Status of ILC Project

Nick Walker – DESY

ILD Meeting – Cracow – 24.09.2013

Overview

The GDE is over!

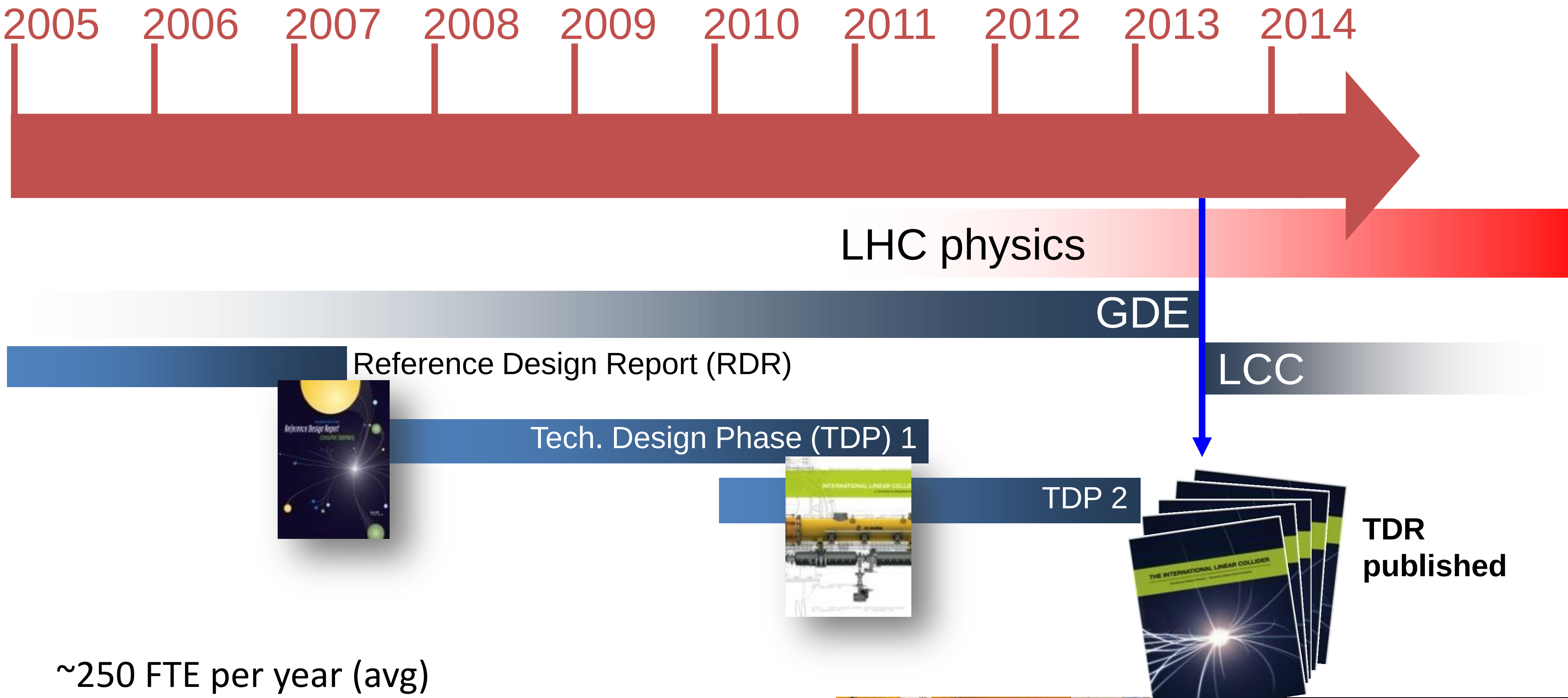
Technical news: XFEL (ILC prototype) construction

Beyond TDR:

- **Under new management: LCC**
- **Beginnings of a 3-year technical programme**
- **Light Higgs Factory & 10-Hz running**

Where do we go from here?

GDE Timeline



2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

LHC physics

GDE

LCC

Reference Design Report (RDR)

Tech. Design Phase (TDP) 1

TDP 2

TDR published

~250 FTE per year (avg)

~2,000 MY (→ ~5,000 if pre-GDE included)

~300 M$ globally

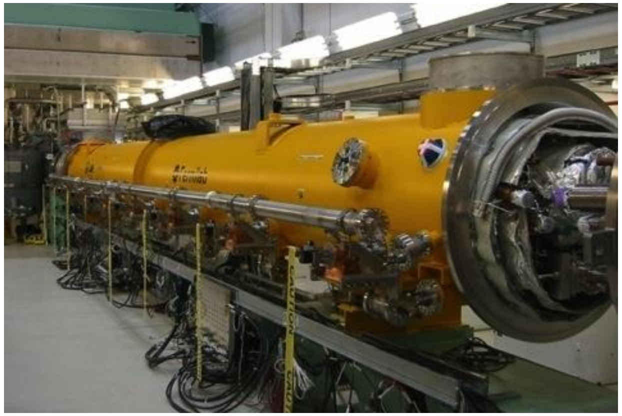
Global Event
June 12

Tokyo

CERN

Fermilab

Worldwide Cryomodule Development



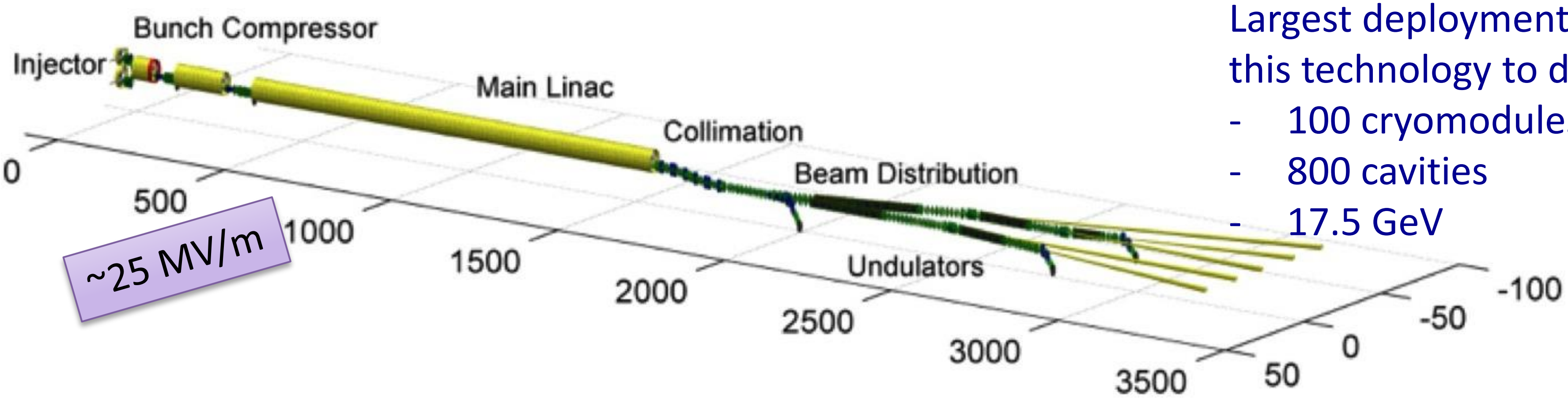
CM1 at FNAL NML module test facility

S1 Global at KEK SRF Test Facility (STF)

PXFEL 1 installed at FLASH, DESY, Hamburg

→ now commencing XFEL production

European XFEL @ DESY



~25 MV/m

Largest deployment of this technology to date
- 100 cryomodules
- 800 cavities
- 17.5 GeV



Institute	Component Task
CEA Saclay / IRFU, France	Cavity string and module assembly; cold beam position monitors
CNRS / LAL Orsay, France	RF main input coupler incl. RF conditioning
DESY, Germany	Cavities & cryostats; contributions to string & module assembly; coupler interlock; frequency tuner; cold-vacuum system; integration of superconducting magnets; cold beam-position monitors
INFN Milano, Italy	Cavities & cryostats
Soltan Inst., Poland	Higher-order-mode coupler & absorber
CIEMAT, Spain	Superconducting magnets
IFJ PAN Cracow, Poland	RF cavity and cryomodule testing
BINP, Russia	Cold vacuum components

The ultimate '**integrated systems test**' for ILC.

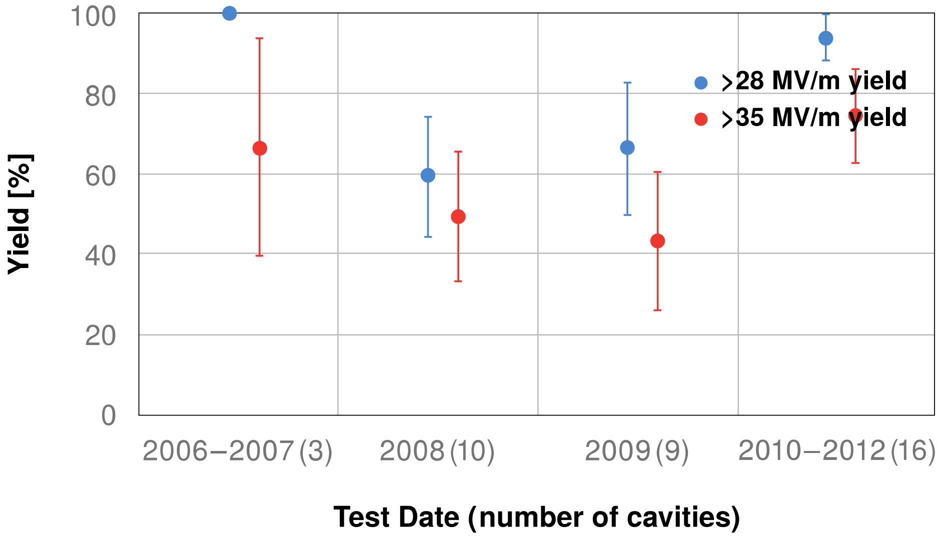
Quest for high gradients

GDE worldwide R&D effort to establish high-gradient cavity production

6 Now qualified cavity vendors

XFEL (mass) production

- large (~800) unbiased statistical sample
- 2 vendors
- Currently ~10% tested
- critical for ILC



TDR published result

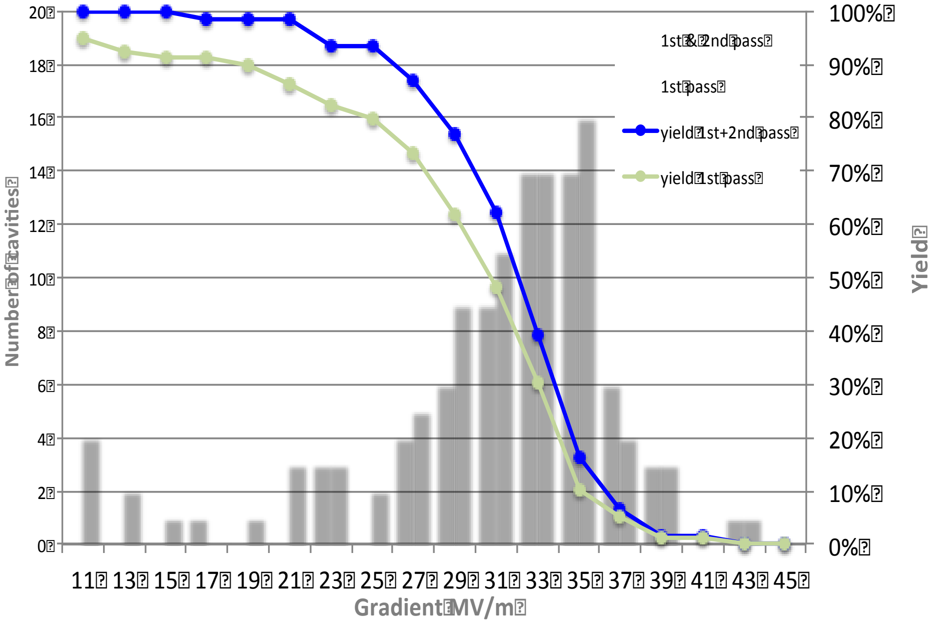
XFEL cavity production status

As of 11.09.2013

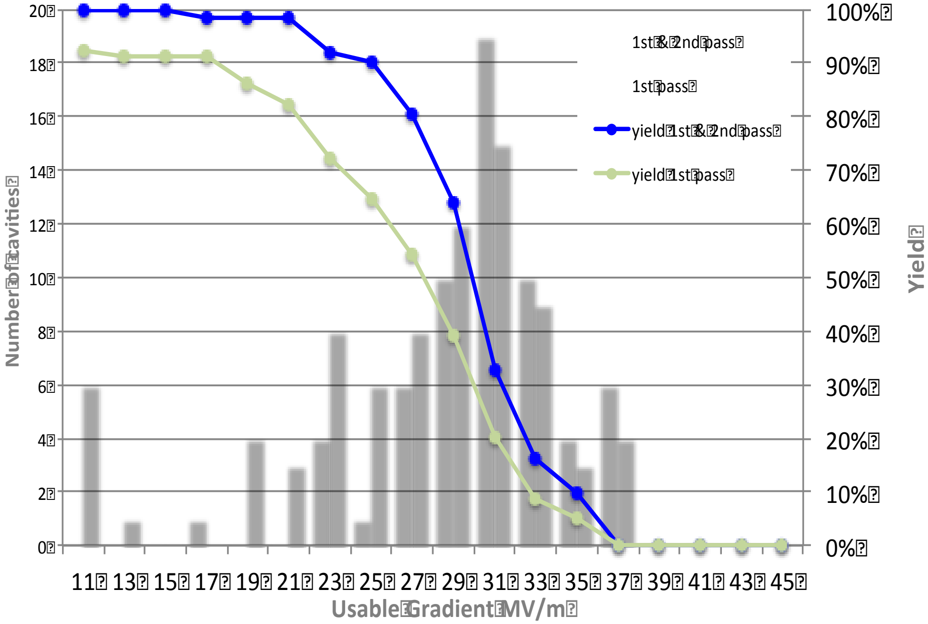
Num. of cavities:
vendor 1 23
vendor 2 56

2nd pass: additional high-pressure rinse

		Vendor 1	Vendor 2	Total stats
max. gradient	1st pass	30.5 ± 7.5	28.8 ± 6.9	29.3 ± 7.1
	1st+2nd pass	33.4 ± 3.8	31.4 ± 4.5	32.0 ± 4.4
usable gradient	1st pass	27.6 ± 6.8	26.0 ± 6.5	26.5 ± 6.6
	1st+2nd pass	31.8 ± 2.9	29.5 ± 4.1	30.1 ± 3.9

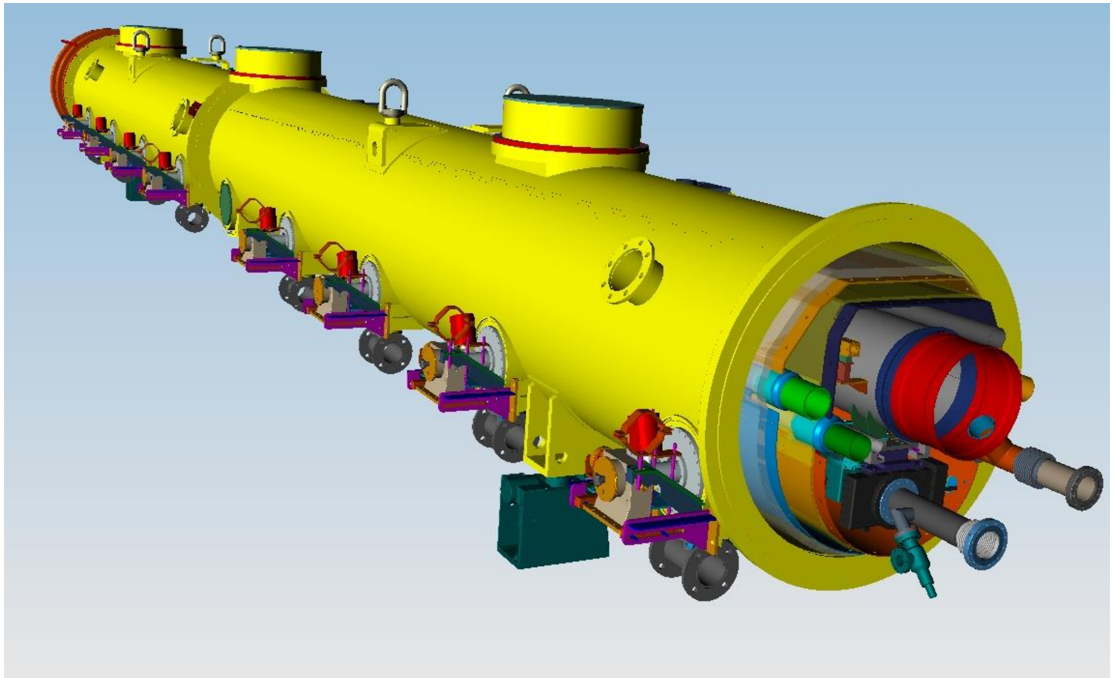


Maximum gradient



usable gradient: X-ray limited (dark current)

XFEL Cryomodule Assembly

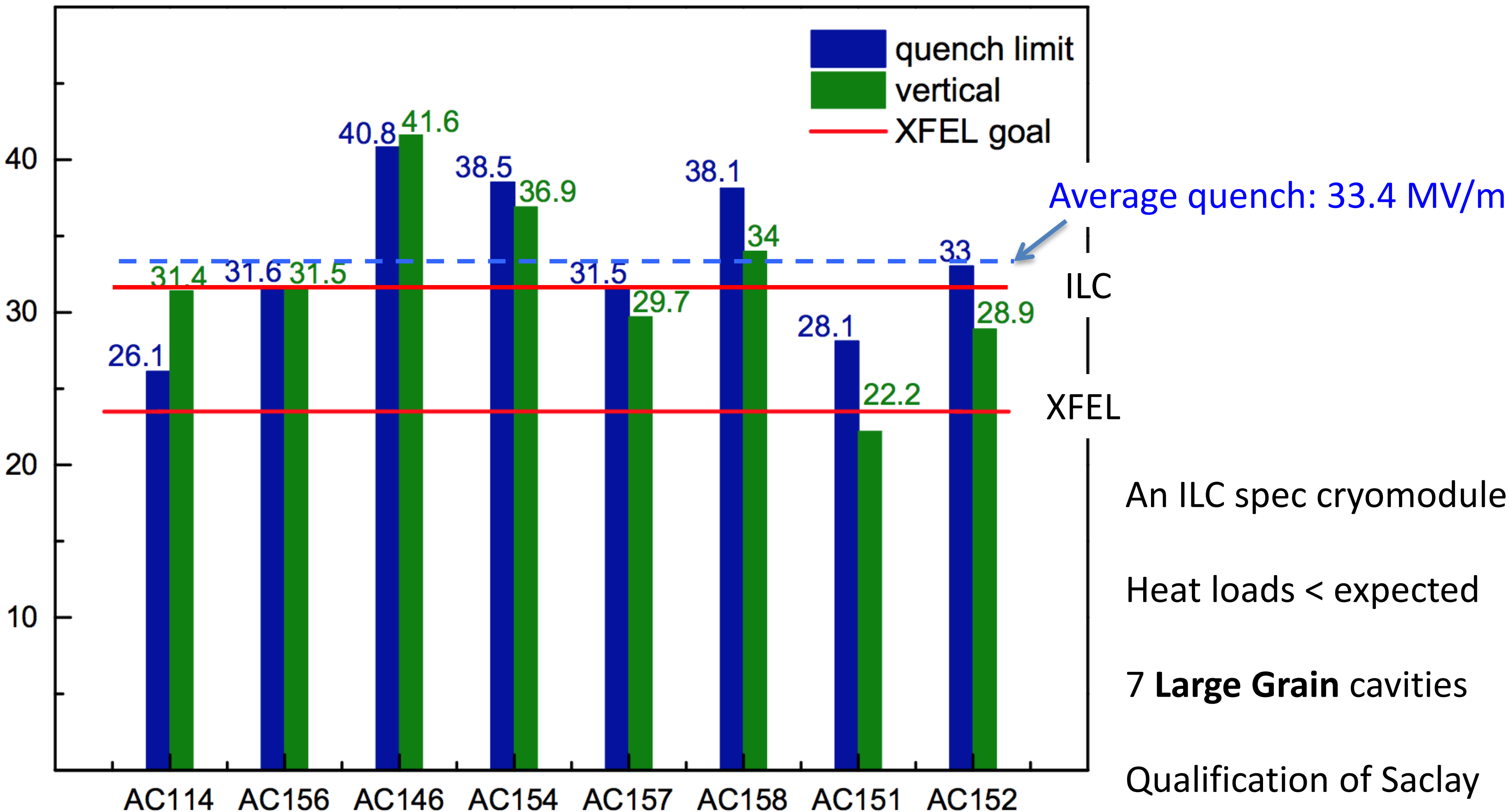


Module assembly at CEA Saclay

Just starting	1 CM / 2 weeks
Peak rate:	1 CM / 1 week
(possibly	1.5 CM / 1 week)

XM-3 tested @ DESY
XM-2 cool down @ DESY
XM-1 assembly @ Saclay
XM+1 prep @ Saclay
XM+..
XM+101

XM-3 Result



Average quench: 33.4 MV/m

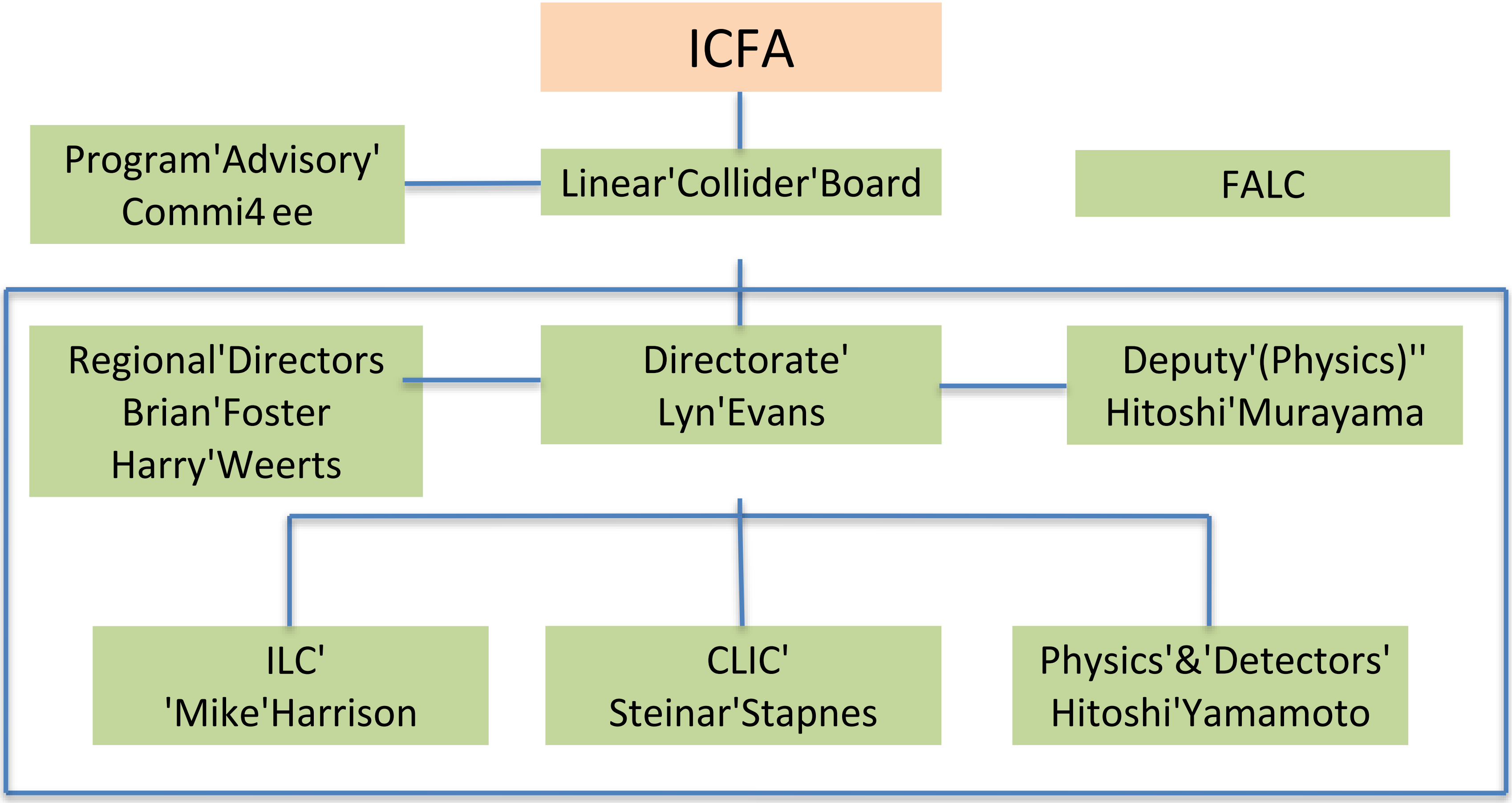
An ILC spec cryomodule!

Heat loads < expected

7 **Large Grain** cavities

Qualification of Saclay assembly facility

Linear Collider Collaboration



ICFA

Program'Advisory'
Committee

Linear'Collider'Board

FALC

Regional'Directors
Brian'Foster
Harry'Weerts

Directorate'
Lyn'Evans

Deputy'(Physics)''
Hitoshi'Murayama

ILC'
'Mike'Harrison

CLIC'
Steinar'Stapnes

Physics'&'Detectors'
Hitoshi'Yamamoto

ILC Organisation

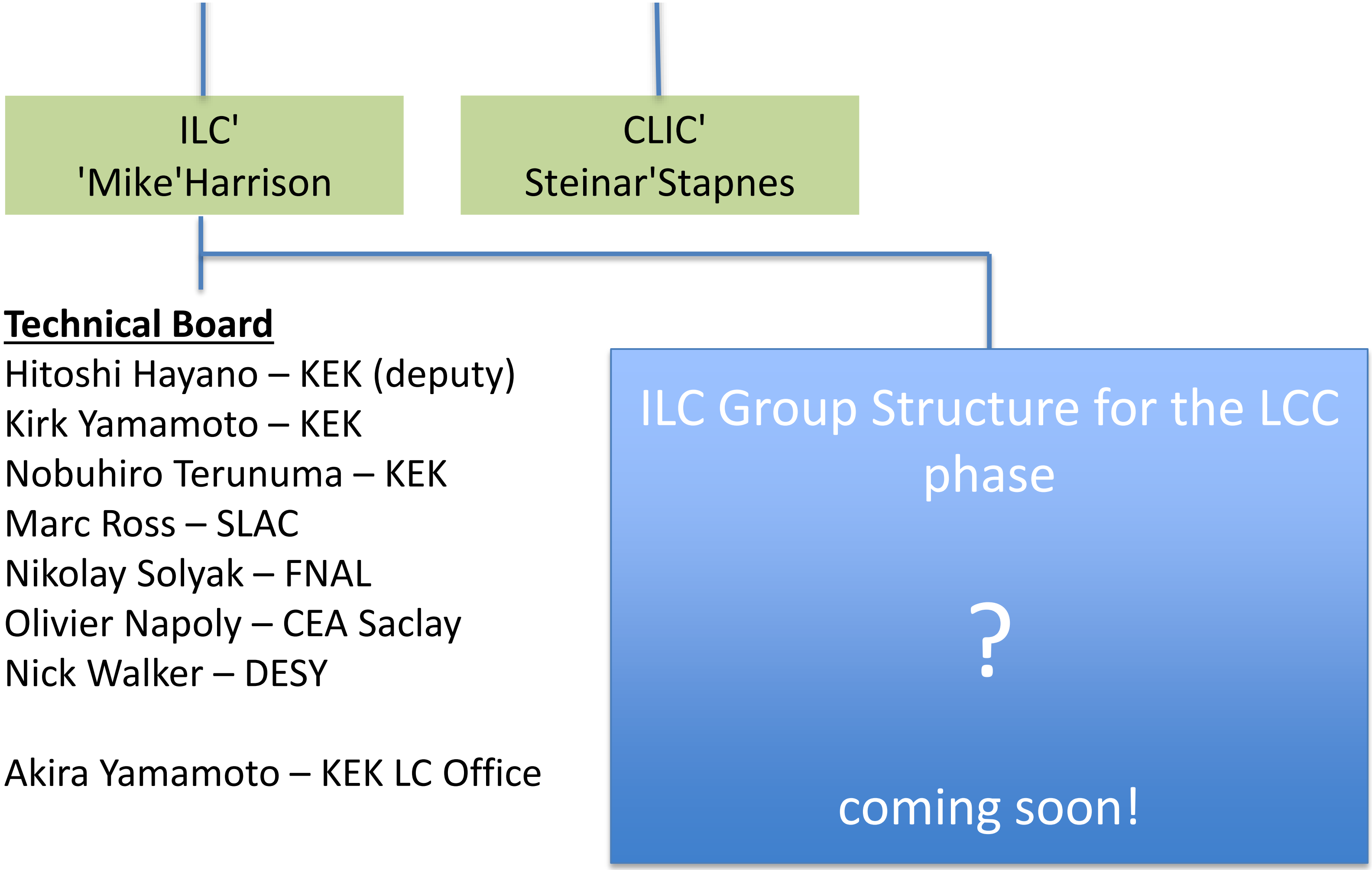
ILC'
'Mike'Harrison

CLIC'
Steinar'Stapnes

Technical Board
Hitoshi Hayano – KEK (deputy)
Kirk Yamamoto – KEK
Nobuhiro Terunuma – KEK
Marc Ross – SLAC
Nikolay Solyak – FNAL
Olivier Napoly – CEA Saclay
Nick Walker – DESY

Akira Yamamoto – KEK LC Office

ILC Organisation



ILC'
'Mike'Harrison

CLIC'
Steinar'Stapnes

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Kirk Yamamoto – KEK
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Marc Ross – SLAC
Nikolay Solyak – FNAL
Olivier Napoly – CEA Saclay
Nick Walker – DESY

Akira Yamamoto – KEK LC Office

ILC Group Structure for the LCC phase

?

coming soon!

Work for TB at LCWS - Tokyo

LCWS Working Groups

ILC'
'Mike'Harrison

CLIC'
Steinar'Stapnes

ILC-specific

AWG7: Conventional Facilities
Vic Kuchler (FNAL)
John Osborne (CERN)
Atsushi Enomoto (KEK)

AWG9: SCRF Technologies
Akira Yamamoto (KEK)
Hitoshi Hayano (KEK)
Wolf-Dietrich Moeller (DESY)

Linear Collider Groups

AWG1: Sources
Wei Gai (ANL)
Steffen Doebert (CERN)
Masao Kuriki (KEK)

AWG2: Damping Rings
Ioannis Papaphilippou (CERN)
David Ruben (Cornell)

AWG3: Beam Delivery & MDI
Rogelio Tomas (CERN)
Tom Markiewicz (SLAC)
Gao Jie (IHEP)
Lau Gatignon (CERN)

Joint ILC-CLIC groups

AWG4: Beam Dynamics
Nikolay Solyak (FNAL)
Andrea Latina (CERN)
Kiyoshi Kubo (KEK)

AWG8: System tests and performance studies
Daniel Schulte (CERN)
Marc Ross (SLAC)
Roberto Corsini (CERN)
Nobuhiro Terunuma (KEK)

The Next Three Years

Technical focus will be:

- Site-dependent design (Kitakami)
- Further R&D
  - SRF infrastructure, mass production, coupler design
  - Positron source
  - BDS (ATF2)
  - …
- Pre-implementation project studies
  - ILC cryomodule production in all three regions
  - International project structure and project tools development

Site dependent design

- Understanding constraints from the Kitakami site
  - Specific geological and topographical issues
  - Infrastructure and support planning
- Modifying the TDR design as necessary
  - Expect to be driven by Conventional Facilities and Siting
  - Example: shifting main linac access ways
  - Detector hall and “central region” will likely be a focus
- Considerations of a staged approach
  - starting at 250 GeV centre of mass

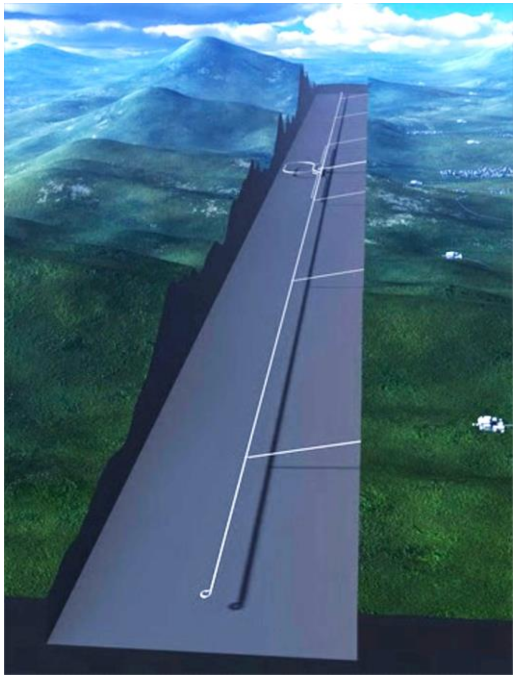
Not discussing change of scope!

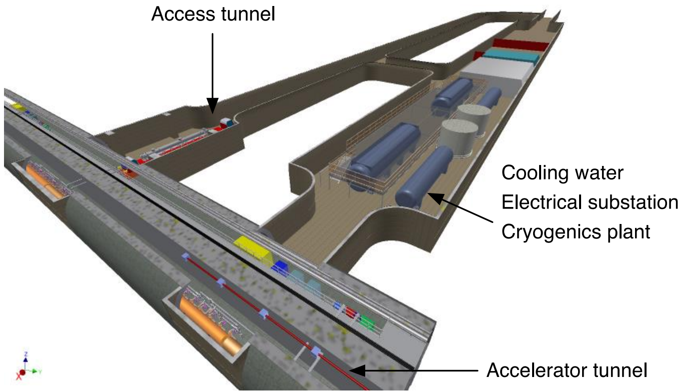
TDR: Japanese site-dependent design

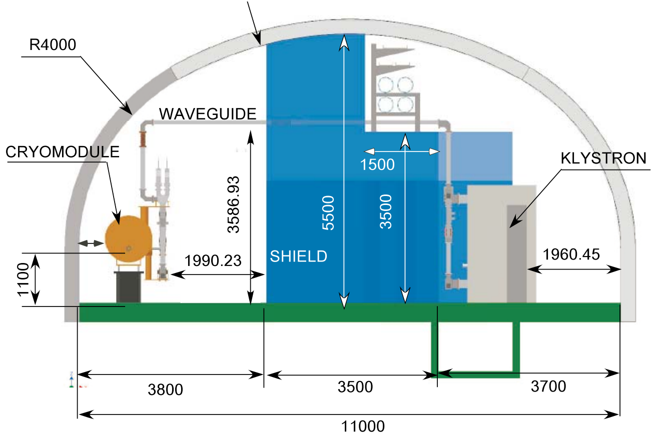
Challenges of a mountainous terrain

Long horizontal access tunnels (≤ 1 km)

Almost entirely under ground installation

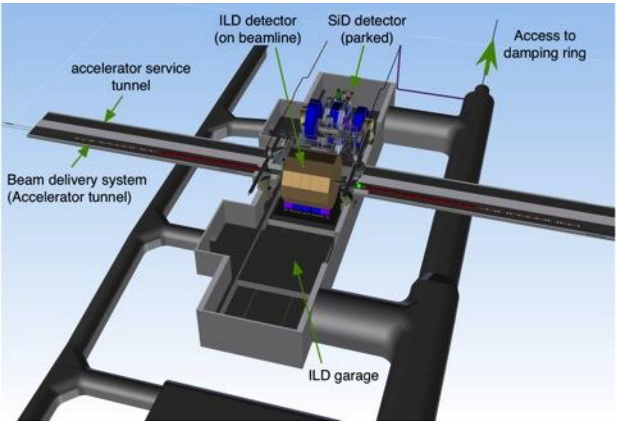




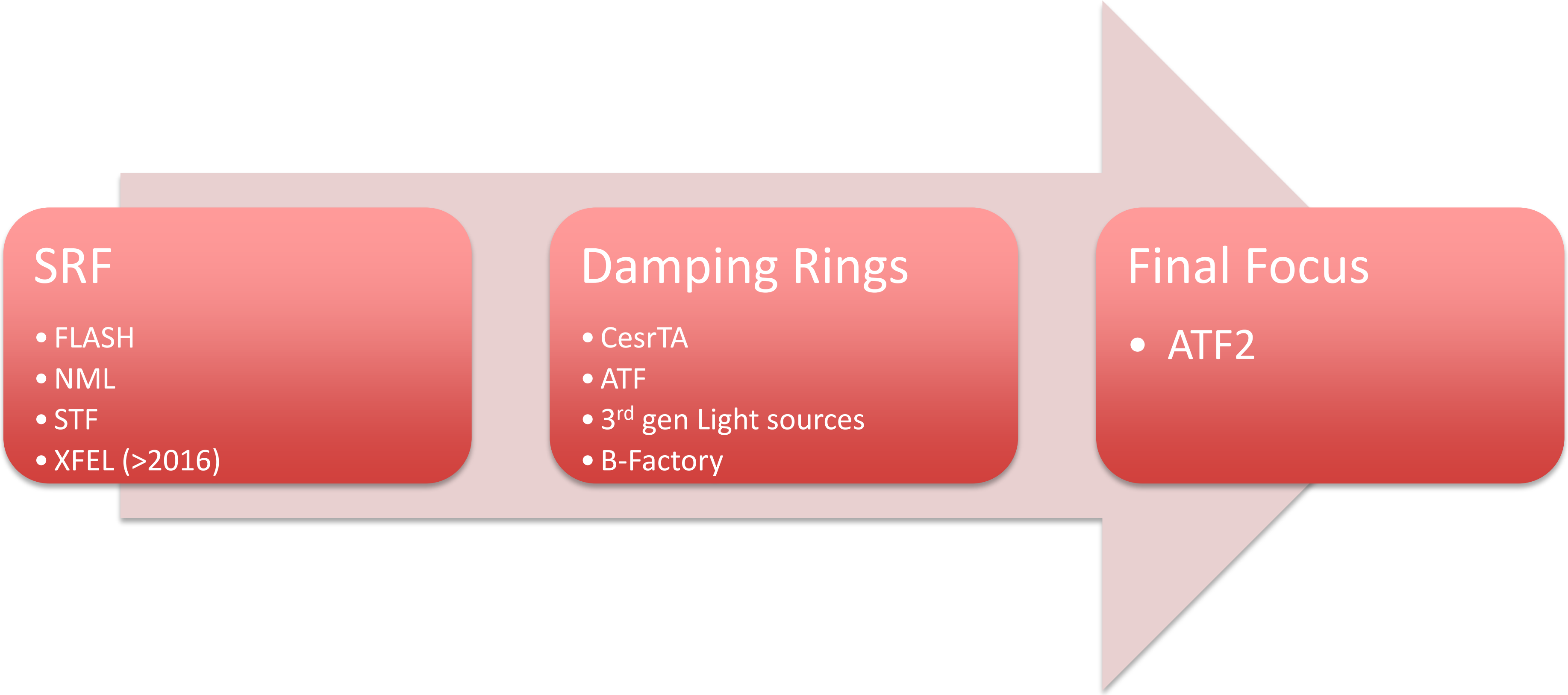


LCC forming plans for site-dependent study

LCWS will be an important meeting in this regard



Beam Test Facilities



SRF

- FLASH
- NML
- STF
- XFEL (>2016)

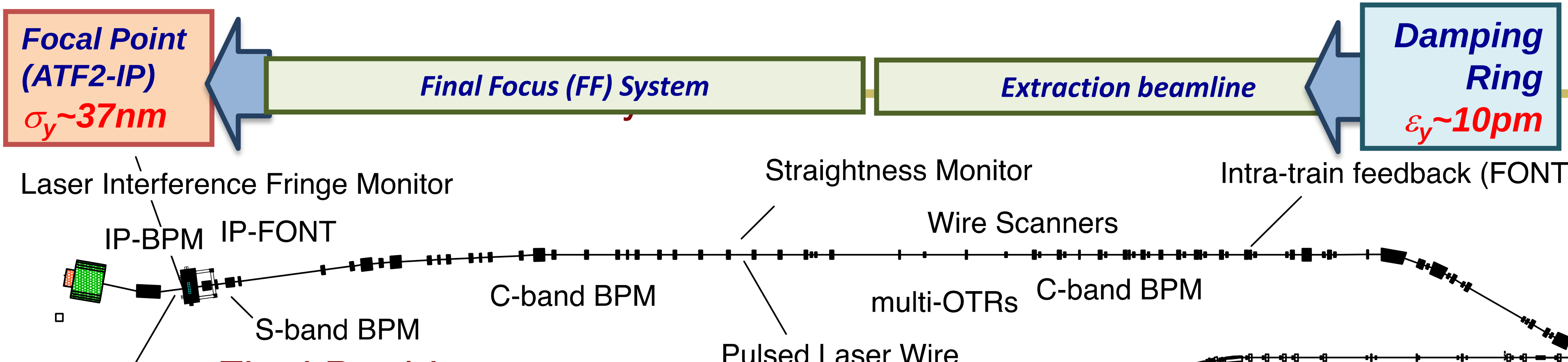
Damping Rings

- CesrTA
- ATF
- 3rd gen Light sources
- B-Factory

Final Focus

- ATF2

Final Focus R&D: ATF2 @ KEK



Focal Point (ATF2-IP)

σ_y~37nm

Final Focus (FF) System

Extraction beamline

Damping Ring

ε_y~10pm

Laser Interference Fringe Monitor

IP-BPM

IP-FONT

S-band BPM

C-band BPM

Straightness Monitor

Pulsed Laser Wire

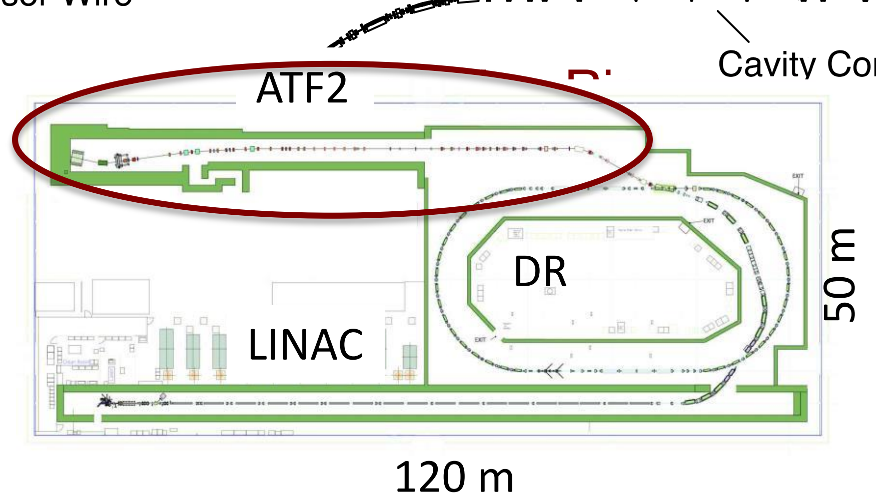
Wire Scanners

multi-OTRs

C-band BPM

Intra-train feedback (FONT

Cavity Co

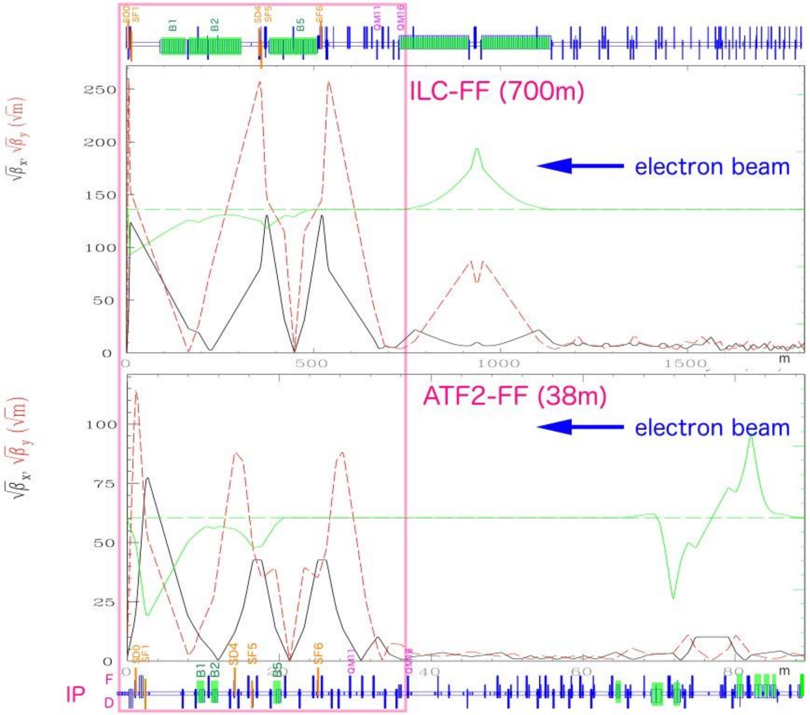


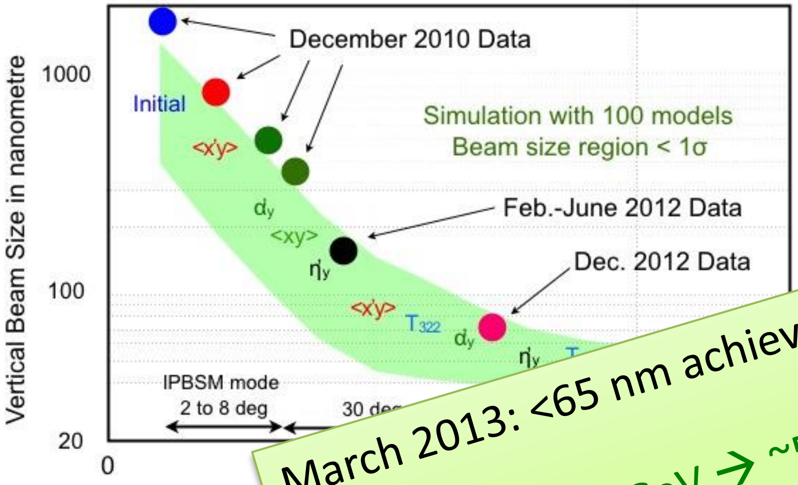
Formal international collaboration

Final Focus R&D: ATF2 @ KEK

Test bed for ILC final focus optics

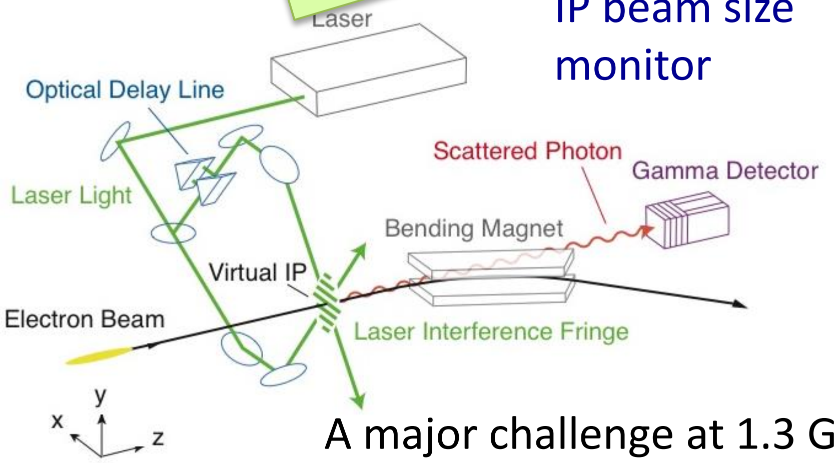
- strong focusing and tuning (37 nm)
- beam-based alignment
- stabilisation and vibration (fast feedback)
- instrumentation





March 2013: <65 nm achieved

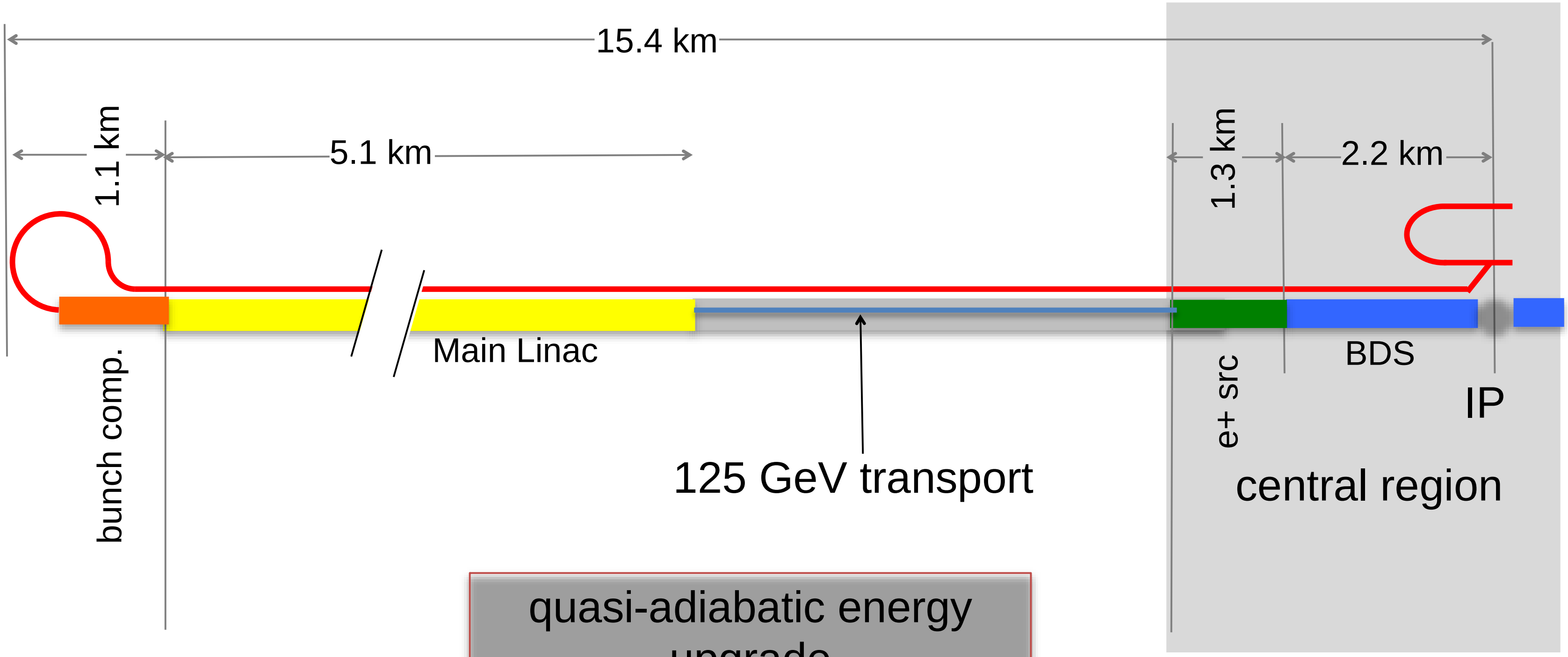
(γ scaling to 250 GeV → ~5nm)



IP beam size monitor

A major challenge at 1.3 GeV

Staged construction: 250 GeV



quasi-adiabatic energy upgrade

- Complete civil construction for 500 GeV machine
- Install ~1/2 linacs for fist stage operation (and long transport line)
- Capital savings ~25%
- Adiabatic energy upgrade (lower rate cryomodule production)

Favoured by Japan

ILC Published Parameters

Centre-of-mass independent:

			Luminosity Upgrade
Collision rate	Hz	5	5
Number of bunches		1312	2625
Bunch population	$\times 10^{10}$	2	
Bunch separation	ns	554	366
Pulse current	mA	5.8	8.8
Beam pulse length	μs	730	960
RMS bunch length	mm	0.3	
Horizontal emittance	μm	10	
Vertical emittance	nm	35	
Electron polarisation	%	80	
Positron polarisation	%	30	

http://ilc-edmsdirect.desy.de/ilc-edmsdirect/item.jsp?edmsid=D00000000925325

ILC Published Parameters

Centre-of-mass dependent:

Centre-of-mass energy	**GeV**	**200**	**230**	**250**	**350**	**500**
Electron RMS energy spread	%	0.21	0.19	0.19	0.16	0.12
Positron RMS energy spread	%	0.19	0.16	0.15	0.10	0.07
IP horizontal beta function	mm	16	16	12	15	11
IP vertical beta function	mm	0.48	0.48	0.48	0.48	0.48
IP RMS horizontal beam size	nm	904	843	700	662	474
IP RMS veritcal beam size	nm	9.3	8.6	8.3	7.0	5.9
Vertical disruption parameter		20.4	20.4	23.5	21.1	24.6
Enhancement factor		1.83	1.83	1.91	1.84	1.95
Geometric luminosity	$\times 10^{34}$ cm^{-2}s^{-1}	0.25	0.29	0.36	0.45	0.75
Luminosity	**$\times 10^{34}$ cm^{-2}s^{-1}**	**0.50**	**0.59**	**0.75**	**0.93**	**1.8**
% luminosity in top 1% ΔE/E		92%	90%	84%	79%	63%
Average energy loss		1%	1%	1%	2%	4%
Pairs / BX	$\times 10^{3}$	41	50	70	89	139
Total pair energy / BX	TeV	24	34	51	108	344

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Geometric luminosity	×10^{34} cm^{-2}s^{-1}	0.25	0.29	0.36	0.45	0.75
Luminosity Upgrade	**×10^{34} cm^{-2}s^{-1}**	**1.00**	**1.18**	**1.50**	**1.86**	**3.6**
% luminosity in top 1% $\Delta E/E$		92%	90%	84%	79%	63%
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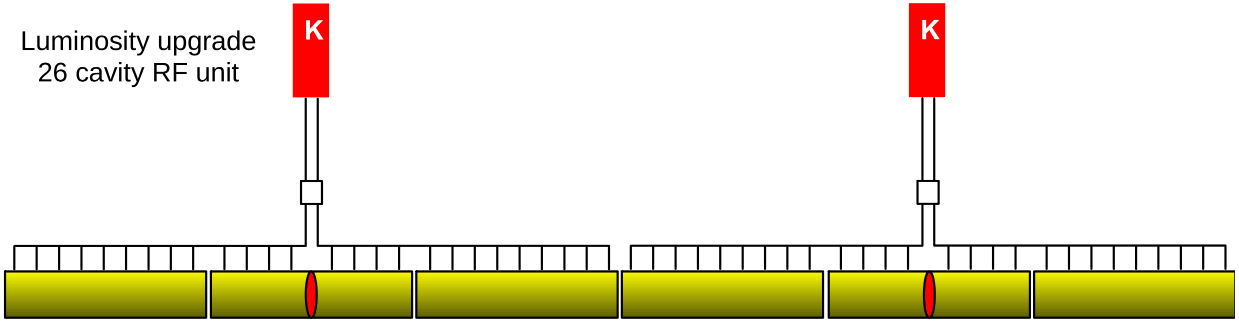
Luminosity Upgrade

Adding klystrons (and modulators)



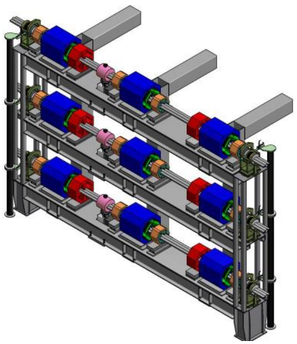
Luminosity upgrade
26 cavity RF unit

Damping Ring:

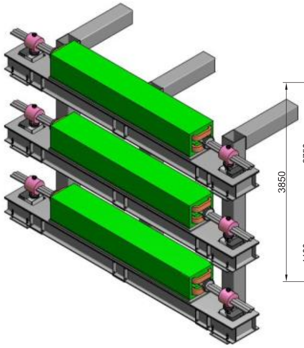
Positron ring (upgrade)

Electron ring (baseline)

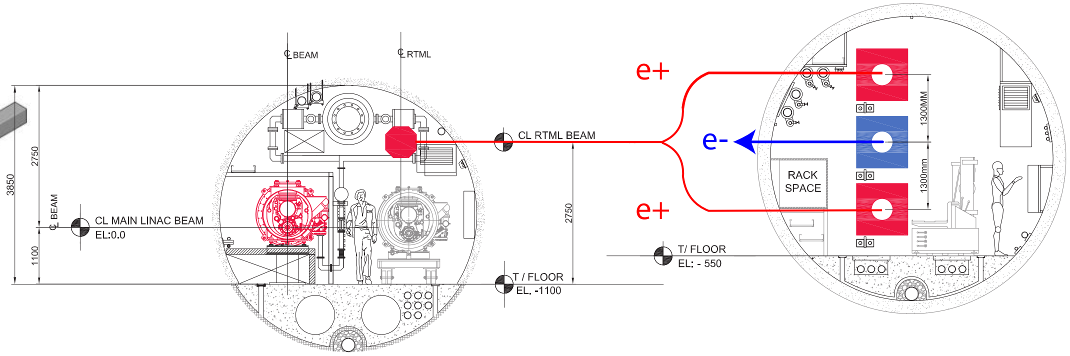
Positron ring (baseline)



Arc quadrupole section



Dipole section



Main Linac Tunnel

Damping Ring Tunnel

ILC Published Parameters

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Higgs Factory

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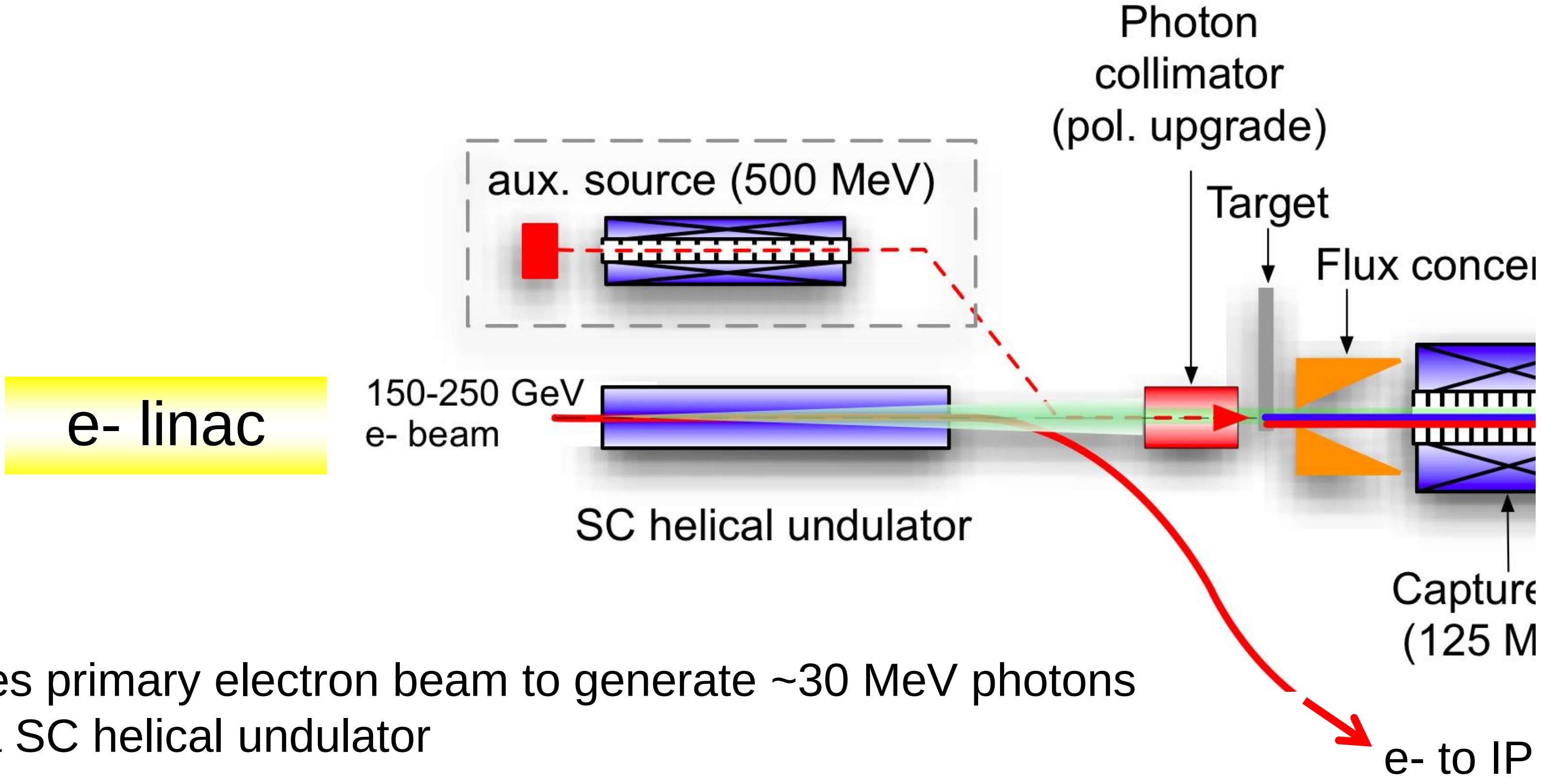
ILC Polarised-Positron Production



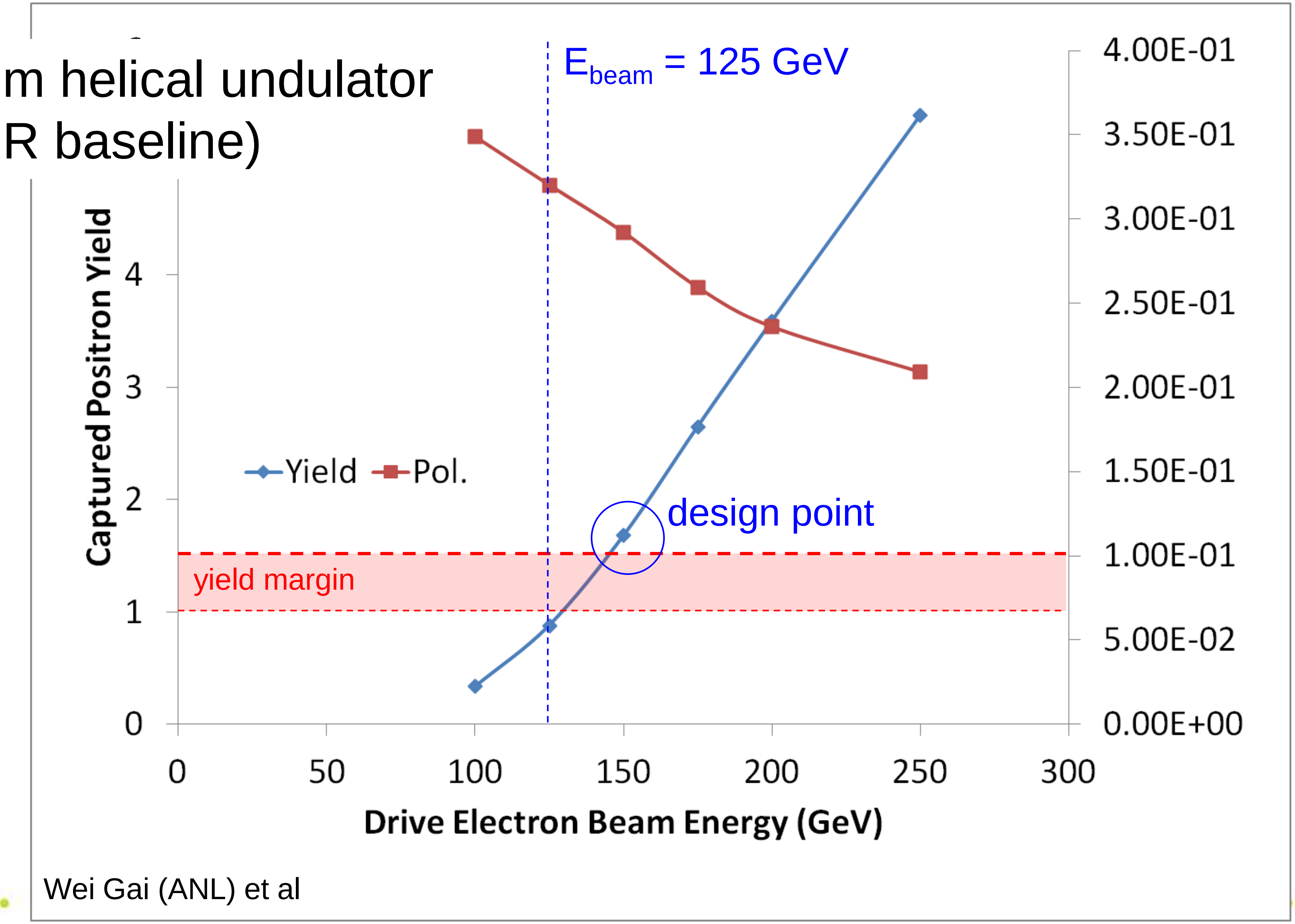
Uses primary electron beam to generate ~30 MeV photons in a SC helical undulator

Photons converted into e+e- pairs in “thin” titanium target

Positron production yield dependent on e- beam energy (and therefore E_{cm})

Positron Yield

147m helical undulator
(TDR baseline)



Wei Gai (ANL) et al

TDR: 10-Hz Mode (e+ production)

- **For TDR, we are required to have solutions down to Z-pole (~45 GeV beam)**

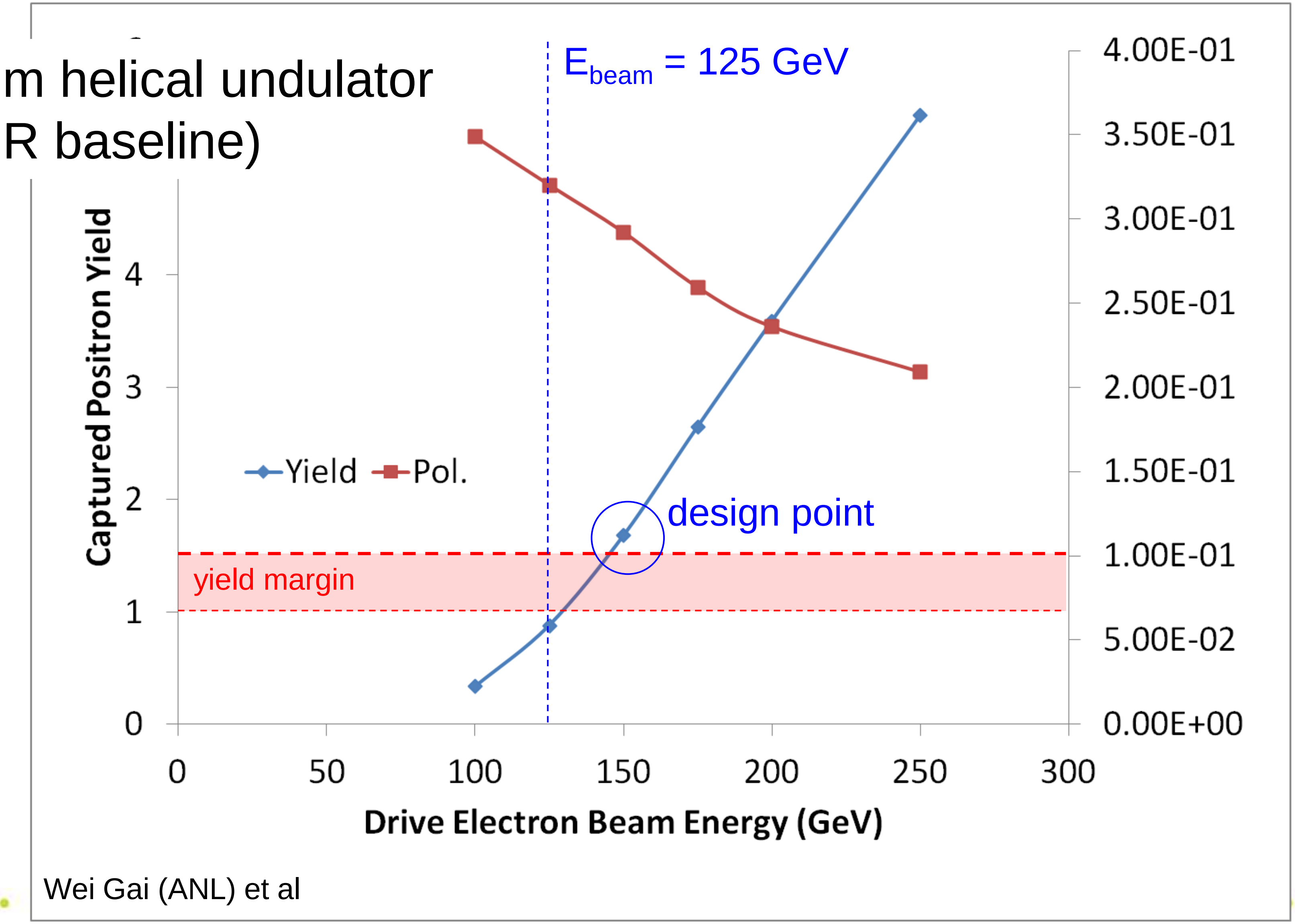
- **ILC TDR assumes 10-Hz mode where**
  - e- linac is pulsed at 10 Hz
  - **first pulse** @ 150 GeV to **make positrons**
  - **second pulse** @ $E_{cm}/2$ to **make luminosity**

collision rate still 5Hz

- **Issues**
  - DR damping time halved (extra cost and MW)
  - Beam dynamics in Main Linac (looks OK)
  - Additional beam lines and pulsed magnet systems
  - Additional AC power for elec linac 10-Hz mode
    - **But for 500 GeV design, additional power already available**
    - Not insignificant cost increase for a dedicated LHF

Positron Yield

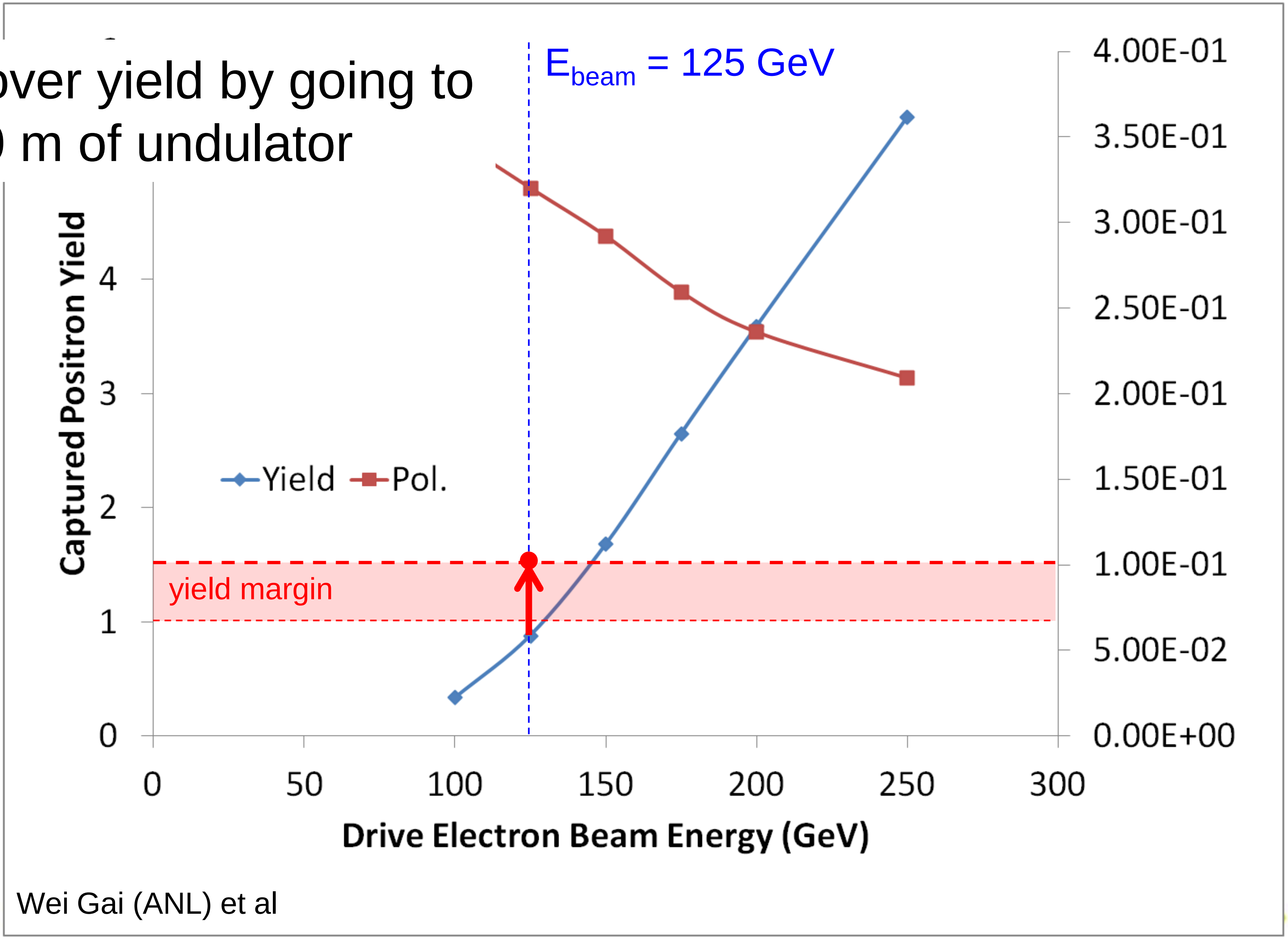
147m helical undulator
(TDR baseline)



Wei Gai (ANL) et al

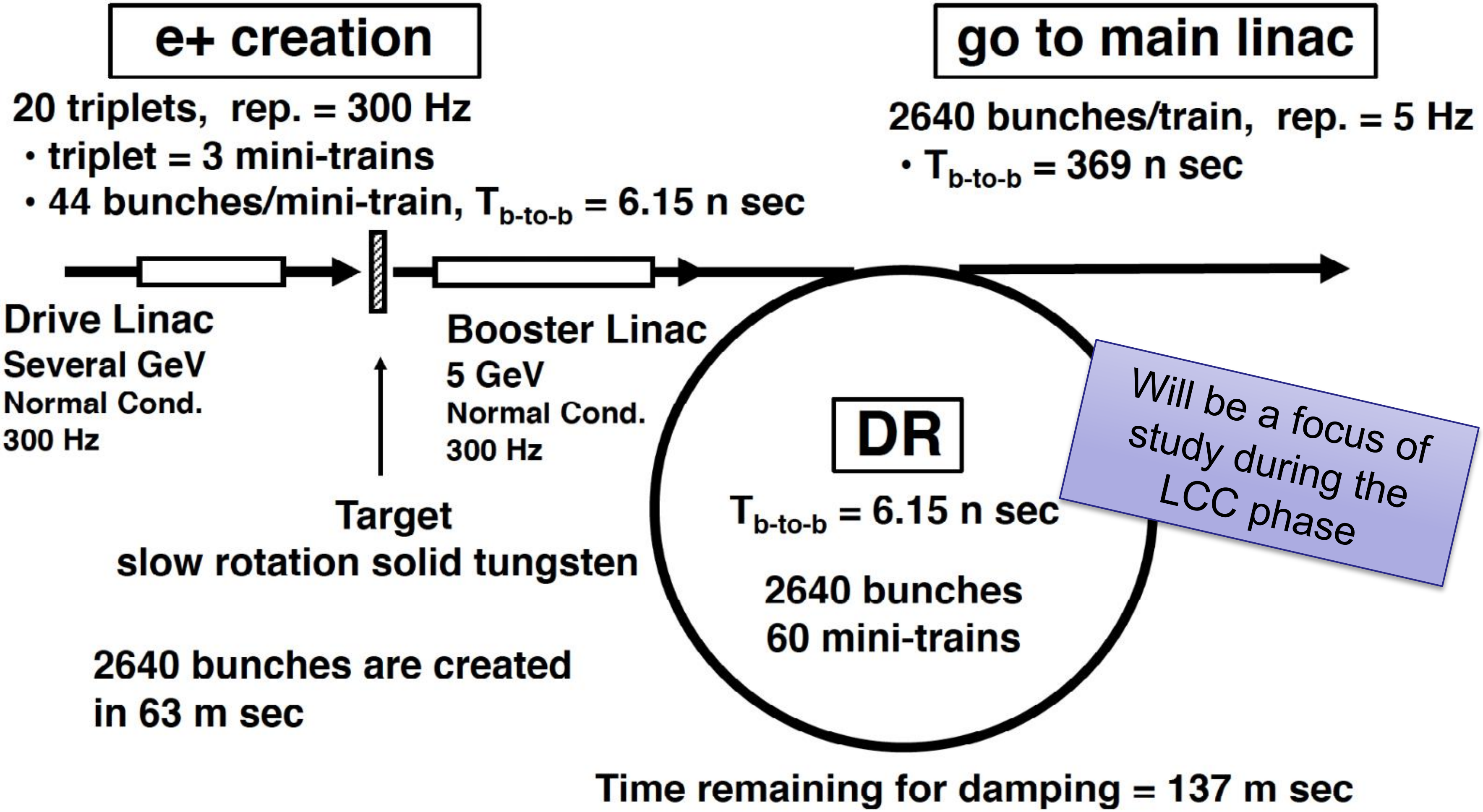
Positron Yield for a LHF

Recover yield by going to ~250 m of undulator



Wei Gai (ANL) et al

Alternative Electron-Driven Source



e+ creation

20 triplets, rep. = 300 Hz
- triplet = 3 mini-trains
- 44 bunches/mini-train, $T_{b\text{-}to\text{-}b}$ = 6.15 n sec

go to main linac

2640 bunches/train, rep. = 5 Hz
- $T_{b\text{-}to\text{-}b}$ = 369 n sec

Drive Linac
Several GeV
Normal Cond.
300 Hz

Booster Linac
5 GeV
Normal Cond.
300 Hz

Target
slow rotation solid tungsten

2640 bunches are created
in 63 m sec

DR

$T_{b\text{-}to\text{-}b}$ = 6.15 n sec

2640 bunches
60 mini-trains

Time remaining for damping = 137 m sec

Will be a focus of study during the LCC phase

T. Omori *et al*, Nucl. Instrum. Meth. A **672** (2012) 52-56

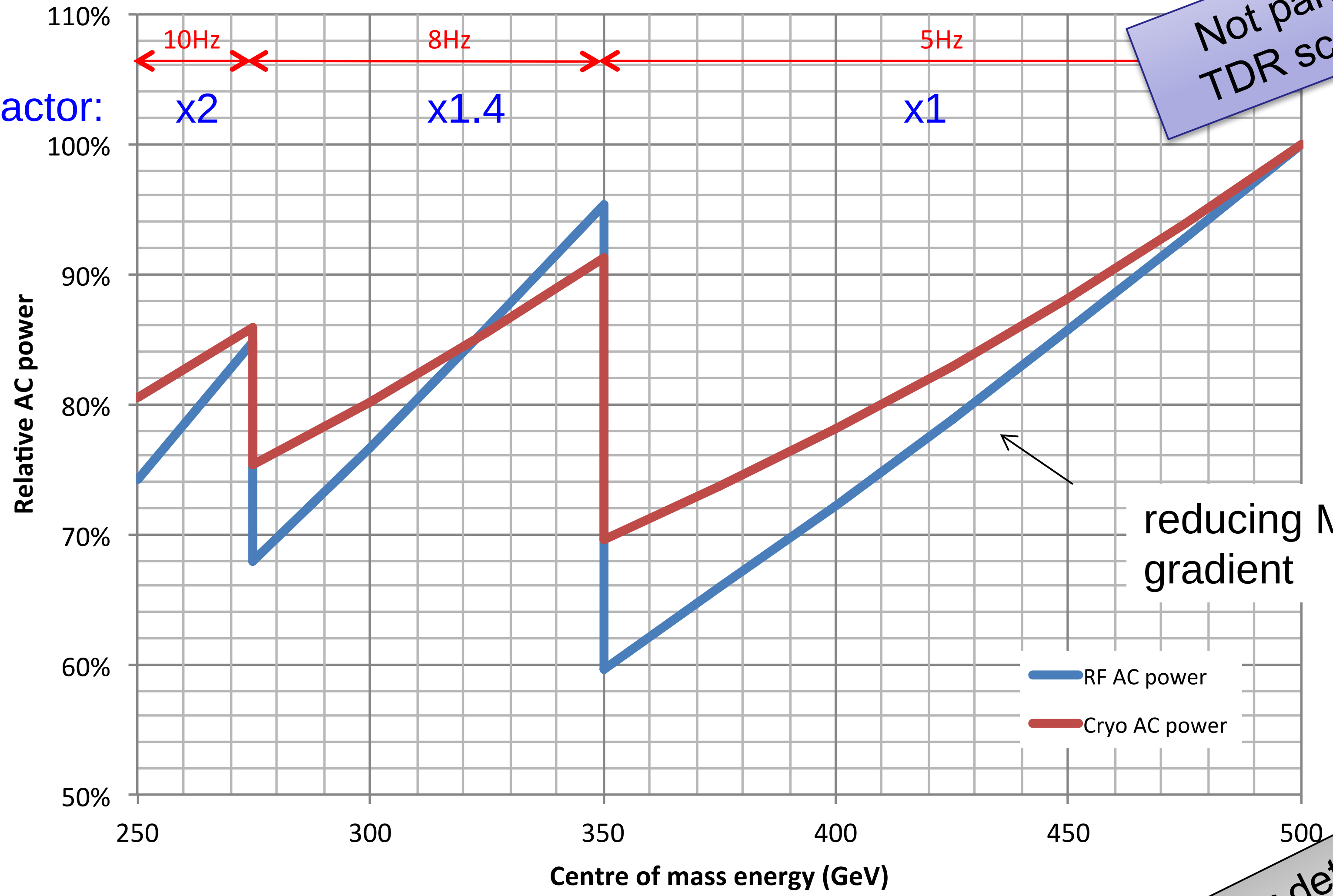
Light Higgs Factory

- **Assume we do not need 10-Hz e+ production mode**
  - – P_{AC} ~ 120 MW → ~100 MW (at least for undulator)
- **TDR still contains**
  - – 10 Hz damping ring (100 ms store time)
  - – 10 Hz e+e- source and injectors
- **Could we run 10 Hz collisions?**

Higher rep rate running

Not part of TDR scope!

lumi factor:



reducing ML gradient

issues for detectors?

Snowmass scenario: http://arxiv.org/abs/1308.3726

Issues for LHF 1st stage?

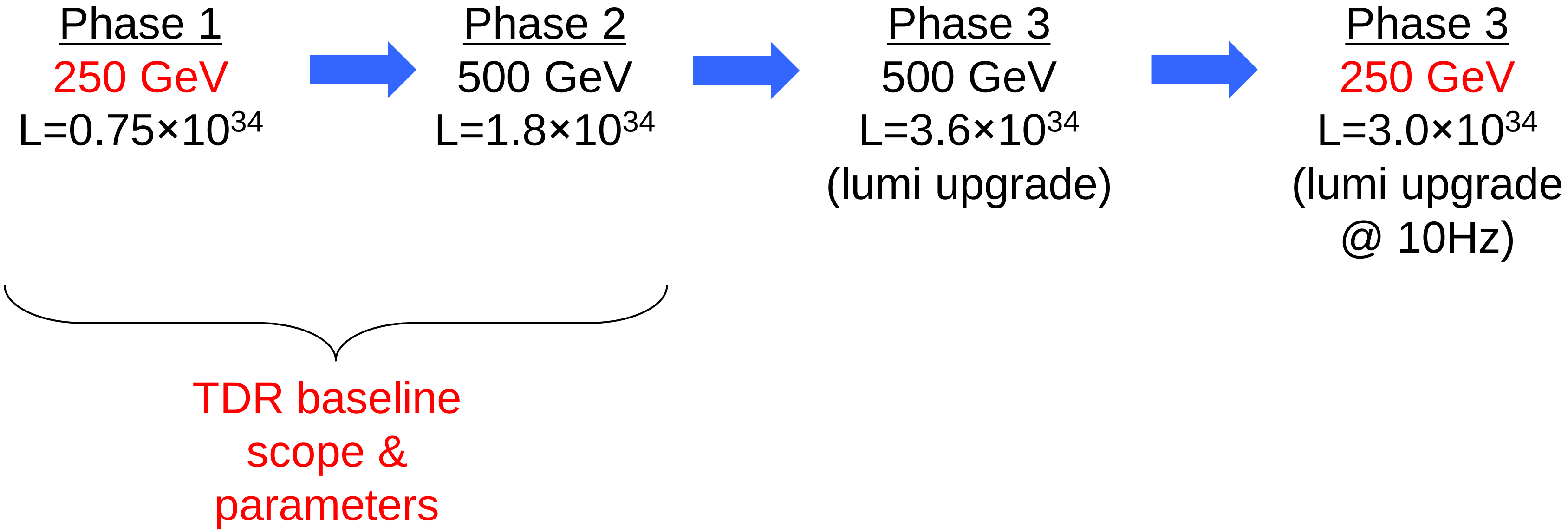
- **Shorter linacs run at full gradient (31.5 MV/m)**
- **10Hz operation would require additional AC power**
  - x2 RF AC power
  - x1.5 Cryo power
- **Requires feasibility study**
  - e.g. cryoplant capacity
  - cost!

Beyond TDR baseline!!

Something to talk about ☺

Snowmass Scenario

- http://arxiv.org/abs/1308.3726



Phase 1
250 GeV
L=0.75×10^{34}

Phase 2
500 GeV
L=1.8×10^{34}

Phase 3
500 GeV
L=3.6×10^{34}
(lumi upgrade)

Phase 3
250 GeV
L=3.0×10^{34}
(lumi upgrade
@ 10Hz)

TDR baseline
scope &
parameters

Next Steps

- **(Wait for Japan!)**
- **Develop a technical plan for the next three years**
  - Site-dependent design study
  - Specific Industrialisation and cost-reduction R&D
- **Work closely with XFEL and monitor progress**
- **Begin to discuss possible contributions to a Japanese hosted projected**
  - Scope of in-kind contributions
  - Project structure
  - …
- **Establish European, American and Asian Regional Teams in the post-GDE era**

Funding!

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See you in Japan ☺