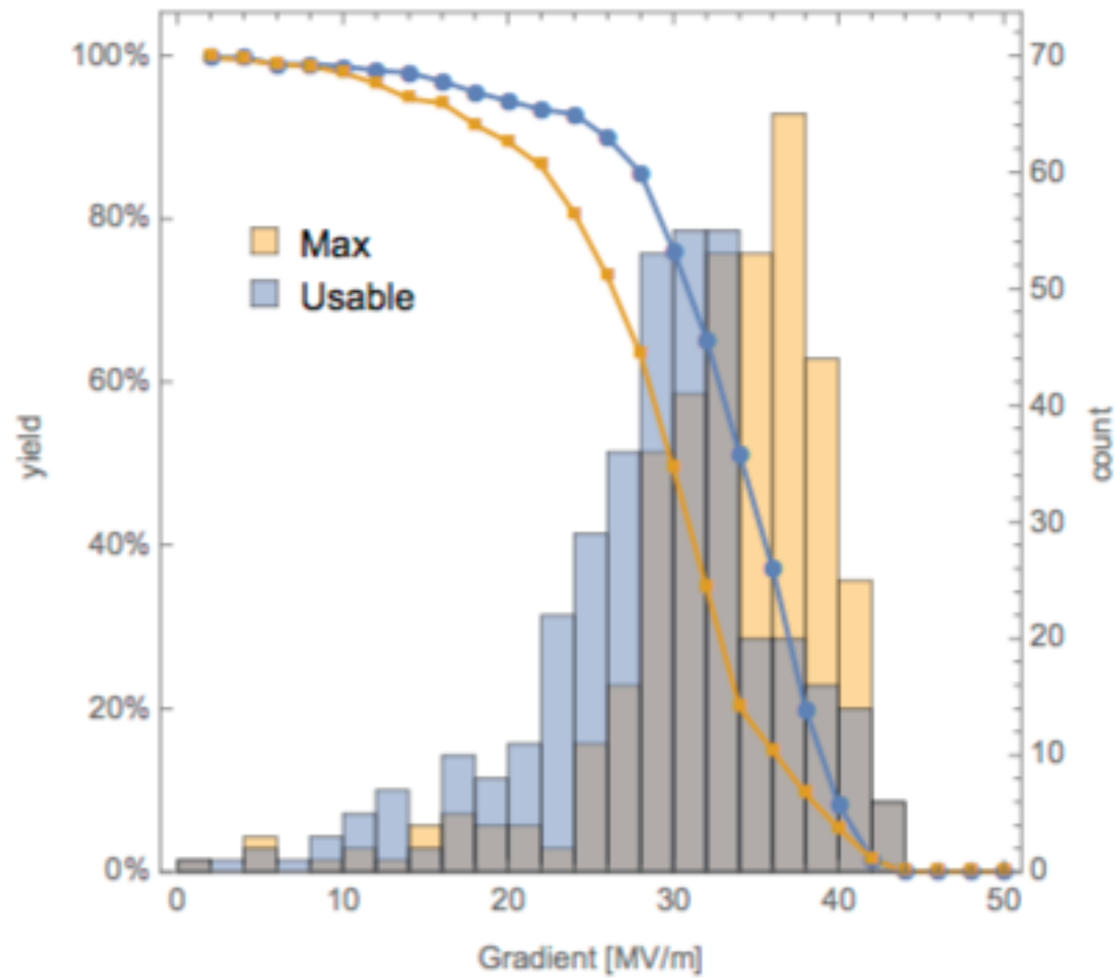
ILC Status Update

Cavities & cryomodules: XFEL final results
ATF 2 recent run
Design activities
SRF R&D & cost reduction

Mike Harrison

XFEL Final Cavity Data - RI cavities only

RI cavities only i.e. ILC processing cycle
 with EP
Will likely exceed ILC gradient specs with ~20% reprocessing as in the TDR



LINEAR COLLIDER COLLABORATION

XFEL Final Cavity Data - RI cavities only

European XFEL

Extrapolation to ILC - VT

- ILC TDR assumed VT acceptance > 28MV/m (XFEL >20 MV/m)
  - Average of 35 MV/m (XFEL 26 MV/m)
  - Assumed first-pass yield: 75%
  - 25% cavities retreated to give final yield of 90% >28 MV/m (35 MV/m average)
    - ➡ 10% over-production assumed in value estimate

RI results only (ILC recipe)		ILC TDR (assumed)	XFEL max	XFEL usable
First-pass	Yield >28 MV/m	75%	85%	63%
	Average >28 MV/m	35 MV/m	35.2 MV/m	33.5 MV/m
First+Second pass	Yield >28 MV/m	90%	94%	82%
	Average >28 MV/m	35 MV/m	35.0 MV/m ✔	33.4 MV/m ✘ *but close!*
First+Second+third pass	Yield >28 MV/m	-		91%
	Average >28 MV/m	-		33.4 MV/m

More re-treatments - but mostly only HPR
Number of average tests/cavity increases from 1.25 to 1.55 (1^{st}+2^{nd}) or 20% over-production or additional re-treat/test cycles ➡ $$$

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XFEL Cryomodule production rate

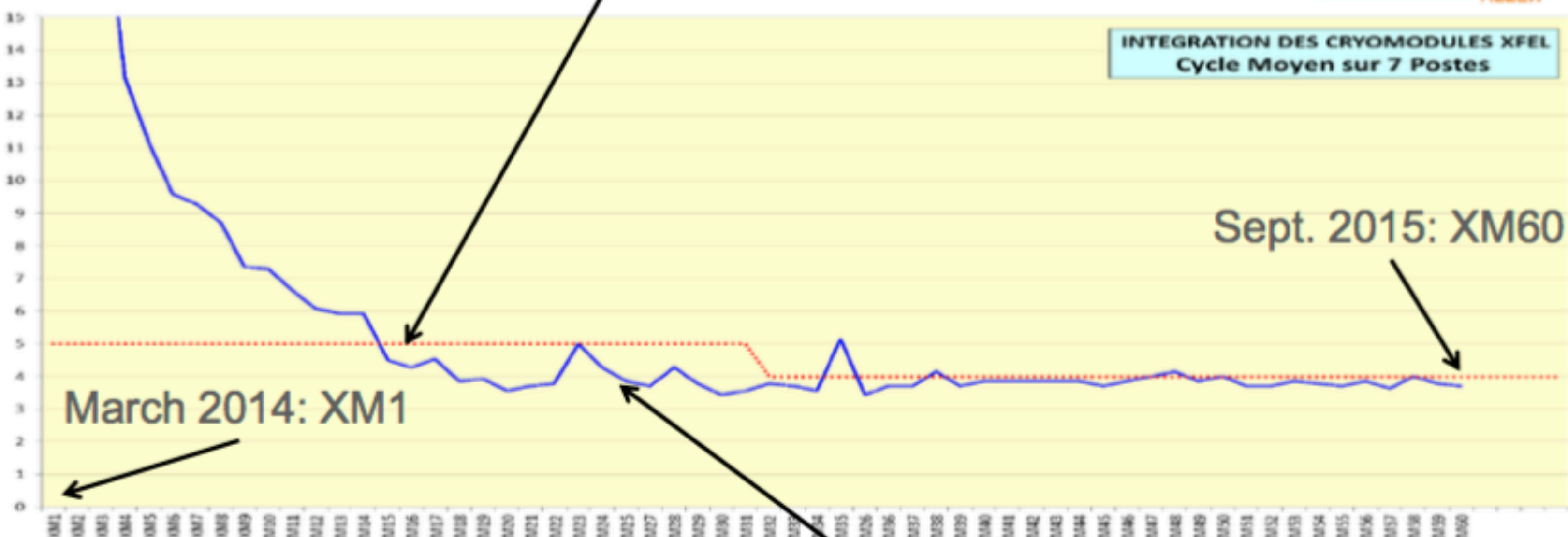
Irfu

Production Rate

XFEL X-Ray Free-Electron Laser

- 5 day throughput was reached **mid-October 2014** with **XM15**
  ⇒ the design of the Assembly Infrastructure was sound

Courtesy ALSYOM ALCEN



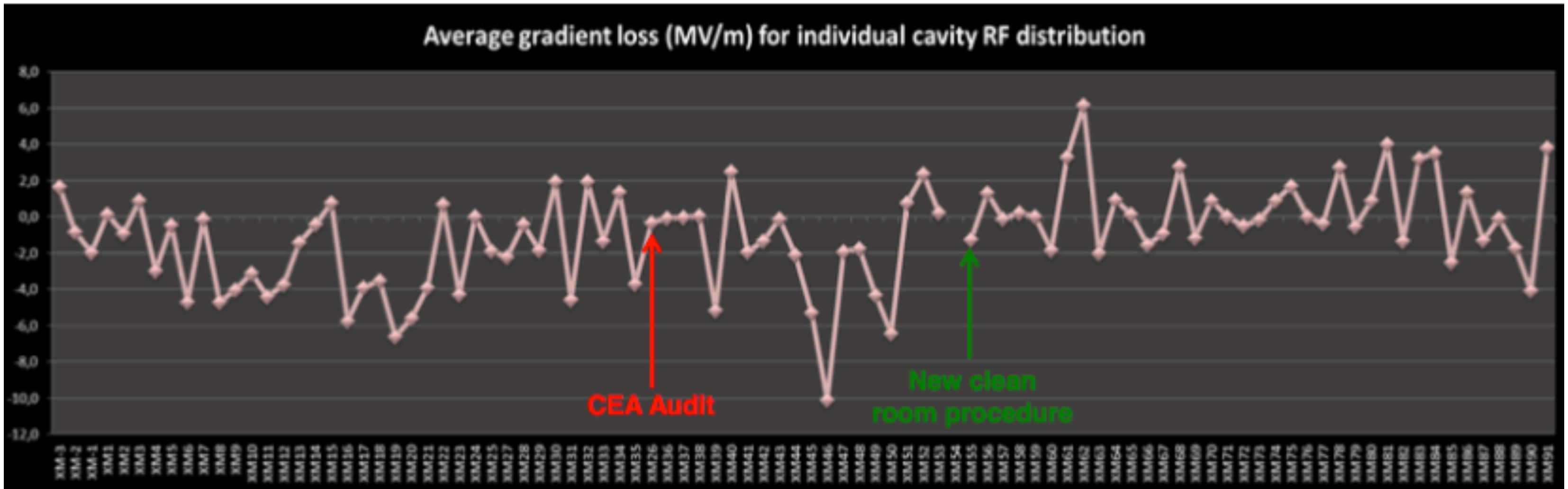
4-day throughput was reached **in January 2015** with **XM25**

This 'accelerated' rate was needed to close the XFEL tunnel mid-2016:

- hoping to deliver XM80 deliver at the end of December 2015
- and XM100 at the end of April 2016

XFEL Cryomodule performance

Irfu — Cryomodule Performance — XFEL X-Ray Free-Electron Laser



1st sample of 32 series CM	2nd sample of 18 series CM	last 29 series CM
ΔE_{op} = -2.2 MV/m	ΔE_{op} = -1.7 (-0.9) MV/m	ΔE_{op} =+0.4 MV/m

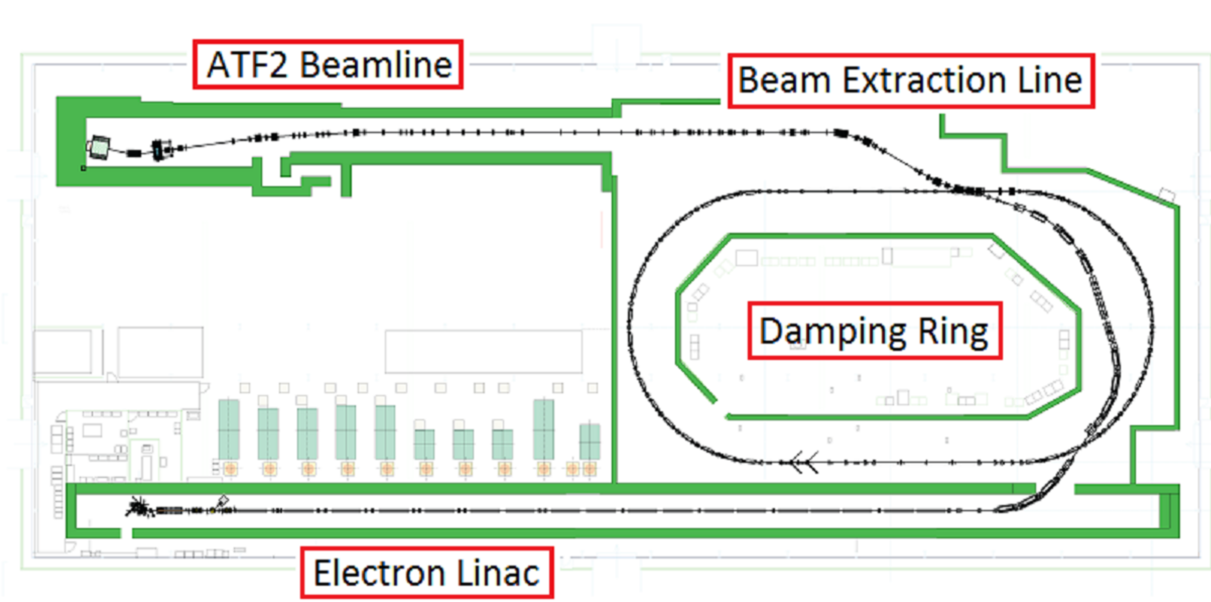
- All but 5 of 81 tested modules are on XFEL specs (23.6 MV/m), 6 modules need(ed) repair.
- Average gradient is 17% above specs : **$\langle E_{acc} \rangle$ = 27.6 MV/m**.
- Significant gradient degradation from XM6 to XM23, while CEA and Alsyom put all their effort in achieving production goal of 1 CM/week: an audit of string and module assembly was conducted by CEA on XM26
- A simplification of the clean room procedures was introduced at XM54: **no degradation after**

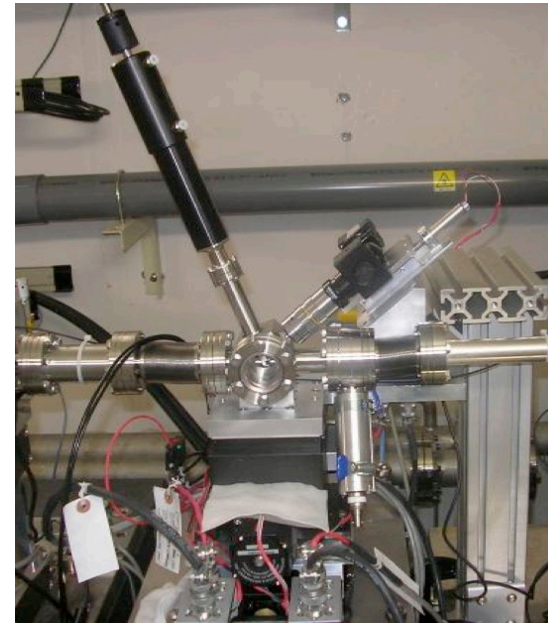
ILC assumed a ~10% degradation

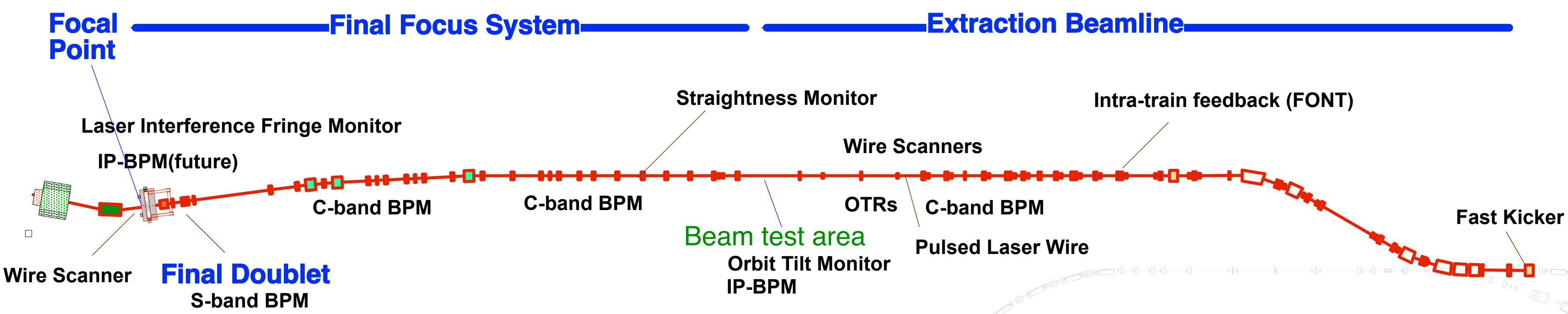
XFEL Experience - conclusions

- ILC gradient spec of 35 MV/m ± 20% is confirmed by XFEL cavities
- XFEL cavity processing cycle again validates ILC assumptions
- ILC cryomodule production rate of 1/wk exceeded towards the end of production
- ILC assumed gradient degradation when the cavities are in the cryomodules (10%) make be conservative

Nano-beams at ATF2 - KEK







Beam Delivery system optics, instrumentation test-bed, tuning and feedback demonstration. Common interests for both CLIC & ILC

Goals of ATF2

- Achievement of small (37 nm) beam size (Goal 1) ✔
  - Demonstration of final focus system based on local chromaticity correction
- Control of beam position (Goal 2) ✔
  - Demonstration of beam orbit stabilization with nano-meter precision at the IP, using intra-pulse feedback
- Beam size intensity dependence (“Goal 3”) ✗
- Other studies:

Lower beta-y* (mainly for CLIC)

Ground motion – orbit feedforward

Development of instrumentation (beam monitors)

2016 ATF2 results

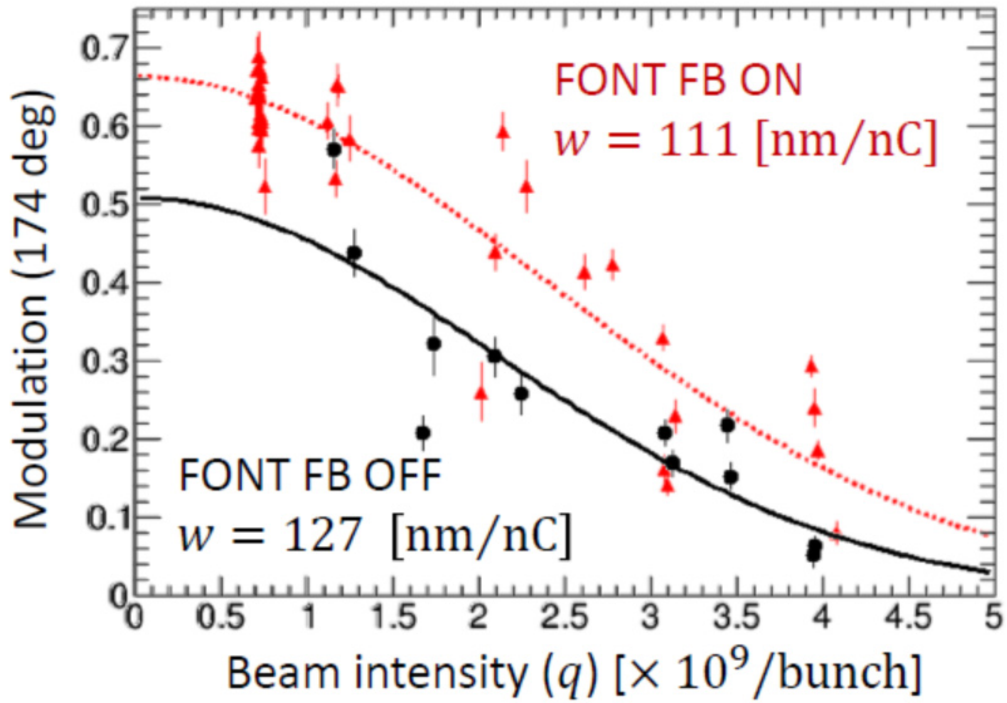
IP beam size with/without FONT FB

To be presented by Y.Kano at ECFA LCWS2016

Fitting function:

$$M = M_0 \exp\left[-2(k_y w q)^2\right]$$

Two bunches 180 ns separation. Feedback on the second bunch from the first

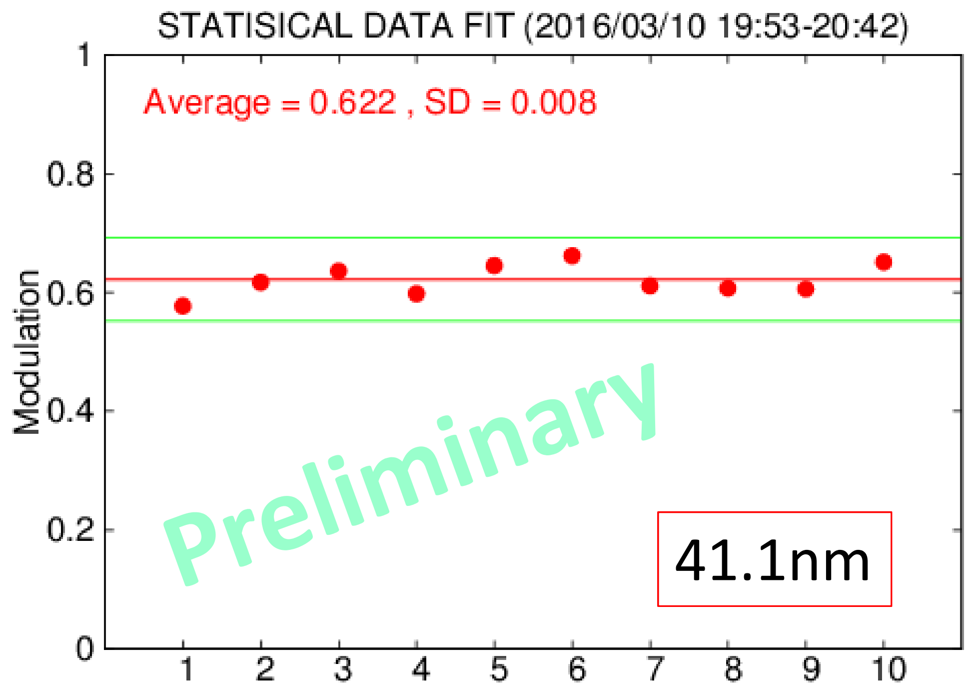


- *Intensity dependence was not changed so much by FONT FB.*
- *Maximum modulation was increased by FONT FB.*

ECFALC16, T.Okugi(KEK)

2016 ATF2 results

IP beam size with FONT FB at N=0.7e9

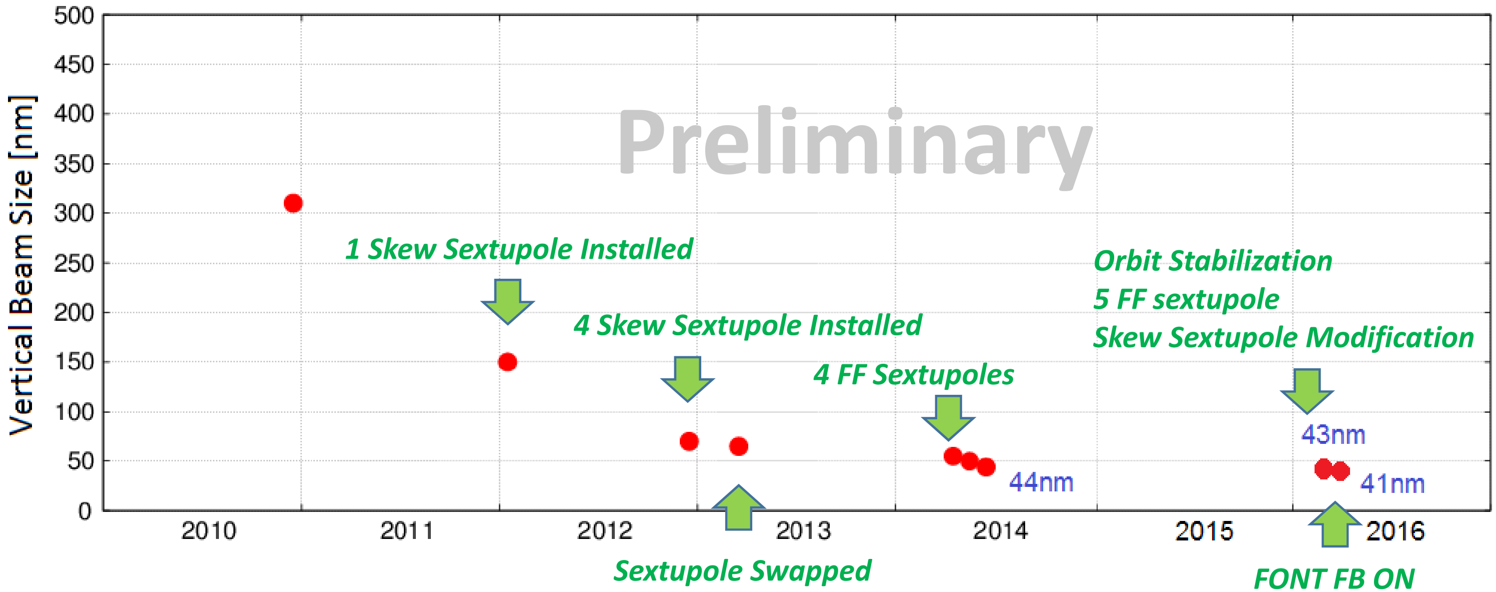


Beam size at N=0.7e9 with FONT FB was present record of ATF2 IP beam size

ECFALC16, T.Okugi(KEK)

2016 ATF2 results

Summary of the IP vertical beam size measurement



*Beam size was focused to less than **44nm at 2014/06 at** N=0. 5e9.*
- without orbit FB, because the temperature stability was good in summer.

*Beam size was focused to less than **43nm at 2016/02** at N=1.0e9.*
- with orbit FB, 5 normal sextupole magnets, new skew sextupole magnets.
- The beam size was kept in 1 day.

*Beam size was focused to less than **41nm at 2016/03** at N=0.7e9.*
- 2nd bunch beam size with FONT FB.
- We cannot understand yet the reason of the difference with/without FONT FB.

ECFALC16, T.Okugi(KEK)

ATF2 Next Run: Oct 2016

Main emphasis is now the intensity effects.

We are planning to remove 1/3 of the cavity BPM's.

This will reduce the wakefields by ~ factor of 2

We hope it will give clear results in terms of how to proceed

Design Activities

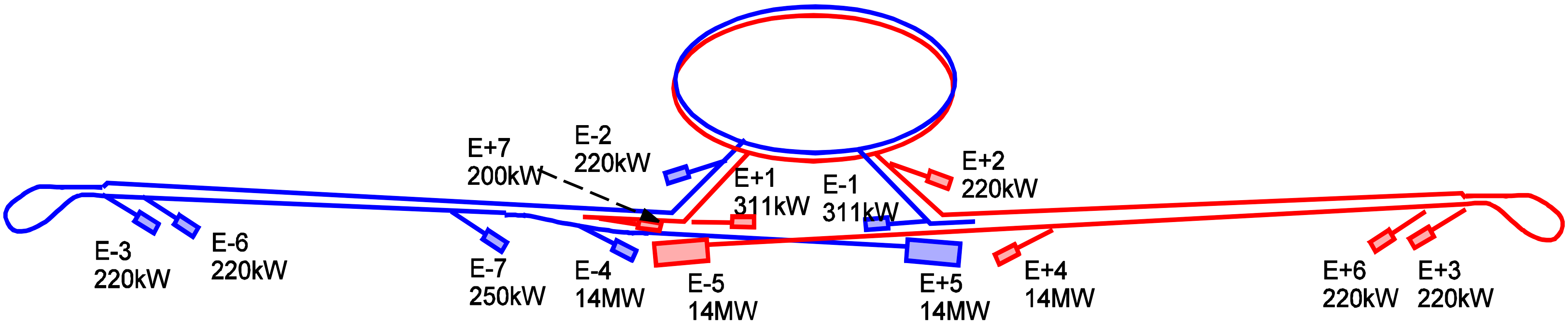
CHANGE REQUEST NO. ILC-CR-NNNN	EDMS No: **D*0XXXXXX**	Created: **1/8/2016** Last modified: **1/8/2016**

UPDATE OF THE ILC BEAM DUMP SPECIFICATIONS

The ILC Central Region Working Group has reviewed the requirements for the beam dumps foreseen in the ILC, based on scenarios for operation, commissioning, and emergency beam extraction, and proposes a new set of specifications. The main change concerns the tune-up dumps, which are reduced from 14MW to 400kW rating.

ILC Baseline Tune-up Dumps

ILC Tune-up (abort) dumps with maximum design ratings



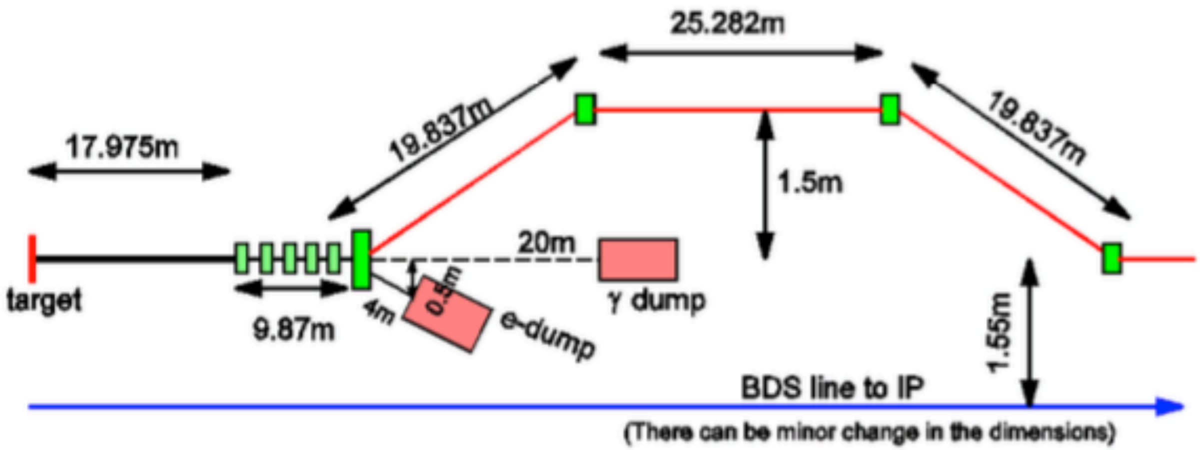
E+/E- Dumps 1,2,3 are at a fixed 5 GeV, with E+/- 6 at 15 GeV.
4,5 & 7 at 250 GeV or full energy.

All dumps except the main final E+/- 5 could have lower ratings with a reduced set of maximum beam parameters used during tuning.

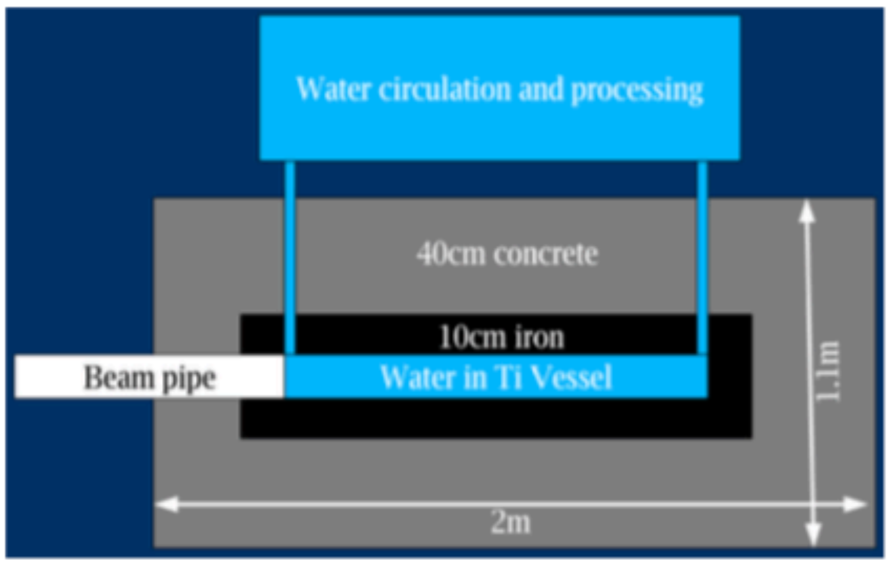
Photon Dump (positron production)

Photon Dump Location and Geometry

K. Yokoya, MiniWS*, KEK, 19.4.2016

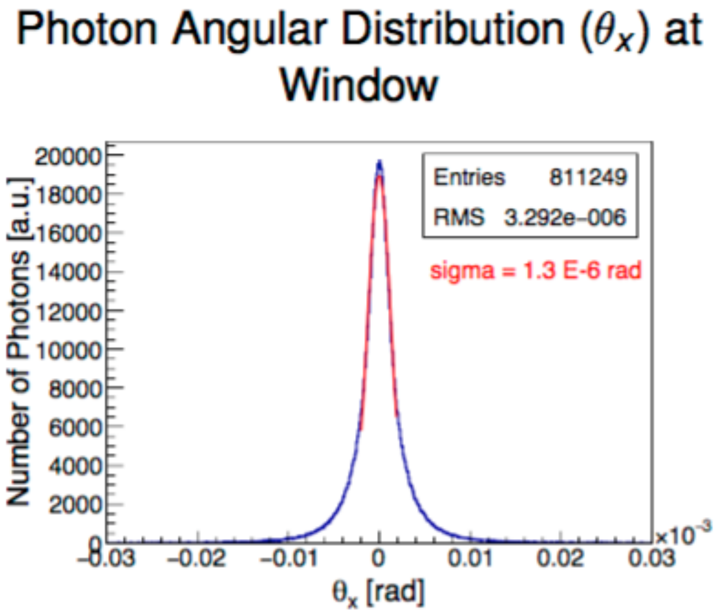


M. Kuriki, MiniWS*, KEK, 19.4.2016



* MiniWS: Joint Workshop of CRWG, CFS and Positron Source – https://agenda.linearcollider.org/event/7062/

Photon Dump



Number of photons generated in 147 m undulator with $K = 0.45$:

$$1 \cdot 10^{16} \text{ ph/s} \quad \text{or} \quad 1.8 \cdot 10^{23} \text{ ph/5000h}$$

81% undulator photons are reaching window

Accumulated peak damage after 5000 hours of irradiation: **44.1 dpa**

In case of 0.5 dpa limit, **life time** of window is **56.7 hours**

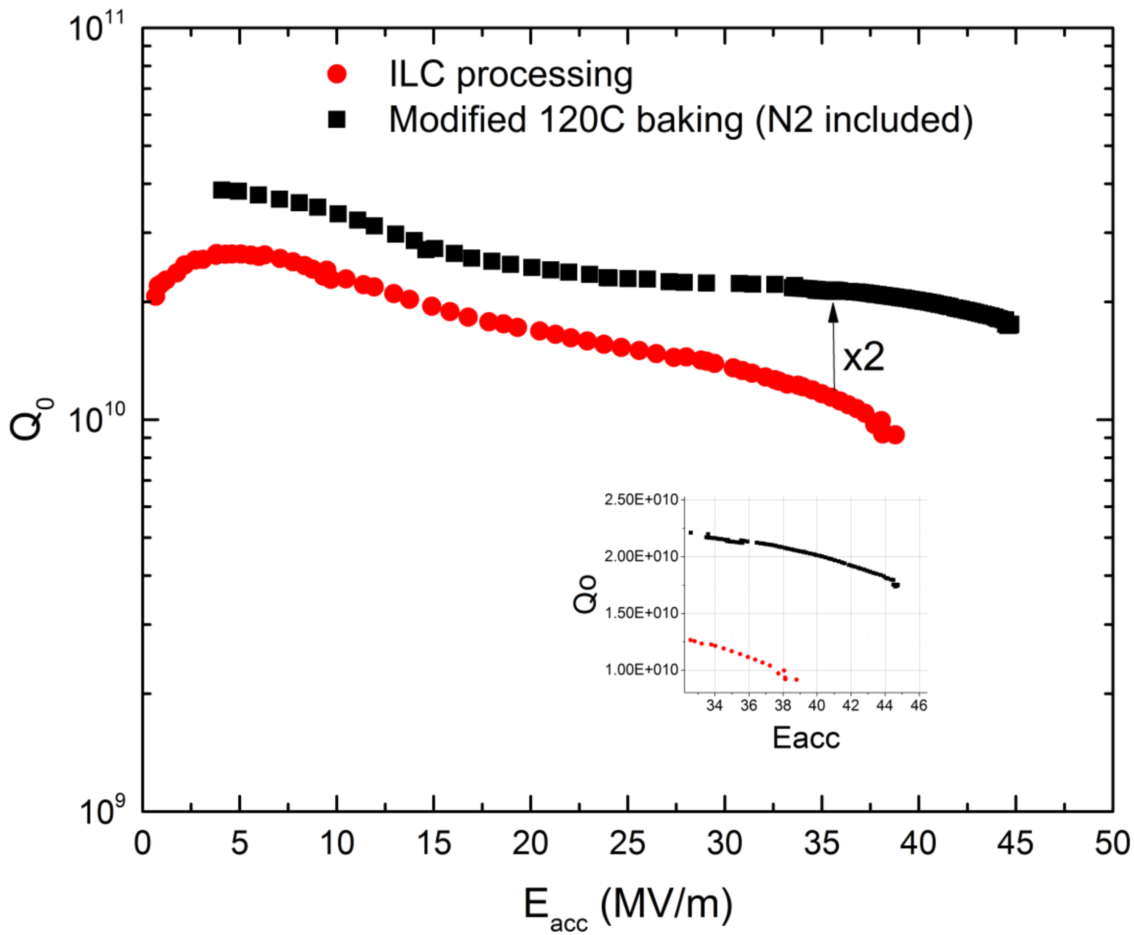
Design Activities: CFS items

- Tunnel length change
- Cryogenic system changes
- Positron Source configuration
- Tunnel cross-section
- Beam delivery system layout
- Detector Hall evolution
- Site specific footprint – IP location, exits and entrances

Essentially tracking the design changes

SRF R&D and Cost Reduction

"standard" 120C bake vs "N infused" 120C bake



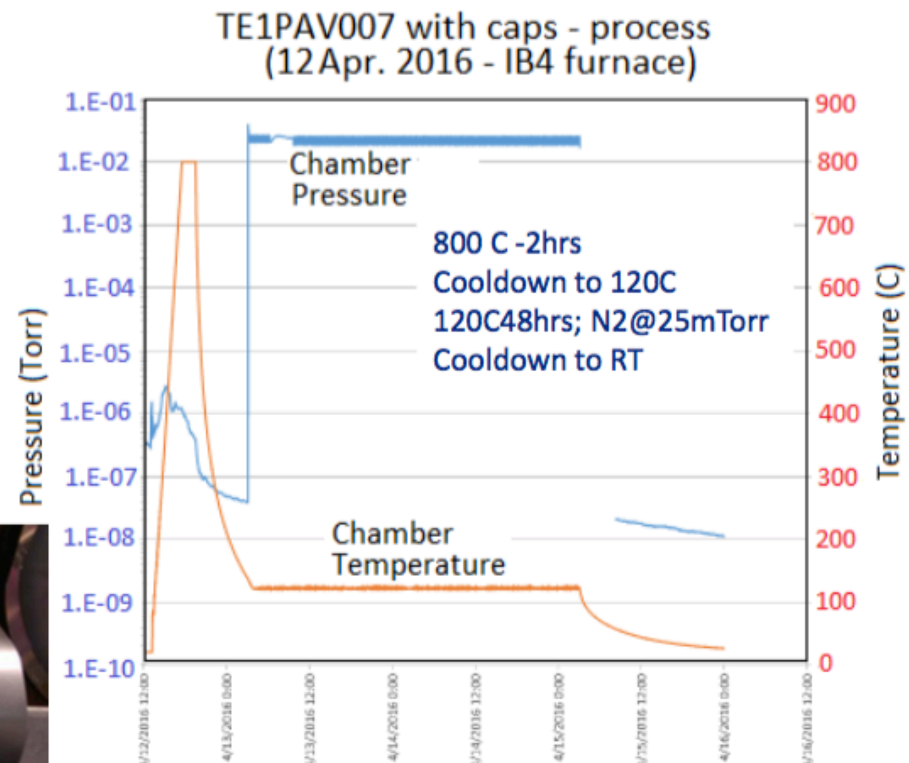
- Same cavity, sequentially processed, no EP in between
- Achieved:
  45.6 MV/m
  → 194 mT
  With Q ~ 2e10!
- Q at ~ 35 MV/m
  ~ 2.3e10

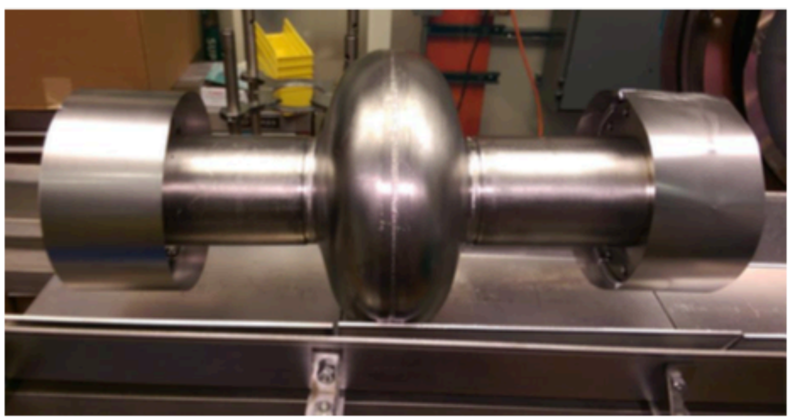
Increase in Q factor of two, increase in gradient ~15%

Grassellino, Aderhold

The surface processing sequence

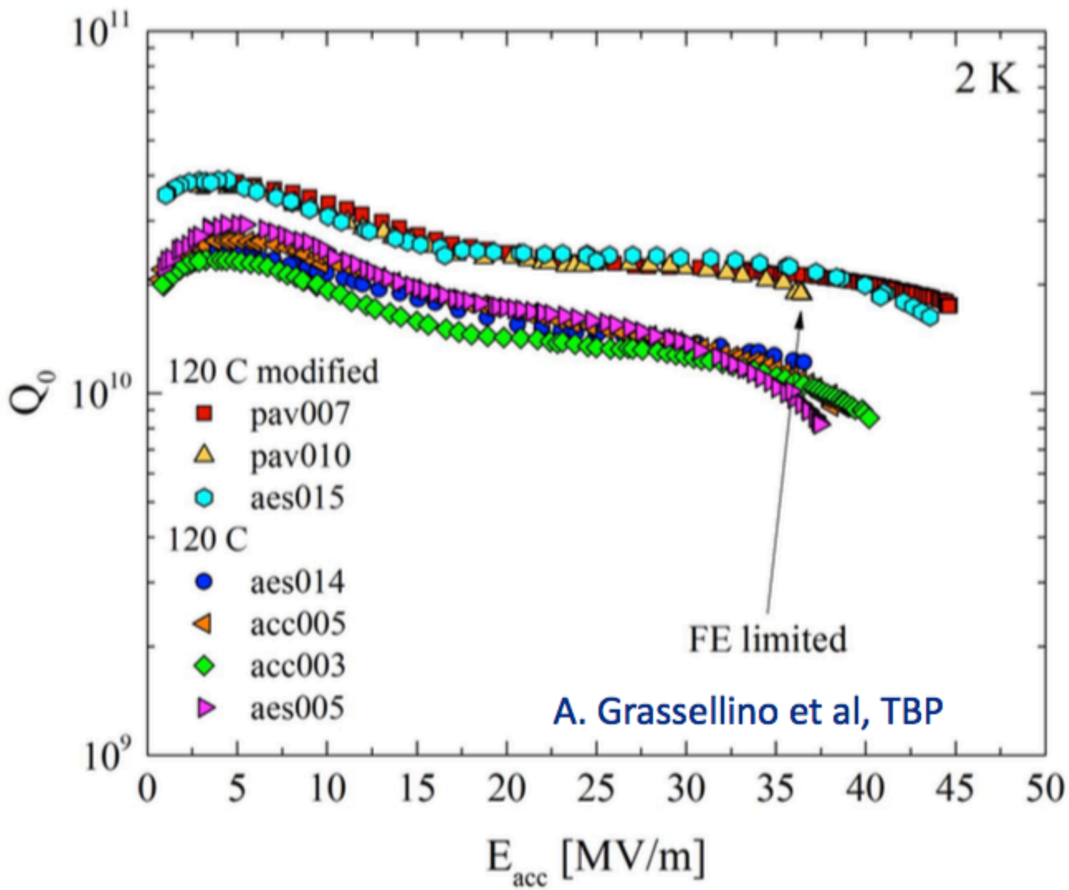
- Bulk electro-polishing
- High T furnace with caps to avoid furnace contamination:
  - 800C 2 hours HV
  - 120C 48 hours with N2
- NO chemistry
- HPR, VT assembly





Fermilab

120C "modified" bake with N2 – repeatedly highest Q ever measured >2e10 at very high gradients>40 MV/m!



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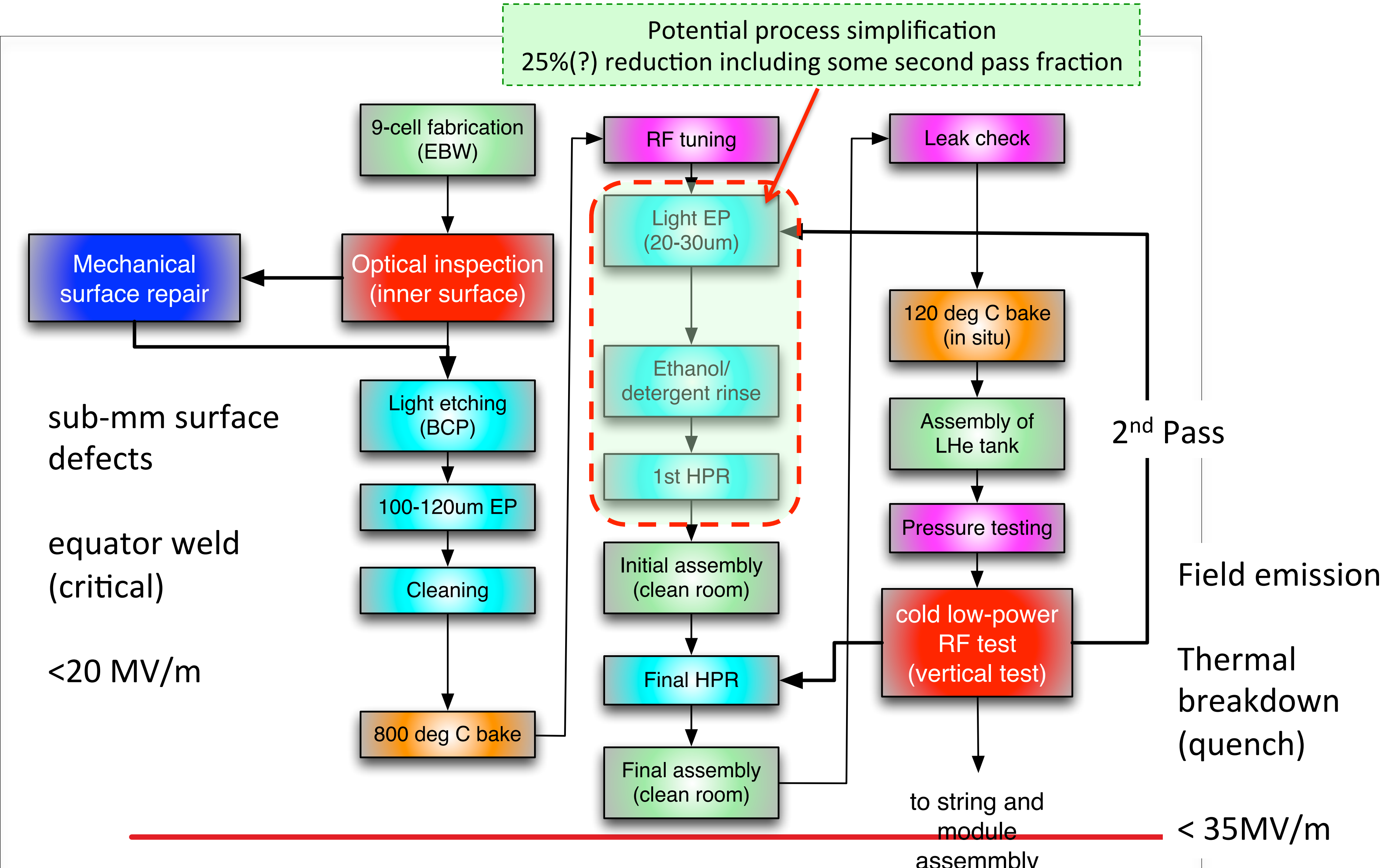
Cavity Preparation



A. Yamamoto

SRF R&D and Cost Reduction

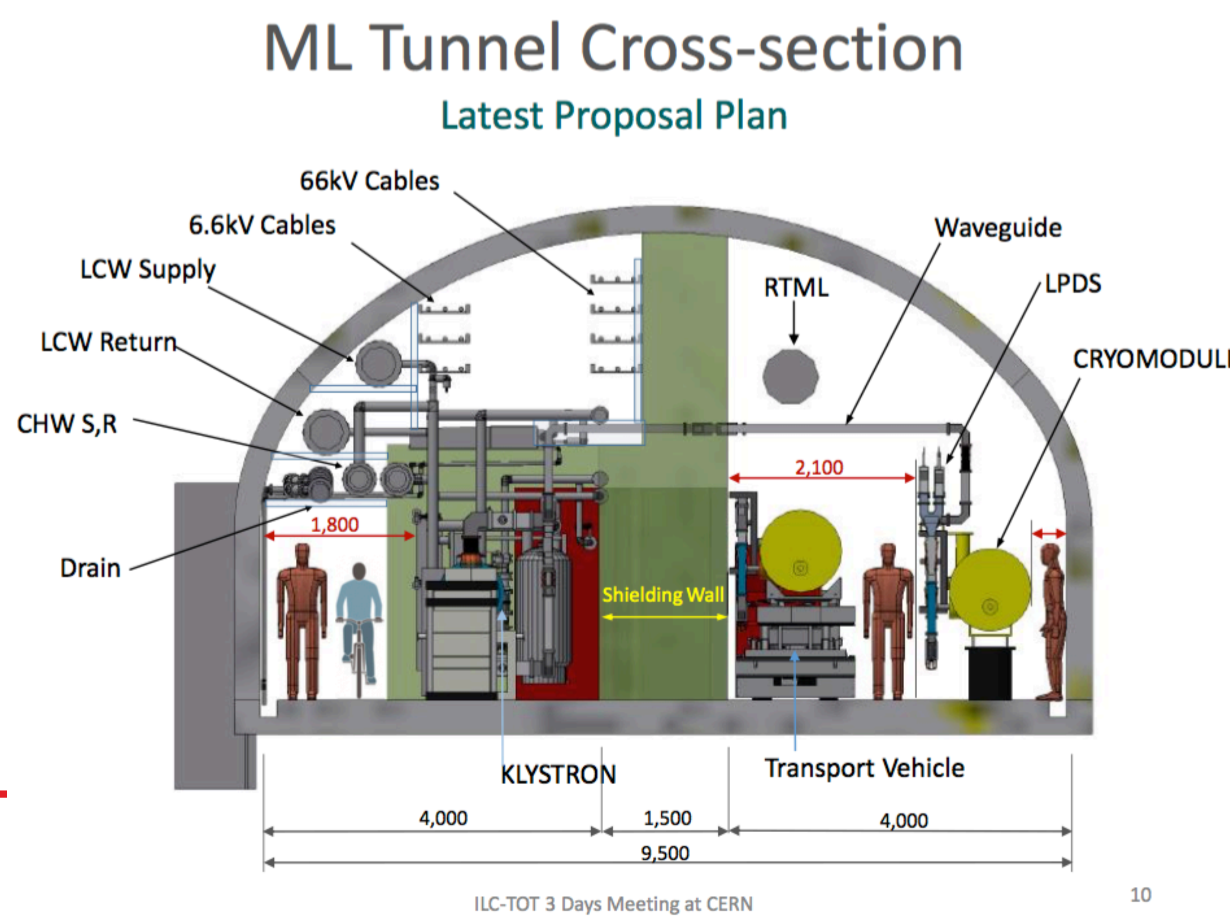
Obviously the results need to be extended to 9-cell cavities. This is taking place at Fermilab now.

These results need to be confirmed independently. This will be done next at DESY.

2K v's 1.8K in this context ? (DESY hi-grade program)

Value Engineering

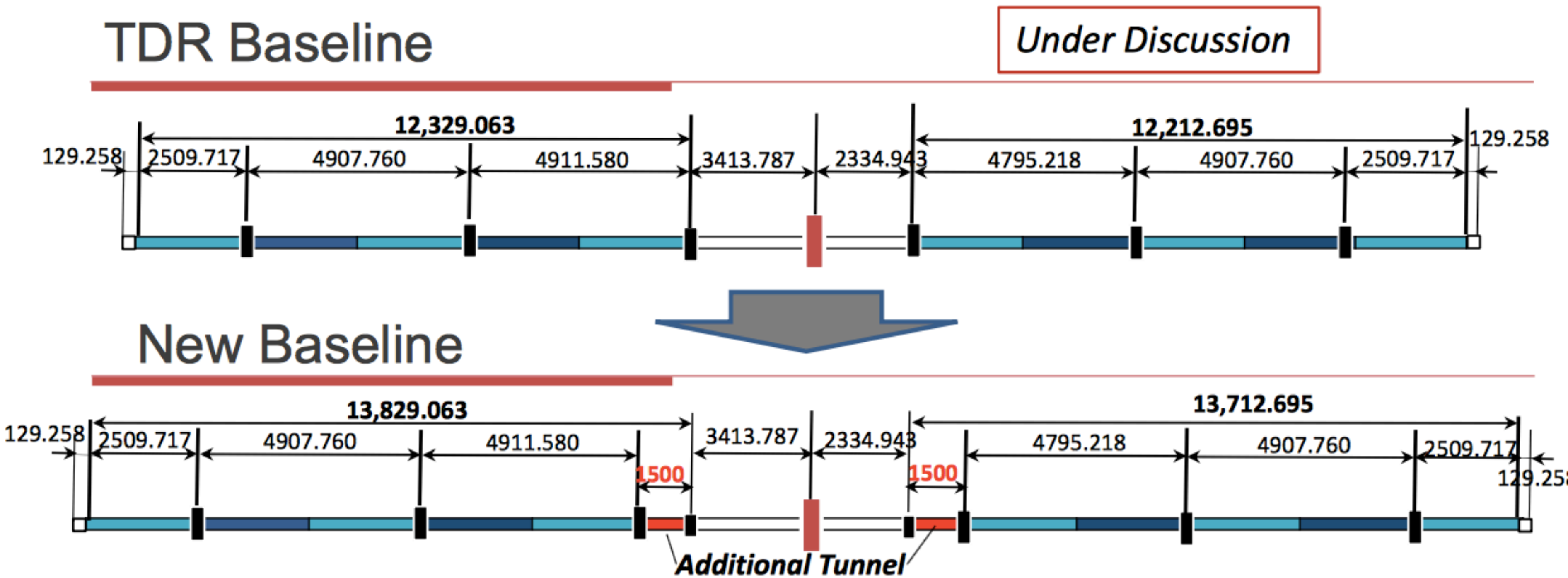
Most cost reducing activities that come under the general rubric of value engineering are relatively benign from a design perspective: tuners, couplers, HLRF, niobium stock, cavity & cryomodule process & production, etc… Thus most beneficial changes can be incorporated at any time within reason.



CR-012

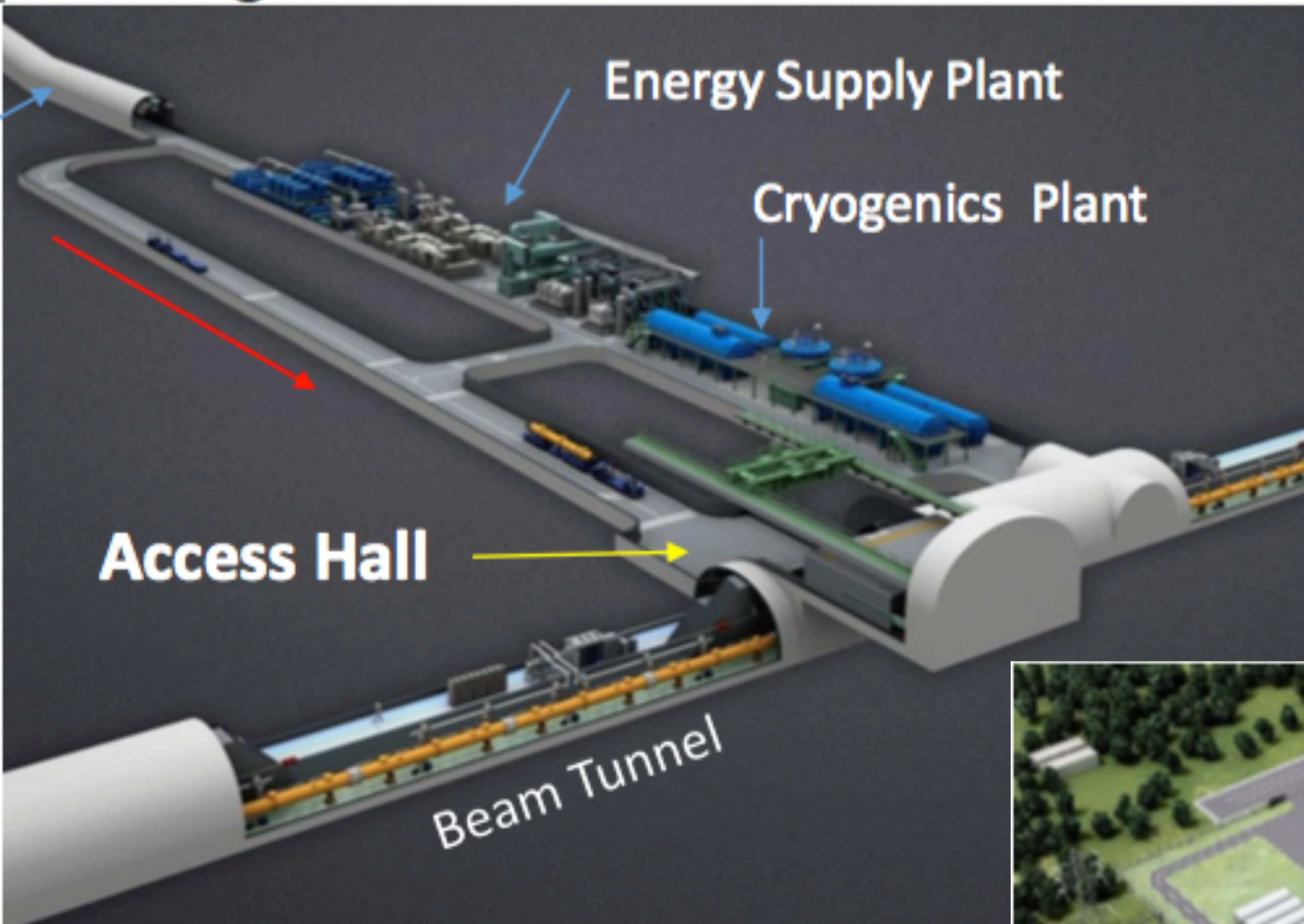
Machine Geometry

The one central topic where that is not not transparent is the operating gradient since that directly effects the machine geometry/collision point.



Cryoloop spacing changes, access point spacing changes, collision point timing changes. None of this can be finalised until the accelerating gradient is defined.

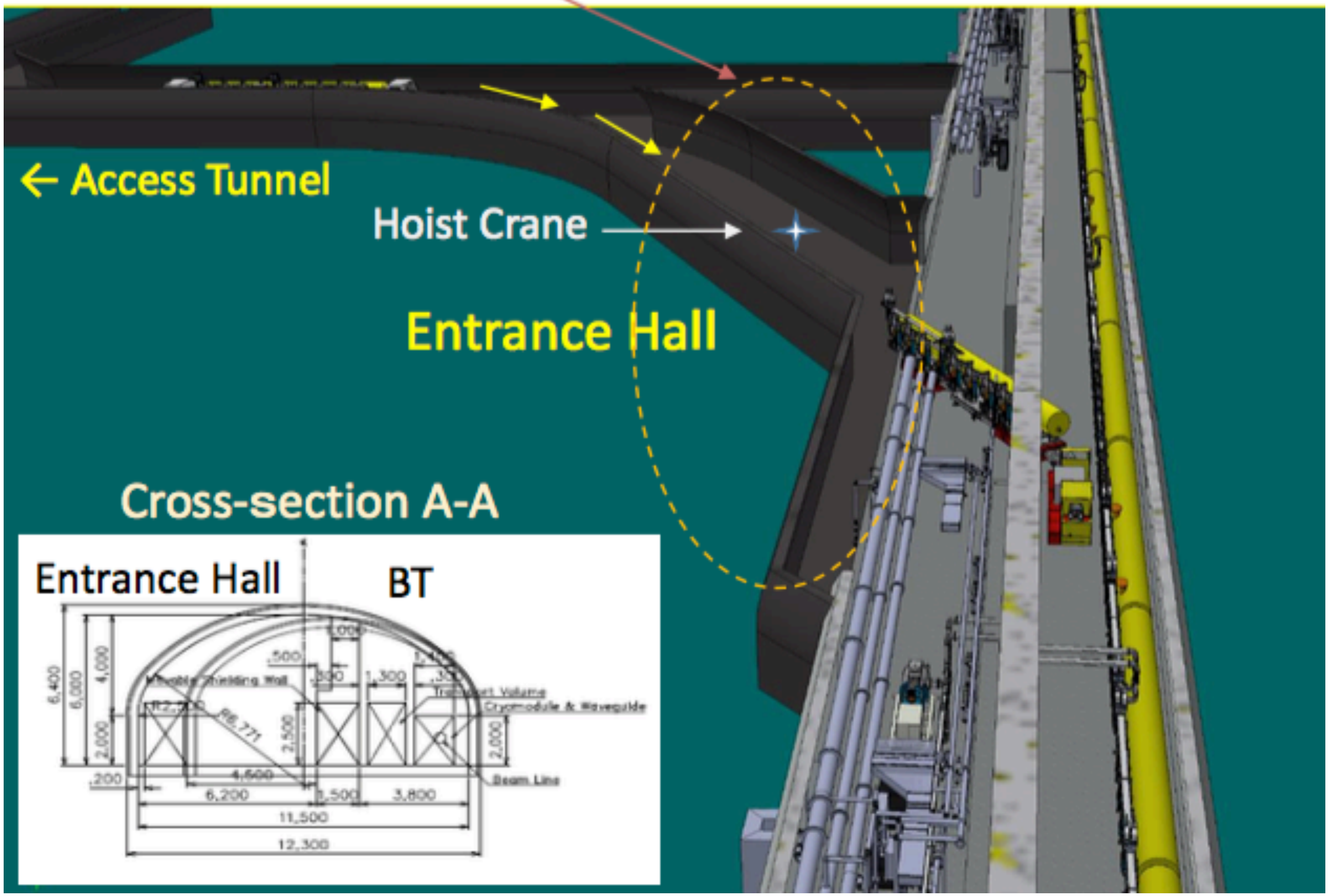
Utility Penetrations



The actual design is more or less the same but the spacing changes

Tunnel Access

- During Construction: Tunneling work passage
- After completion: Air Duct, Smoke extraction path



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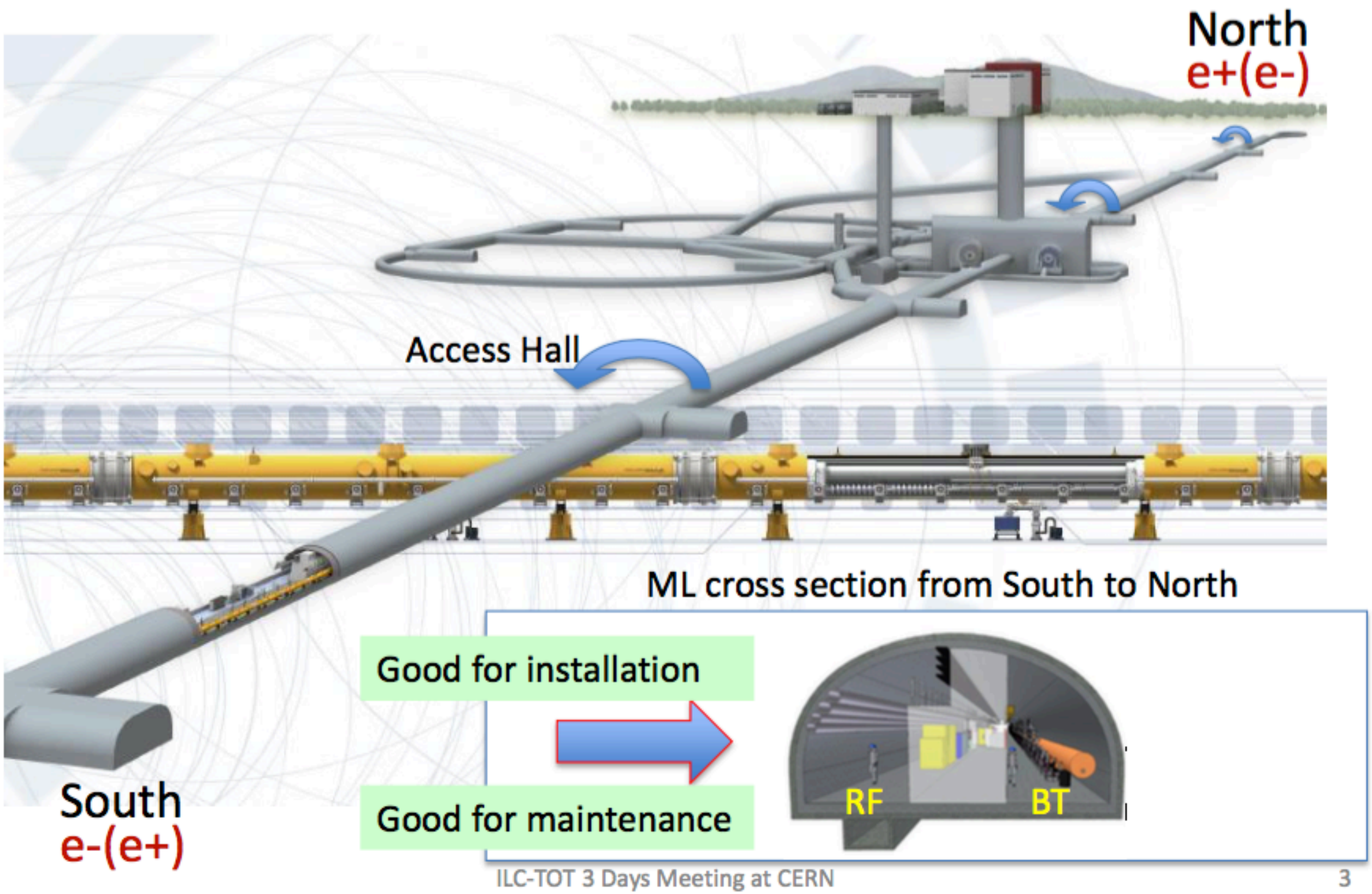
Central Region

Consideration on ML Tunnel Access



How to proceed ?

Many cavities (GDE used 87) are needed to define the actual operating gradient distribution.

In the absence of a fully fledged multi-year cavity R&D program then one could fix the geometry and let the energy float ? Since the cavity gradient is a distribution not a delta function then there is an element of this approach in any case. Unlike a circular machine the energy is not defined by the worst "magnet".

How do we incorporate the XFEL cryomodule degradation results ?

R&D programs by definition can last for ever. How do you define "good enough" ?

Cost reduction

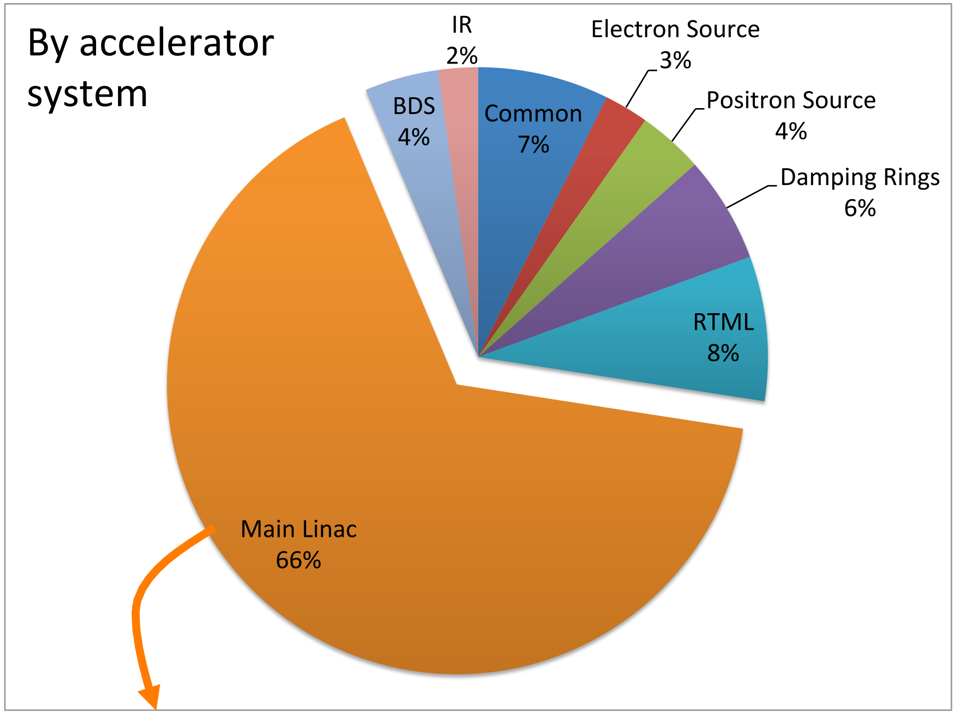
How much could you save ?

To lowest order a gradient/Q increase would result in less cryomodules, less HLRF units, shorter tunnel, less cryogenics. 10% increase in operating gradient -> 6-8 % decrease in total cost

Other items arising from ML value engineering 2-5% ???

Funding for the R&D ?

TDR Value Estimate 500 GeV



CFS-Civil construction	10%
CFS-other	6%
L-band Cavities and Cryomodules	32%
L-band HLRF	9%
Cryogenics	7%
Controls	2%
TOTAL Main Linac	**66%**

7.8 BILCU

ILCU = $FY12

Value estimate – no contingency, inflation, pre-ops, R&D, spares, etc….