Main Linac Area System Review

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Communication since Bangalore

- Main Goal after Bangalore: Finalize ML design to the stage needed for cost estimation. Cost estimation.
- Meetings and reviews
  - **Main Linac System Area Status meetings:**
    - RDR video meetings: March 21, April 18; July 6 - Cost
    - ML workshop: May 11-13 at DESY
    - DOE/GDE program review
  - **Industrial Forums:**
    - Americas Region May 1-2 at SLAC
    - European-XFEL May 9-10 at DESY
- Technical System Status meetings (April-July):
  - **RDR TS Status Reviews:**
  - **Regular Area/Regional TS video meetings (weekly basis):**
    - Acc.Physics meeting, HLRF, LLRF, Instrumentation, CF&S, CM Cost (FNAL/JLAB)

Changes in Main Linac Design

1. Quad spacing reduced from 1Q/4CM to 1Q/3CM. The length of the quads and correctors would be reduced to ¾ of current lengths.

   To simplify the RF distribution system, RF controls, installation

2. Separate quad and corrector magnets to elimination of persistent currents in the quads generated by changes to the corrector settings, and by opening the option of using superferric magnets in the low-energy section of the linac.

3. Only one energy measurement per linac, at the undulator in the e- linac, and the equivalent position in the e+ linac (instead of two).

   in addition to meas. at the end of the RTML and the beginning of the BDS

4. Add six laser-wire stations (3 per linac). Each containing one laser-wire scanner to provide beam profile measurement.

5. Revise the number of RF units on the basis 3% energy reserve and additional units for compensating for the energy loss in the undulators for the electron main linac.

   (not 5% overhead=2% for BNS damping+3% reserve)

Status of ML Accelerator Physics

- Lattice design completed (1Q/4CM – for performance study and 1Q/3CM – "realistic")
  1Q/3CM Lattice matched to Undulator section and BDS. Cold end boxes and warm sections are included. RTML to Linac matching - soon.
- Code benchmarking of different codes done (J. Smith talk)
- Static tuning studies nearly completed (good enough for RDR stage)
  Mostly DFS (Dispersion Free Steering), less others (KA, AA, …)
  Bump tuning has been also shown to be effective.
  Sensitivity studies and Failure analysis nearly completed
- Dynamic studies
  – Stability tolerances (jitter, vibrations, RF) are being studied.
  Some results but not enough
  –Performance study of feedback have not been done.
  Focus work on dynamic studies and integrated DR→ IP simulations

HLRF Functional Description

- The High Level RF (HLRF) system: 628 10 MW RF Stations.
- Each ML station distributes RF power to 24 accelerating cavities housed in 3 Cryomodules, about 36 m of Linac.
- The major components of each station starting with the 34.5 kV HV power distribution are:

  34.5-12 kV ** **step-down transformer and switchgear,**
  modulator charging supply,
  modulator pulse-forming system, HV cables,
  10–120 kV output step-up transformer,
  klystron,
  HLRF WG system from klystron to acc. structures
  Auxiliary systems (systems all reside in local racks)
  LLRF subsystem for each station
  Additional local rack subsystems (vacuum, T, BPM, Quad/Corr PS)

** Note – Present prototypes use 480V step-down and step-up

Status of the HLRF System

- All basic RF BCD models have been agreed.
- Tunnel size and basic layout in ML service tunnel was agreed with CF.
- Reducing the size of the power supply, charger and modulator. Modifying charger to 12 kV input has been agreed.

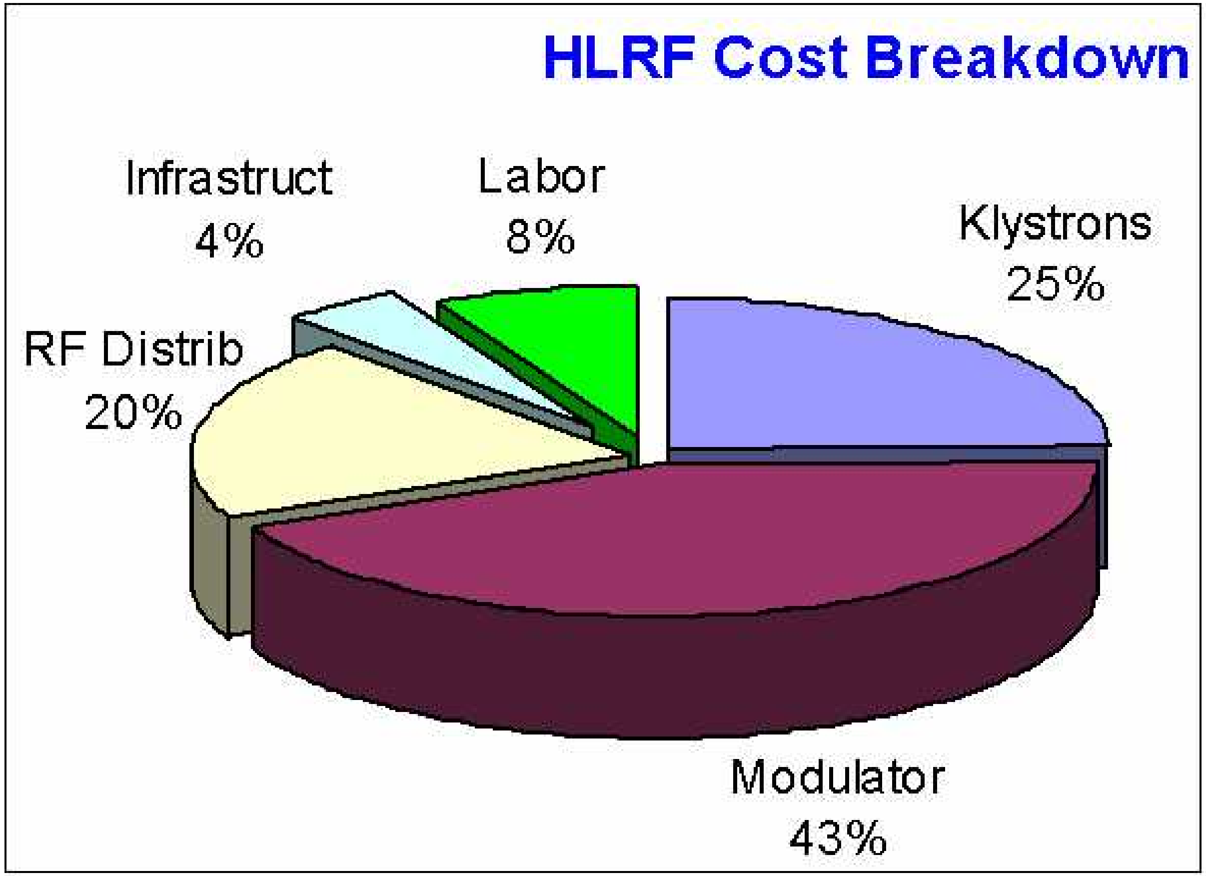
  The main power source in the support tunnel 34 kV AC line. The current Baseline charger has a 480V to 10kV step-up transformer.This will be tapped at every RF station to provide a step-down to 12 kV AC for the charging supply which delivers 10kV DC to the modulator.
- WG Layout from klystron to cryomodule thru penetration completed. New features: welding procedure for the WG in the penetration hole; PDS is prefixed on cryomodule and adjusted before installing to the tunnel. Components list of the PDS is completed.
- Water and air-conditioning requirements completed.
- LLRF and cabling requirement are nearly completed.

HLRF Costing

- Cost methodology and production models for klystrons, Modulators, RF Distribution system are completed
- HLRF System Cost estimates are completed in three Regions: *Modulator, Klystron, RF Distribution, Infrastructure. Estimates made at WBS level 6 or 7 in most cases.*
  - **Three Region's methods are different but all have a reasonable basis of cost justification**
    - Europe-Based on XFEL cost studies, vendor quotes, experience
    - Americas - Based on bottom-up cost models
    - Asia-Based on Companies' mass production experience

HLRF System Cost breakdown

Americas Region



W/o labor: Mod/Kly/RFD/Infrastr. = 46/27/22/4

Europe (TESLA TDR):

- Mod/Kly/RF_Distrib.

  51% / 29% / 20%

(Labor & Infrastr inside)

Asia Region:

- Costs for Klystron and Modulator are similar
- Cost of RF distribution systems is higher???

Cryomodule Design Status

R&D work

- Continue R&D work on TTF-IV cryomodule design
- Discussing ILC CM (Type V) design with larger piping tube diameter, optimized for mass production
- Magnet Package in separate Cryostat

Costing Efforts in USA

- Costing Methodology, Production, Assembly and Testing models, Risk analysis, based on SNS and TESLA-TDR, XFEL experience
- Two parallel efforts in US
  - **U.S. Industrial Study (AES, CPI, Meyer Tool…) - contract**
  - **Internal Cost Estimate (JLAB, SLAC & FNAL) – for Vancouver**

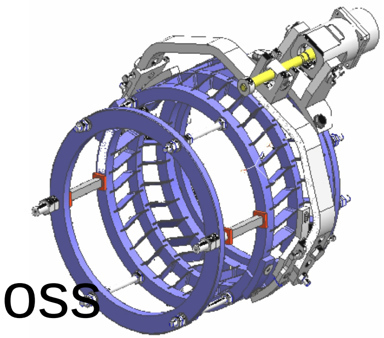
    Broke the cost estimate up into parts:
    - ***JLAB*** ***Cavity Fabrication***
    - ***FNAL*** ***Cryomodule Assembly***
    - ***SLAC*** ***RF Power System***

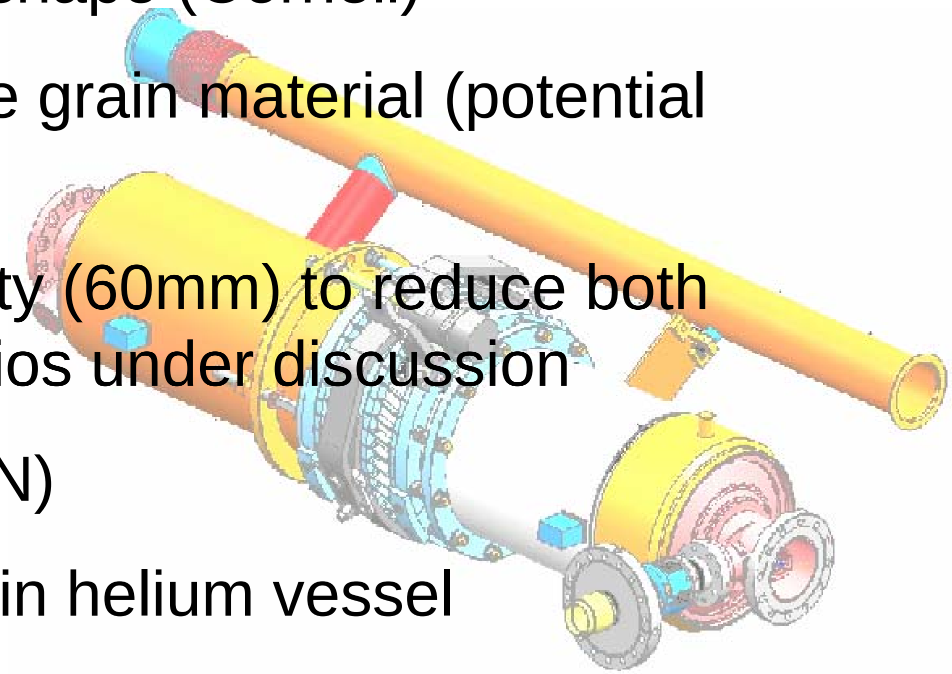
Costing efforts in Europe and Asia

- TESLA TDR (Industrial)
- XFEL Cost Project Update - Second iteration on costing (finished early 2006). Adjusted to
  - Inflation, increased material / energy costs
  - Modified cavity fabrication spec from 1400°C to EP & 800 °C & 130°C bake
  - Modified infrastructure lay-out
- Process of finding cost numbers for ILC linac system by W.Bialowons (ongoing activity)
  - Adjust TESLA TDR cost for inflation, increased material / energy costs
  - Translate adjusted TESLA TDR cost to requested numbers of ILC components
  - Analyze XFEL project construction cost and recent cost Update
  - From above findings synthesize ILC linac cost
- Asia: Combination of Industrial Studies and learning curve

Cavity design Status

- Cavity flange to flange length reduced
- Shorter Cavity interconnection length 283 mm
- Continue R&D on a alternative designs: Low-Loss (ICHIRO) and Reentrant shape (Cornell)
- Cavity build from the large grain material (potential saving)
- Smaller radius of the cavity (60mm) to reduce both Ep/Eacc and Hp/Eacc ratios under discussion
- Blade-Tuner Design (INFN)
- Magnetic Shielding Build-in helium vessel





Coupler Status

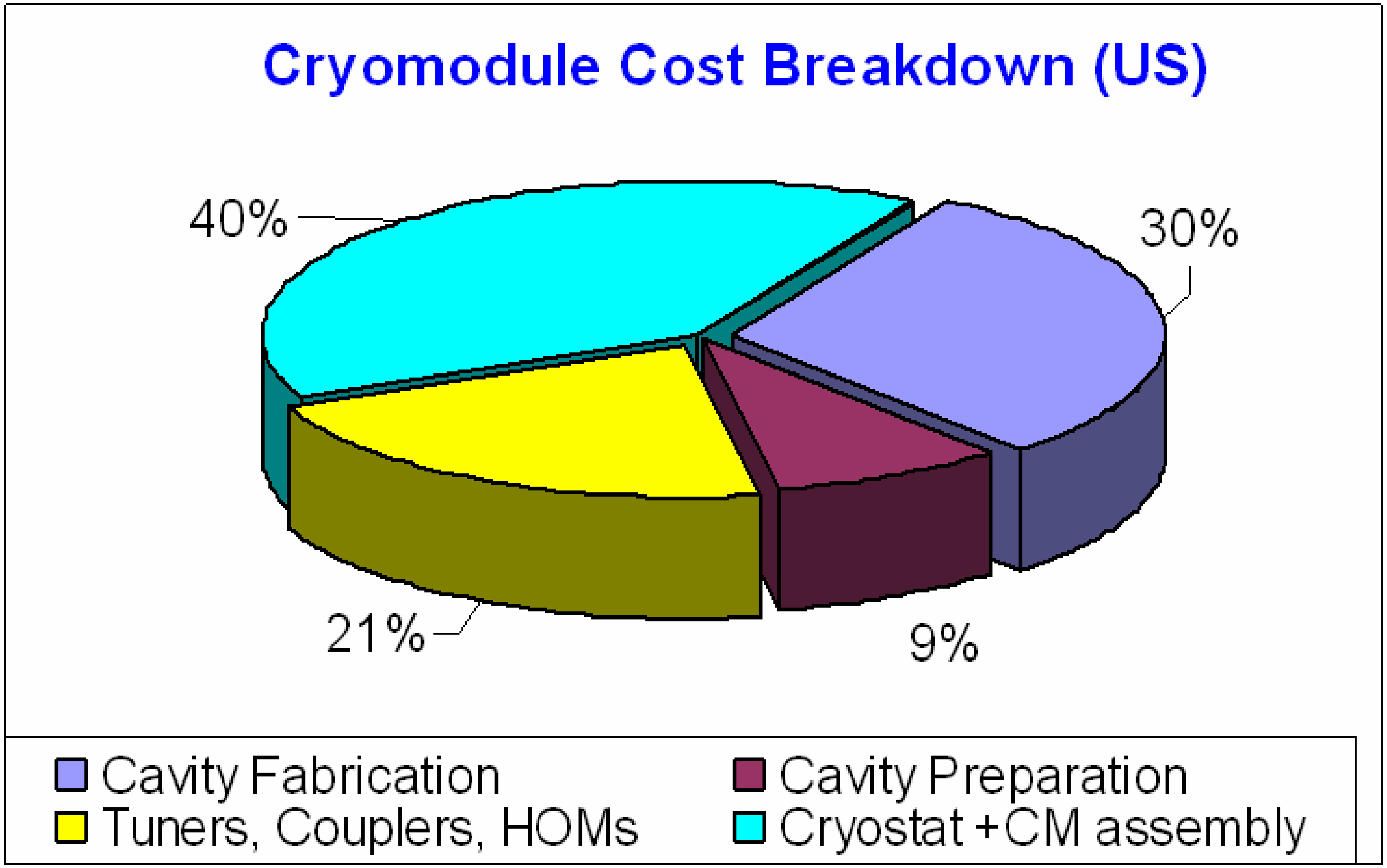
- R&D: New design of capacitive coupler with flat windows is successfully tested at KEK
- Processing time <20hrs was achieved for TTF3 coupler
- Europe: Definition contract for couplers is placed to 3 companies Contracts have started early 2006, will finish in 18 months
  - **Examine functionality coupler design**
  - **Determine best fabrication methods**
  - **Develop QA strategy**
  - **Fabricate and test new prototypes**
  - **Technical description of the new coupler (public report)**
  - **Evaluate cost of 1000 couplers (non public report)**

Magnet design Status

- ML has 628 SC Quads and correctors (out of ~17000 total)
- No final design yet
- Length of magnet package (BPM/Quad/Correctors) 1200mm are agreed
- To cover large range of the beam energy a few types (at least 2) of magnets are considered
- Separate Quad and Corrector Design (?)
- New Design at the first stage
  - **Early conceptual designs exist - DESY**
  - **FNAL – Vl. Kashikhin et al. -**
  - **KEK – K. Tsuchia, N. Ohuchi**
- Cost Estimation
  - **Cost estimations are based on best in-house expertise**

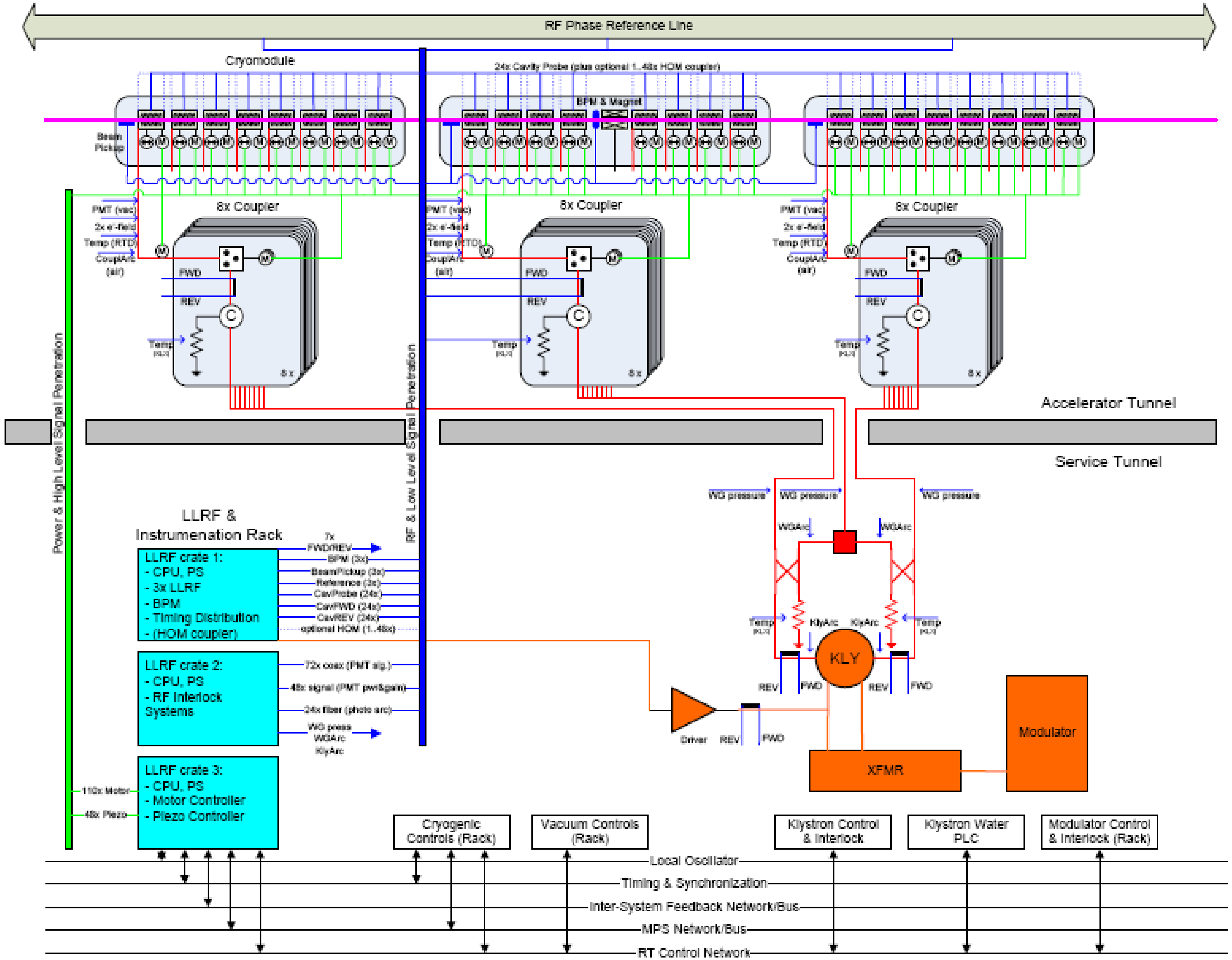
* Note: Magnets are not a cost driver in CM cost

Cryomodule cost estimation

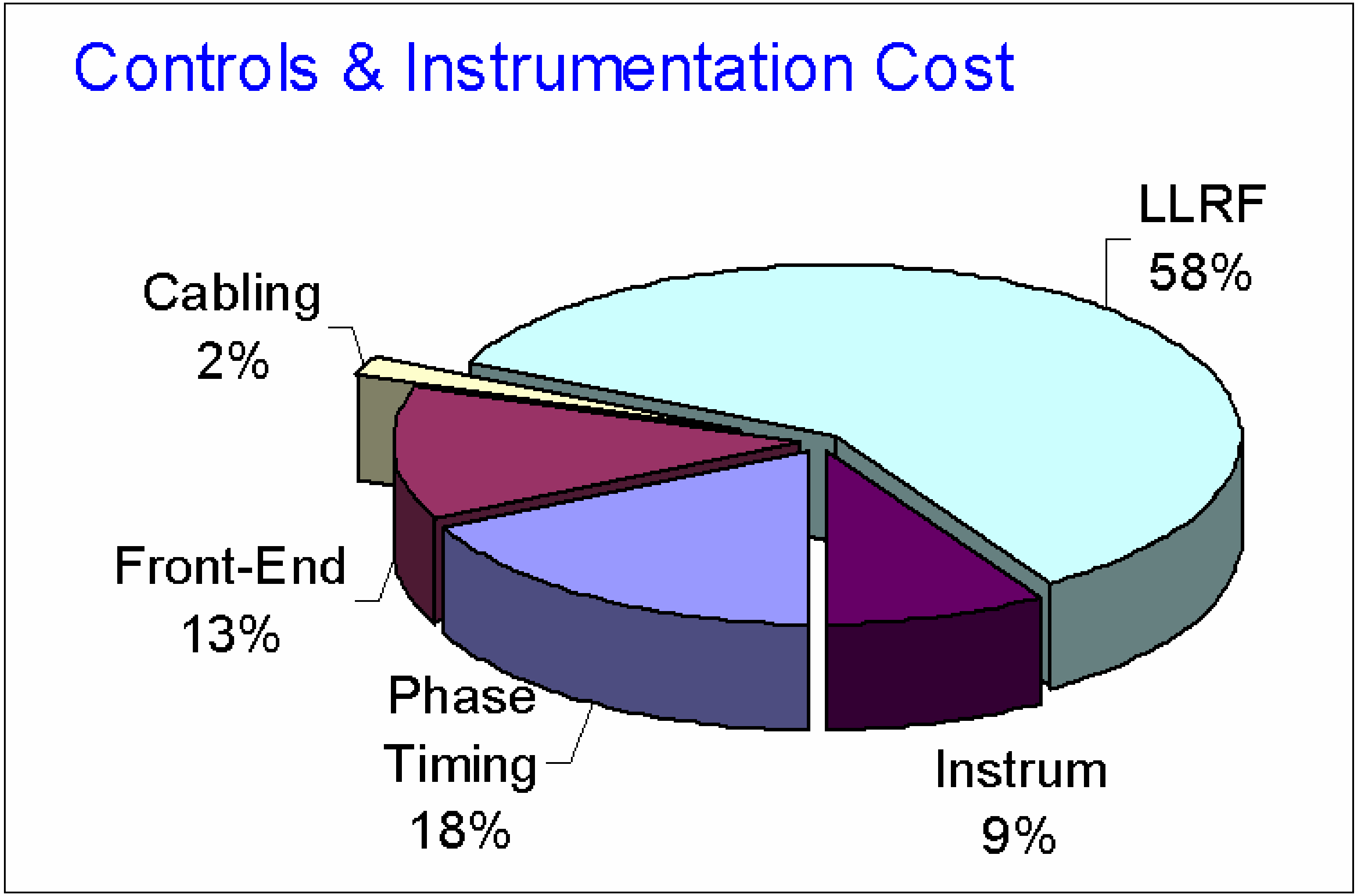


* Cavity Fabrication cost includes cost of materials
** Facilities costs are included in each item

LLRF and Instrumentation



Integrated Controls & Instrumentation



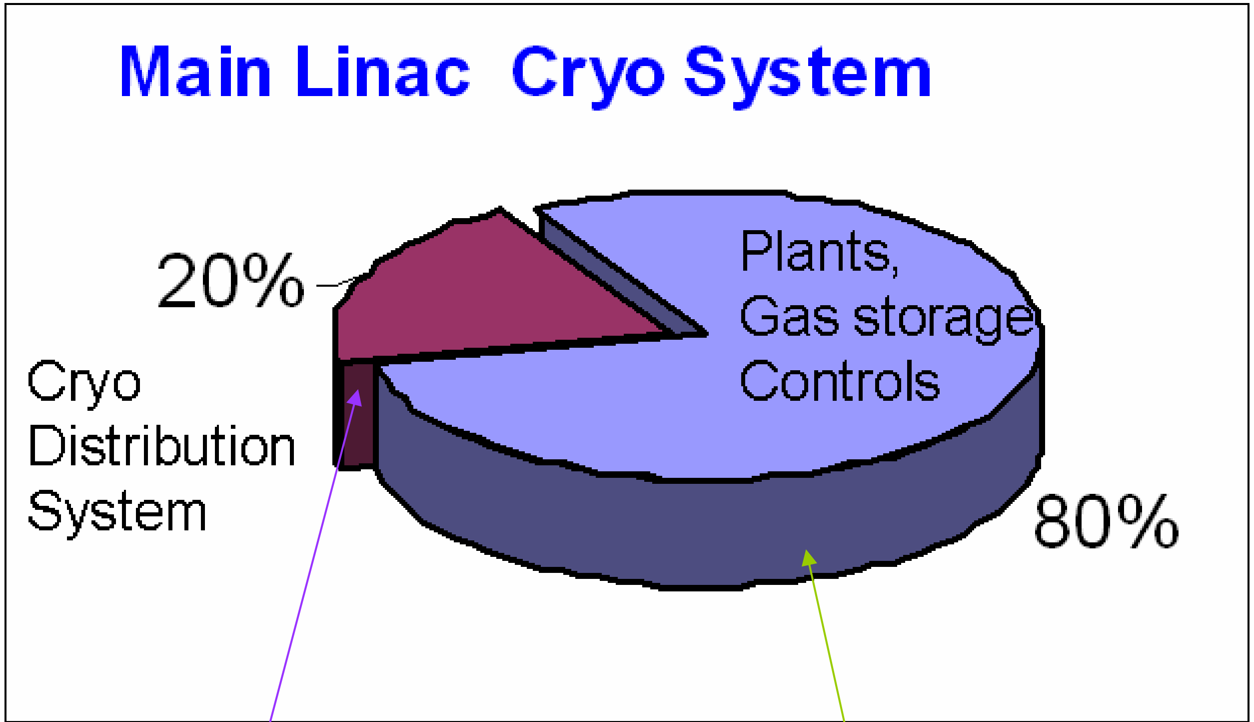
Cryogenic system design status

- The status of the design
  - **Almost complete accounting of cold devices with heat load estimates and locations**
  - **Component concepts (boxes, transfer lines) needed**

- What's new since Bangalore
  - **Main linac refrigerator arrangement**
  - **ML lattice details with string end box lengths (2.5m), vacuum segmentation (~2.3km), warm drift spaces (~7m)**

- Decisions still pending
  - **More precise heat load estimates for all areas**
  - **Transfer line lengths and cryo box features in all areas**

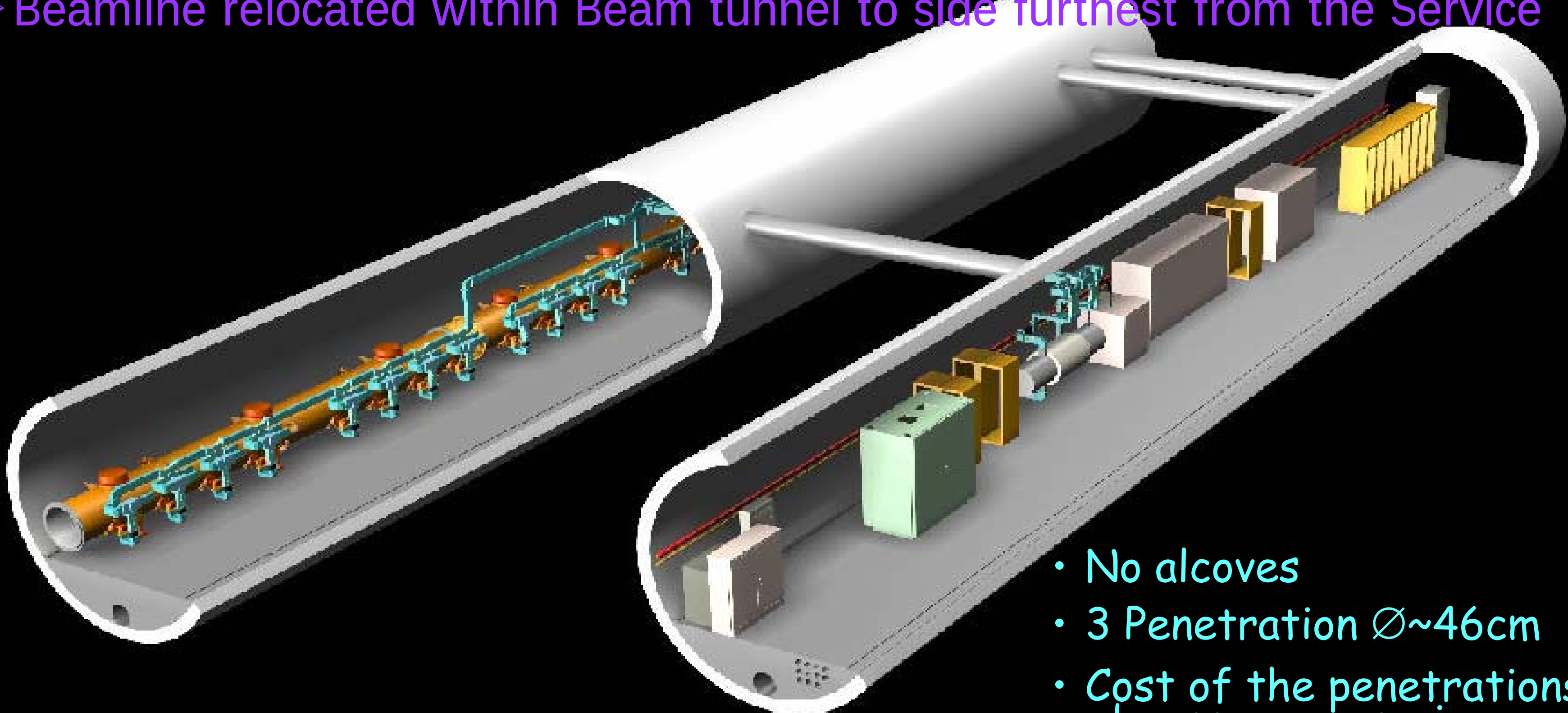
Cryo system major cost drivers



- Main cost drivers:
  - **Main linac cryogenic plants itself (~54% of total cost)**
  - **String end boxes (~13% of total cost)**

Civil Engineering(1)

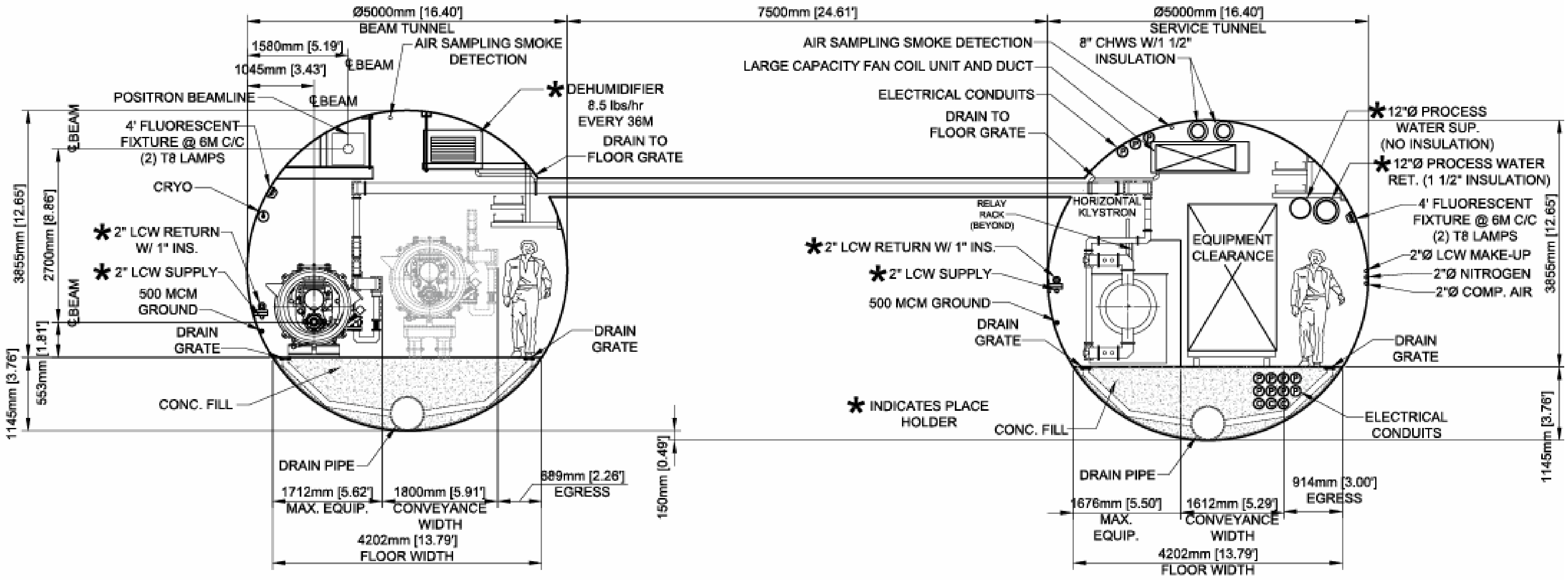
- Developments since last review.
  - Tunnel cross-section diameter reviewed, studied and accepted at DESY.
  - Labyrinth passageway between Beam and Service tunnels received initial radiation safety approval. 500 m spacing established.
  - Beamline relocated within Beam tunnel to side furthest from the Service

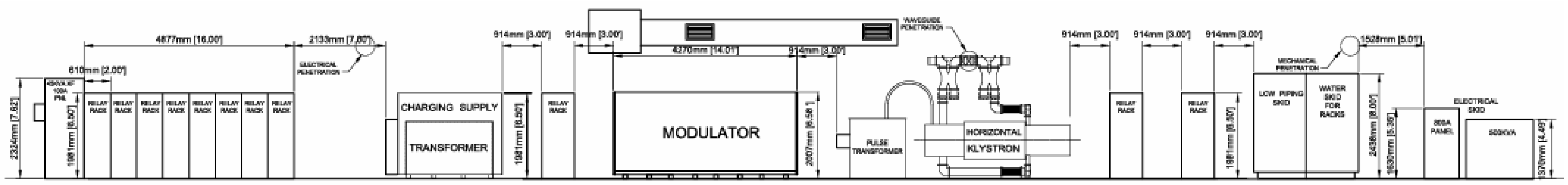


- No alcoves
- 3 Penetration ∅~46cm
- Cost of the penetrations and passageways minor

Tunnel Layout

(5 m Diameter, 7.5 m between tunnels)



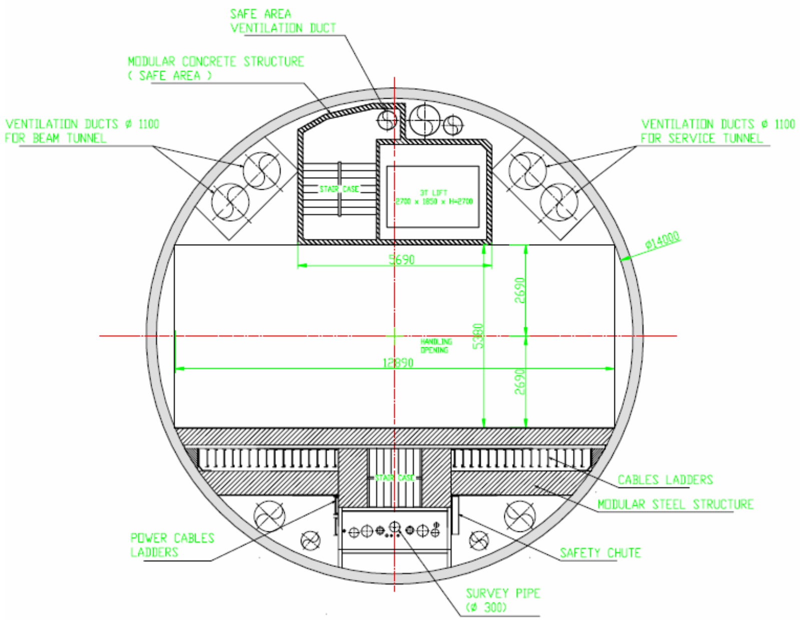


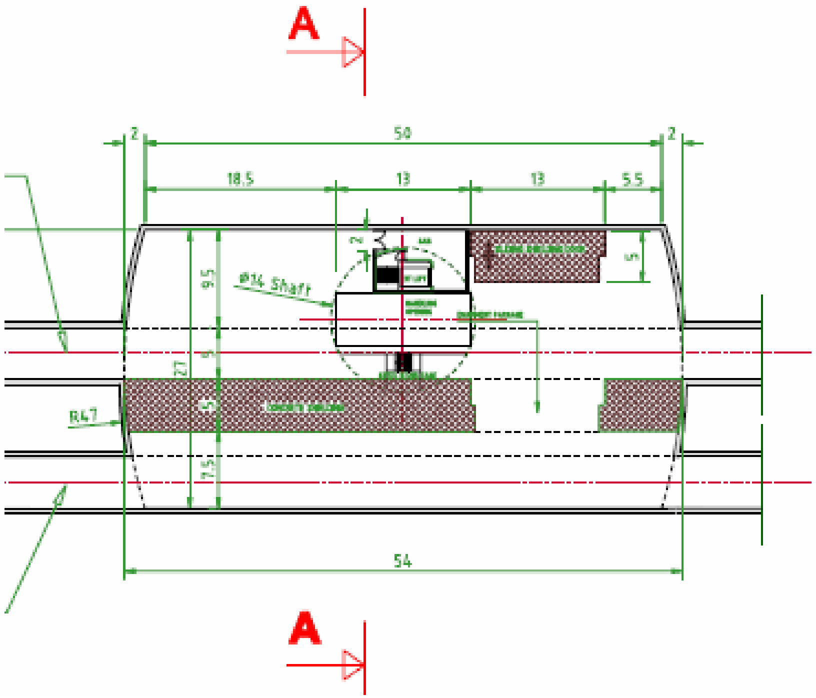
Service Tunnel Elevation View – One RF Unit (36 m)

Civil Engineering (2)

TL

- Developments since last review.
  - Designs established for shaft locations, shaft cross-sections, shaft caverns, and waveguides.





  - RF input power changed to medium voltage AC~10.6KV.
  - Consultant Cost models for tunnel, shaft, shaft cavern, and shaft campus developed in each region.
  - First pass: Ventilation, Water cooling, Fire safety,, Electrical, Transportation

CF&S: Cost Status

- The Main Linac criteria is developed to a degree that allows preliminary design to layout and size technical systems and make quantity take-offs for the estimate.

Completion (July 10)

Criteria	99%
Drawings	100%
Costs Estimate	90%

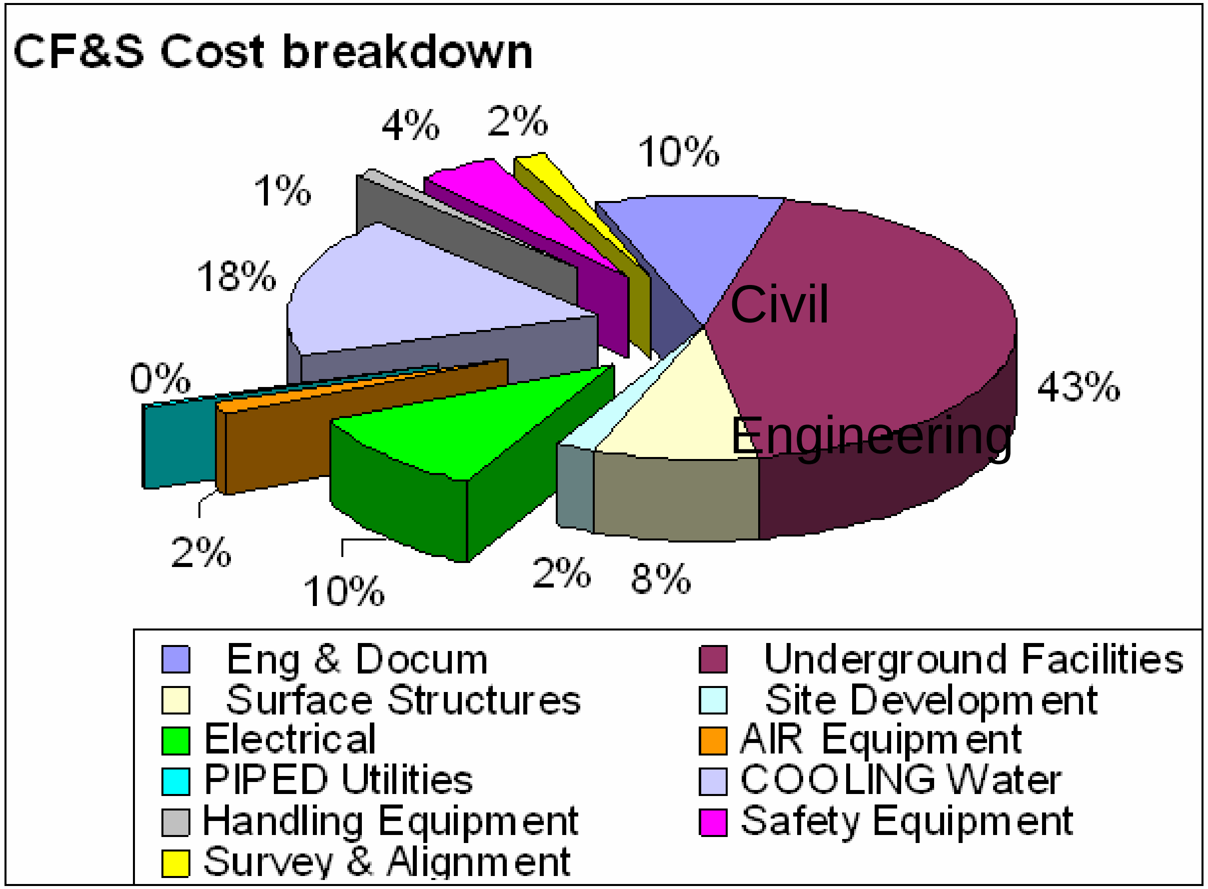
Costs used in pie chart are:

Americas region

1.71. Civil Eng
1.7.3 Air Treatment Equipment
1.7.4 Piped Utilities
1.7.5 Cooling Water

Site independent cost

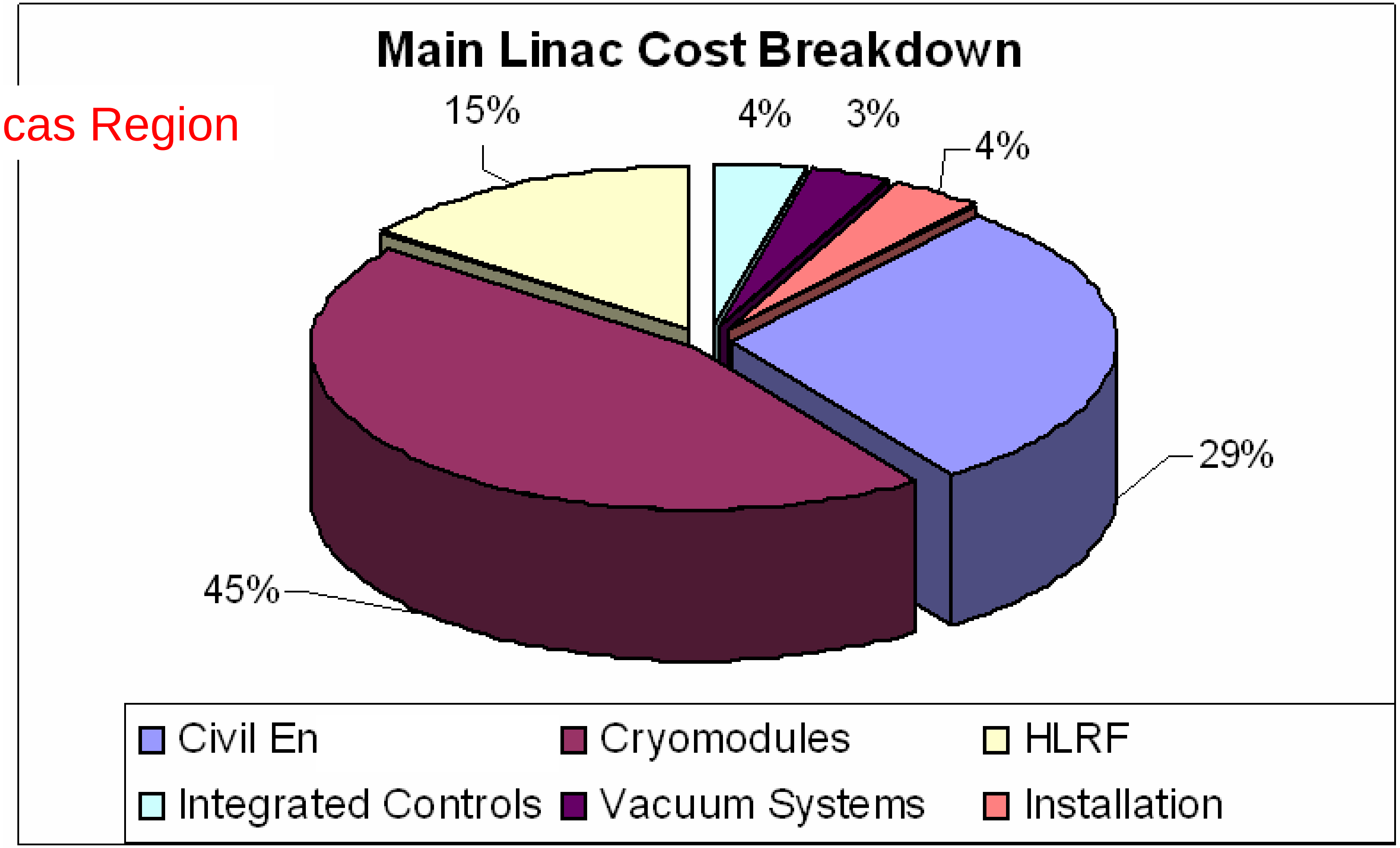
1.7.2 Electrical – CERN
1.7.6 Handling Equipm –CERN
1.7.7 Safety Equipment –KEK
1.7.8 Survey & Alignmt -CERN



*All items except 1.7.1 are considered site independent

Major Cost drivers in Main Linac

Americas Region



* Instrumentation Cost are included in the Integrated Controls Cost

Cost Roll-Up Status

- Cost Roll-Up status
  - The first pass of costing >90% completed
  - Some not completed. Some less level of detailed.
  - Cost Drivers are well defined.
  - Need regional industrial studies (US, …)
- What is missing
  - Consistency

Possibilities for Cost Reductions

- Civil
  - **One tunnel option**
    - Similar to TESLA TDR and XFEL option. Klystrons and modulators in the tunnel. Issues – radiation shielding (electronics), reliability, etc…
  - **Water Cooling System (saving in construction and operation power cost)**
    - Hotter tunnel: temperature (85F/29C) close to tower water Tº
    - Cascaded cooling: Air→Electronics→WG→Kly body & magnet→collector
    - Reduce water flows and increase in the delta-T
    - Eliminates chilled water distribution system
    - Relaxes or eliminates requirement to dehumidify tunnel air
    - Re-examination of power dissipation and cooling requirements
    - Reductions of the primary cooling plant infrastructure

Cost reduction: Cryomodules

- One design for cavities cryomodule
- Use independent Q-magnet cryomodule
- Magnet and BPM with diameter 35mm (now ~78mm)
- Selection of cavities with similar performance in CM
- Automated cavities installation/alignment

  Develop easy install cavities fixture, easy pipe-welding fixture, easy alignment fixture, automated laser alignment
- Automated (or No) RF power test in horizontal cryostat

Cost Reduction: Cavities

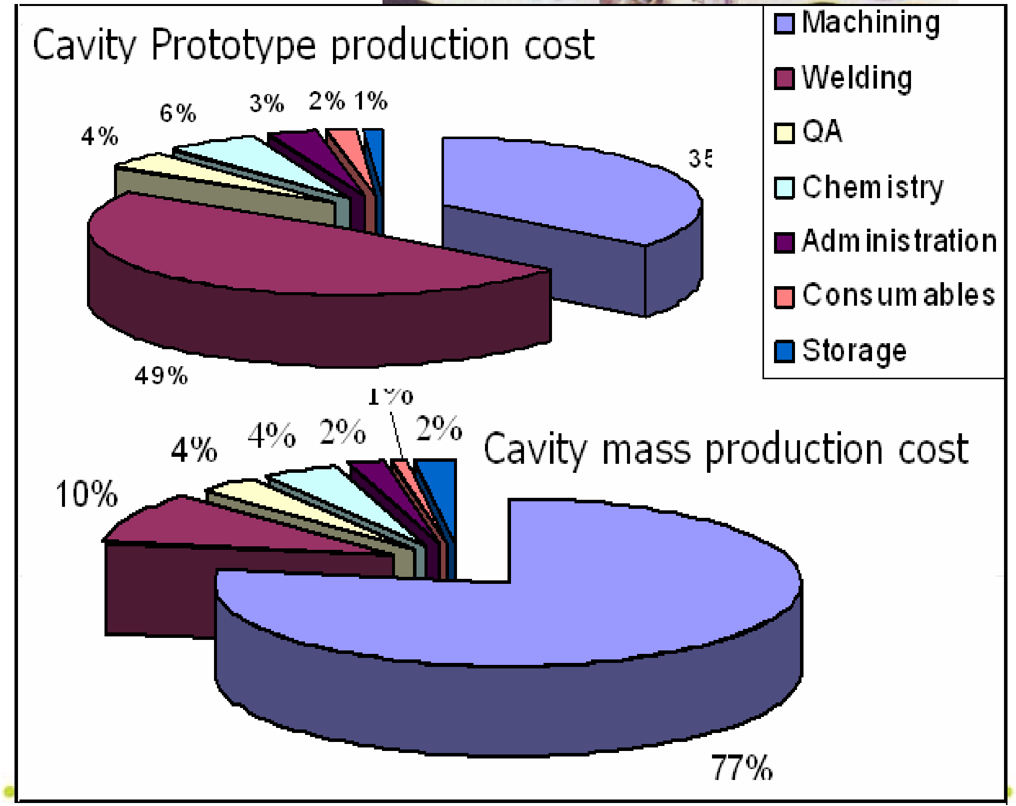
- Optimize cavity fabrication (D.Proch presentation)
- Use LL shape for more gradient margin. Cavity with smaller aperture ∅60mm.
- Develop seam-less cavity (not critical if welding cost reduced)
- Optimize surface treatment

  Simple as possible as we can, make facility as a line-flow like (semi-automated) avoid re-treatment, grouping cavities by performance, minimize disqualified cavity
- Use similar performance cavities in a cryomodule
- Optimize and automate vertical test procedure
- Optimize and automate coupler RF processing

Reduction of Cavity fabrication cost

- Industrial study based mostly on present technology, adjusting tooling and procedures to produce ~20,000 cavities

- For mass production need new approaches:
  - **3 vacuum chamber welding machine (or fast pump):**
    - **Pump down and cool down in separate chamber**
    - **Welding in middle chamber**
  - **Tooling for welding many parts in one cycle**
  - **Outsource machining of parts**



(D.Proch, XFEL Industrial forum)

Cost Savings: Modulators & Klystrons

- Marx generator modulator
- Avoid using oil-filled pulse transformer

  Develop low-voltage klystron (~50kV, KEK)

- Low-voltage klystron (sheet or MB)

  MB-klystron with increased number of beams (6→ 32). Eliminate pulse transformer

- Reduce cathode loading

  Longer lifetime. This leads maintenance cost reduction.

- Use three-way RF output in Klystron

  To avoid three-way distribution waveguide circuit, klystron should be modified for three output port with windows (No 2 hybrid & RF-loads, but add klystron window.)

Cost Reduction: RFD system

- WG welding connection or quick bolting. Modular WG

  To minimize labor cost of bolting waveguide, welded modular WG
- WG Phase Shifter instead of Three-Stub Tuner

  Cheaper, wider phase tuning range, one motor instead of three
- Eliminate circulators
- Eliminate gas filling

  Each 3.3MW line from klystron (3 output klystron) not require gas filling
- No Q_{ext} adjustment. Fixed coupling input coupler

  Since similar performance cavities are grouped, no more adjustment is necessary.

Fixed power divide ratio for cavities

By grouping the cavities with similar performance, LLRF control can take care of different Q_{ext} group.

Plans and Goals

- the plans and goals for this workshop
  - **Cost Review. Discuss Cost models, in close session**
  - **Discuss Cost Reduction strategy**
  - **R&D Status and Strategy Discussion**
  - **Structure of RDR paper and responsibilities**
- between this and the Valencia workshop
  - **Reconcile among regions and Refine costs**
  - **Improve consistency across the technical systems**
  - **Reviewing design choices with TS groups**
  - **Identify cost saving strategy**