively with Funding Agencies and the TTC Collaboration
- The RDB tries to evaluate and coordinate the R&D worldwide. It has not credit for specific R&D progress (although many of its members have as individuals).
- The Alignment between the needs and allocation of resources is generally good.
- The RDB will work in close connection with the EDR Project Management and will align carefully to their Work Packages (maybe not !)

Thanks to Bill Willis and my RDB colleagues,

- **In particular to Tom Himel and Andy Wolski**