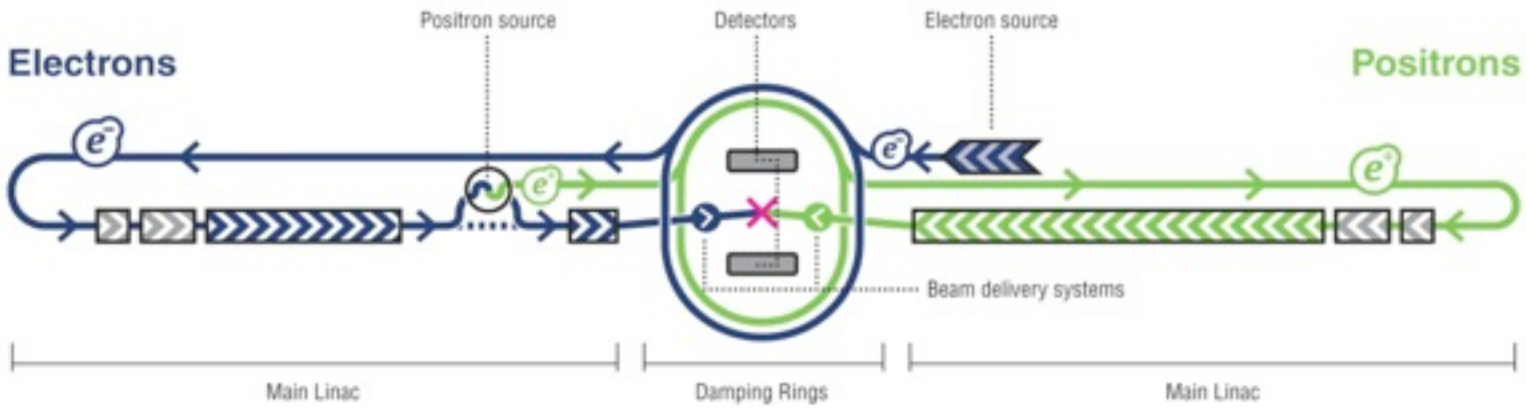
International Linear Collider (ILC)

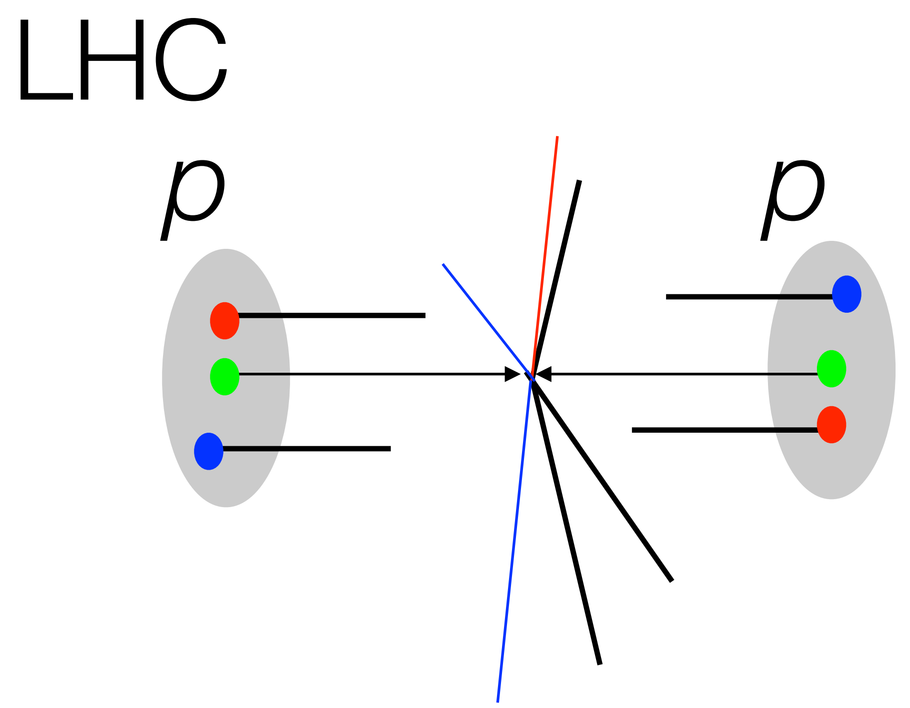
E. Elsen

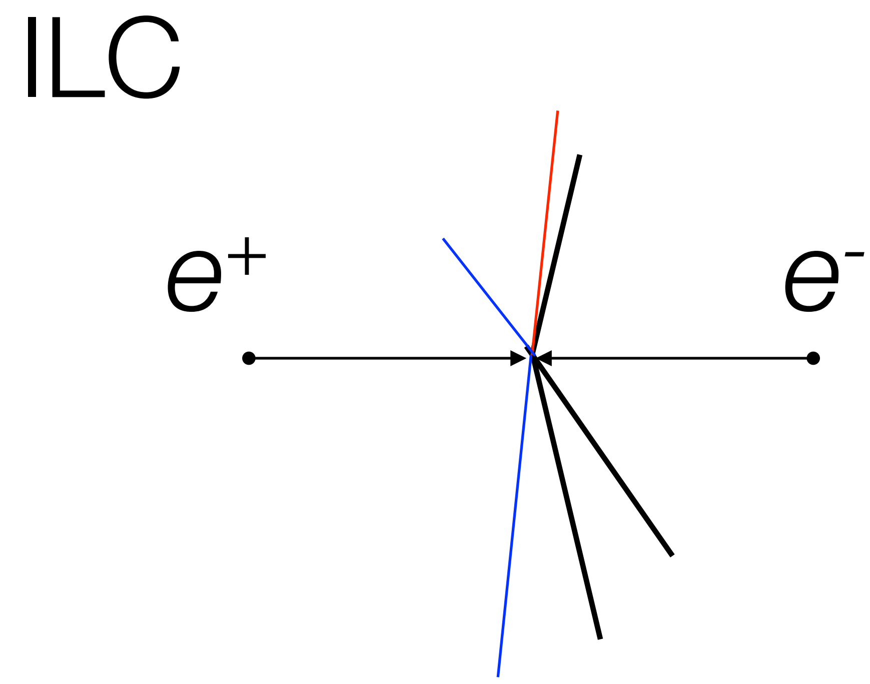


New Particle Physics Facilities, DESY, Seminar June 6, 2012

e^+e^- versus pp - the folklore

- LHC
  - discovery machine
- ILC
  - elementary particle
  - well defined: Energy, angular momentum
  - democratic production of particles
  - Final state (almost) completely captured



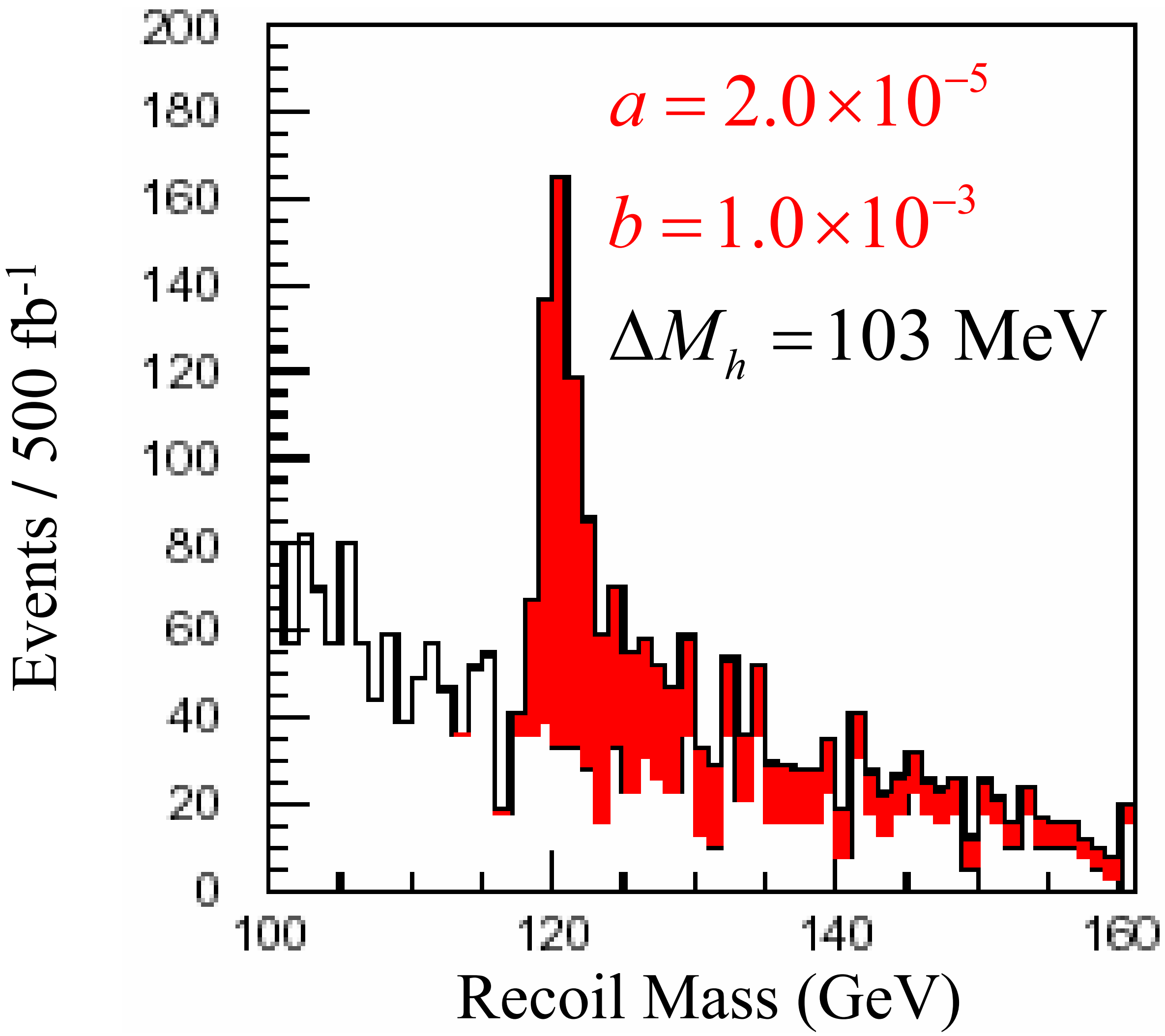


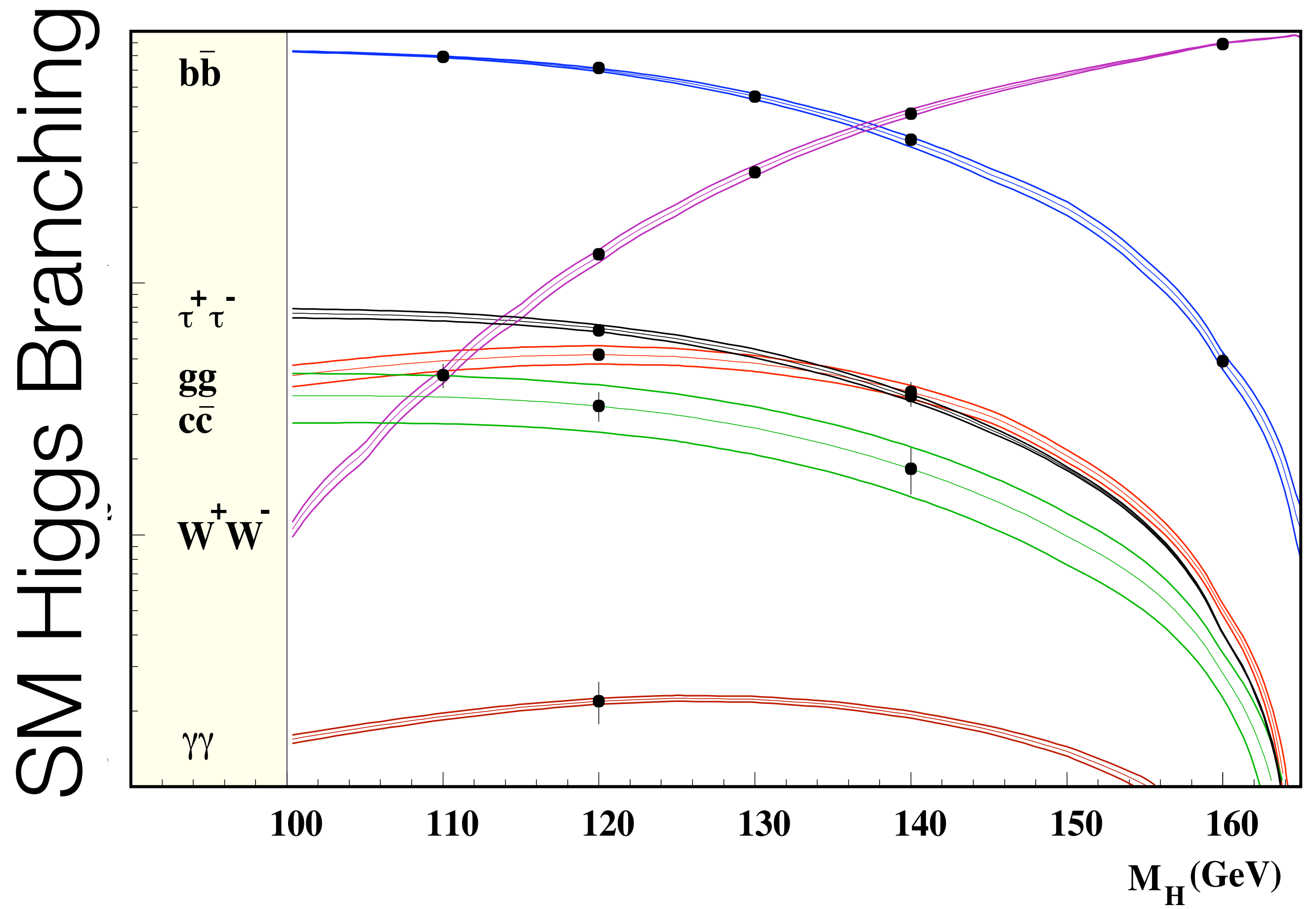
LHC vs ILC

	LHC	ILC
total energy	14 TeV	0.5-1 TeV
usable energy	a fraction	full
beam	composite	point-like
signal rate	high	low
background	very high	low
analysis	specific modes	nearly all modes
reconstruction	loose along beam	full event
status	running	ready for construction

e^+e^- Collider to complement LHC

Example: Higgs reconstruction and branching ratios

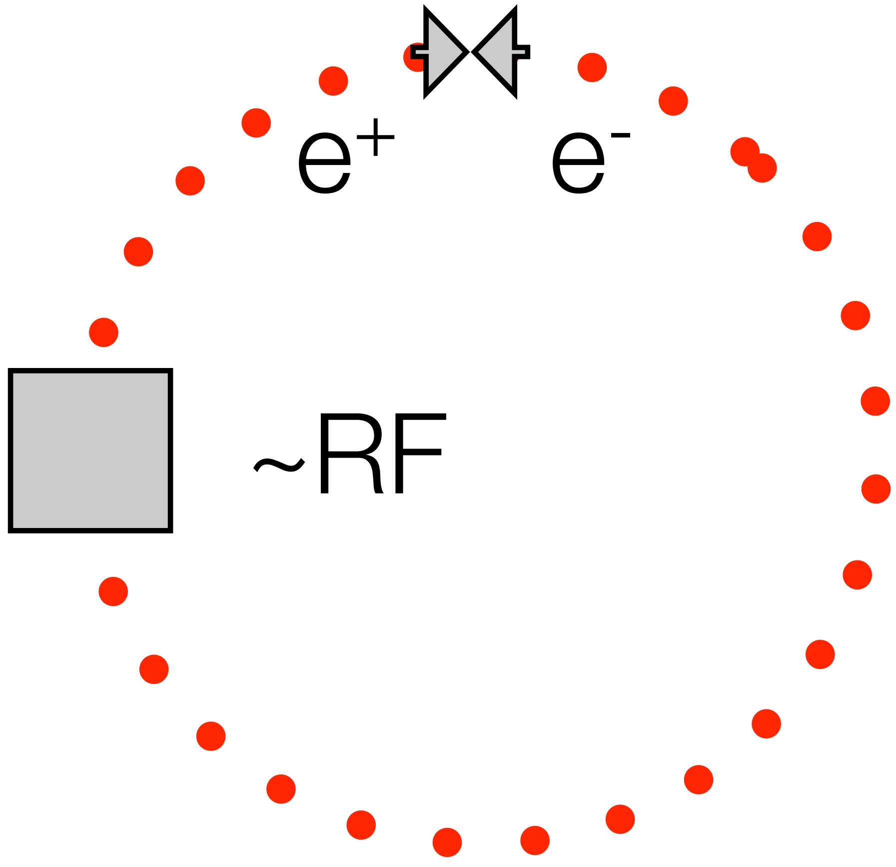




e^+e^- Linear Collider will address new physics by precision measurements

Circular collider for electrons?

- Synchrotrons as a collider
  - relatively small rf installation
    - same acceleration section used again and again
      at LEP/LHC: $f_{rep} \sim 11$ kHz
  - bunches n_b



$$\mathcal{L} = f_{rep} \frac{n_b N^2}{4\pi \sigma_x \sigma_y}$$

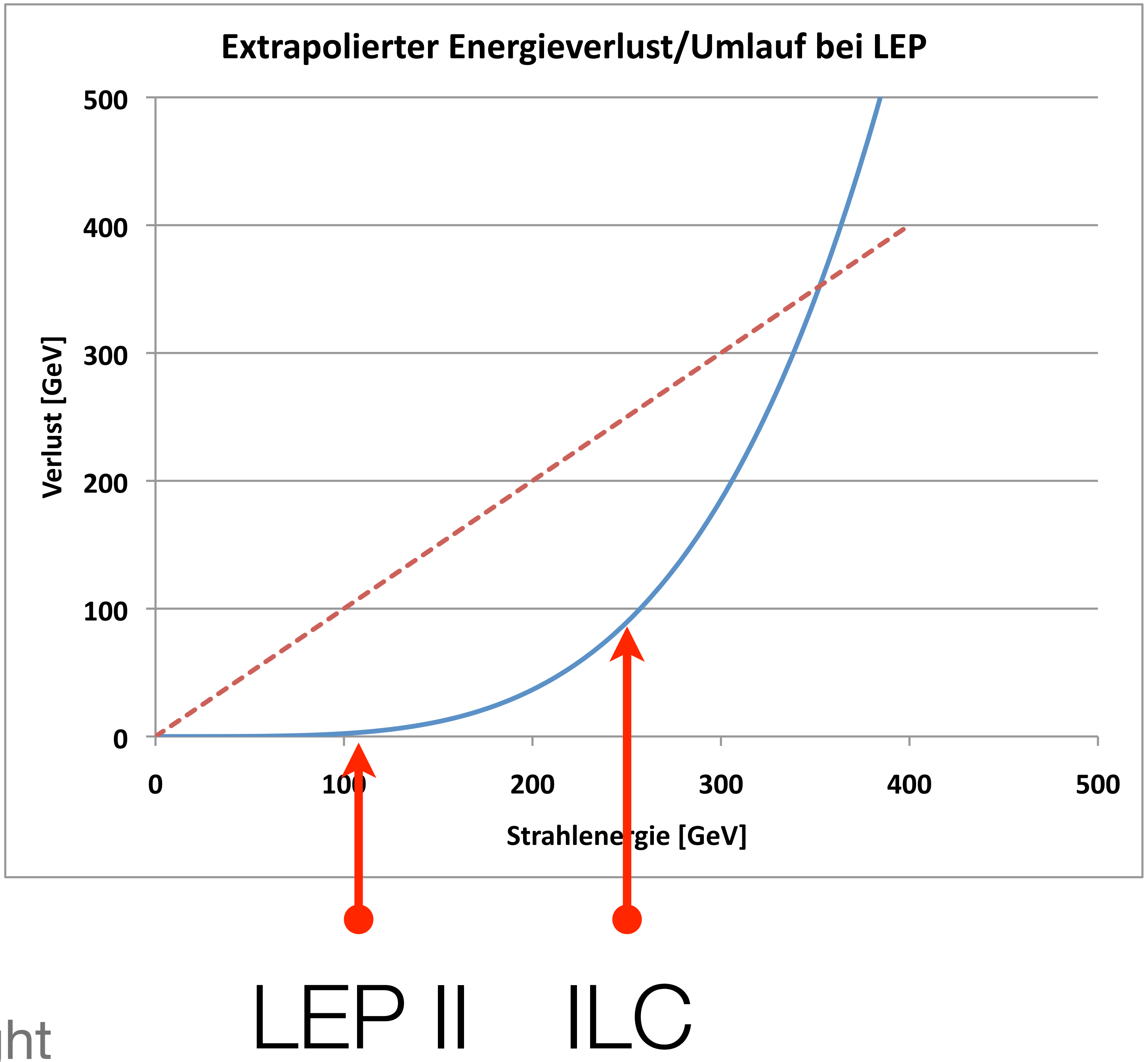
    - Duty cycles
      LHC $f_{rep} * n_b \sim 40$ MHz
      LEP $f_{rep} * n_b \sim 44$ kHz

$$\Delta E_{\mathrm{Umlauf}} \propto \frac{1}{\rho} \left(\frac{E}{m} \right)^4$$

- for electrons:
  Synchrotron radiation is limiting maximum energy!

Circular e^+e^- collider?

- Synchrotron radiation
  - Energy loss for E>100 GeV is a considerable fraction of the beam energy
  - Momentum acceptance of the rings!
  - for E>350 GeV the entire energy is radiated in one turn



⇒ HEP future for electrons is straight

Circular e^+e^- collider?

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  - Energy loss for E>100 GeV is a considerable fraction of the beam energy
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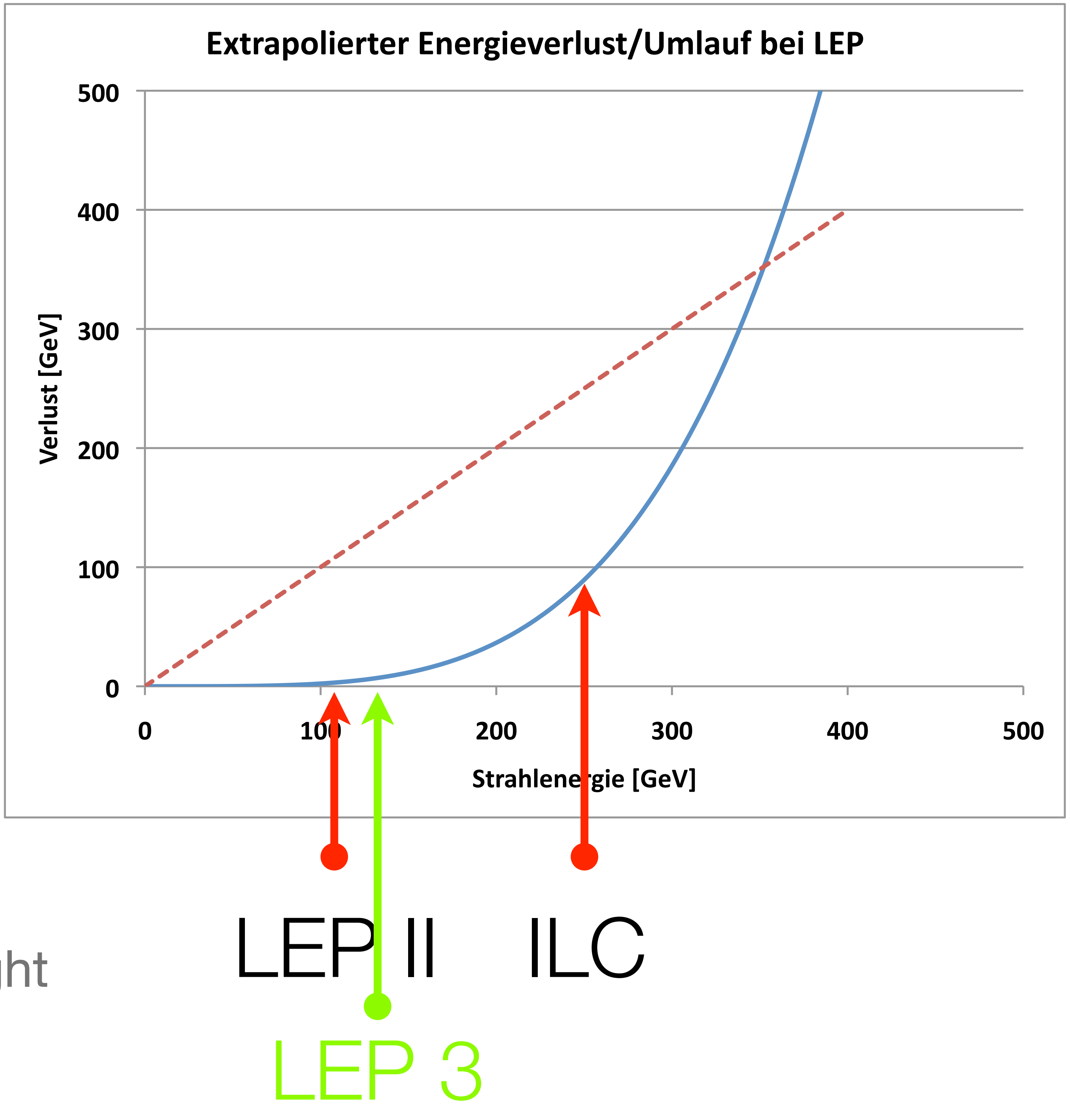
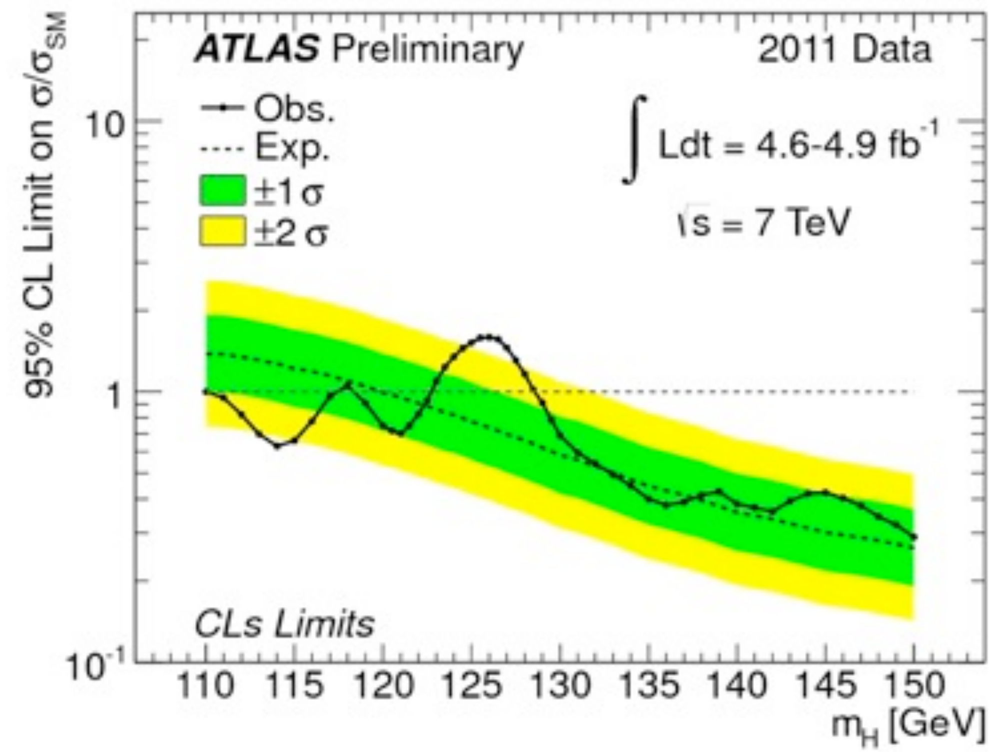


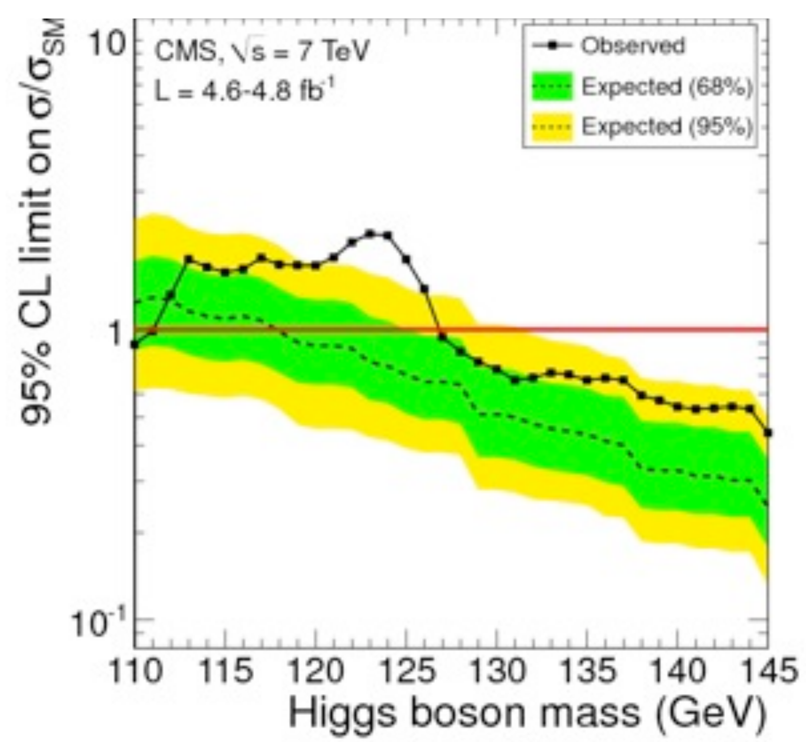
Current status of SM Higgs Search @ LHC

- Based on 2 x ~5 fb^{-1}
    - will be doubled for the summer conferences
    - expect another factor 2 by the end of the year



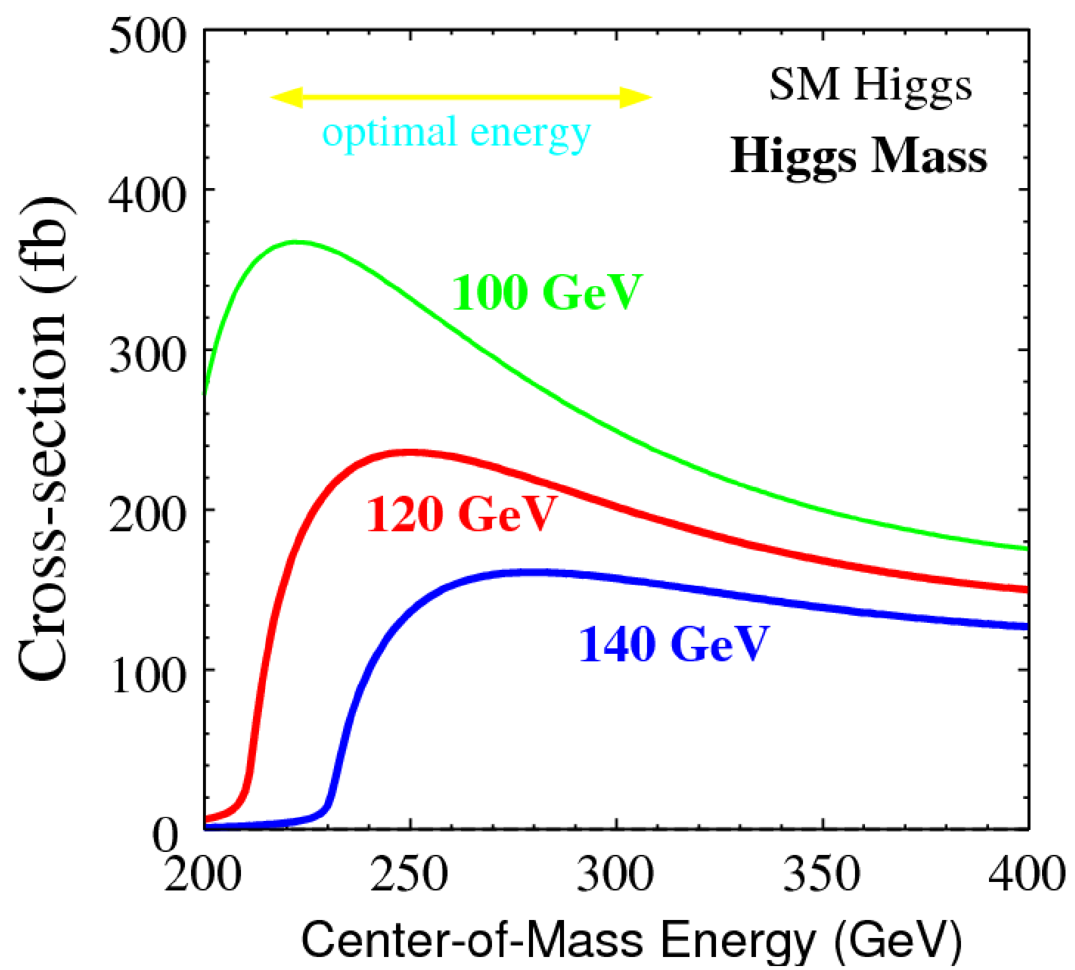
- If hints were statistically confirmed signal needs to be established as e.g. the SM Higgs particle
    - scalar particle
    - branching ratios

eventually requires e^+e^- collider



LEP3 to study a light Higgs?

- If a light Higgs were established at LHC could it be produced in the LEP/LHC tunnel?
  - Higgs of 125 GeV requires an e^+e^--collision energy of 240-250 GeV (peak of cross section in Higgsstrahlung process: $e^+e^- \rightarrow ZH$)
    - for heavy quarks an additional boost in helpful, i.e. $\sqrt{s}$>250 GeV
    - σ_{Higgs} ~200 fb
      - 10-100 fb^{-1}/a required (10^{33} - 10^{34} $cm^{-2}s^{-1}$)



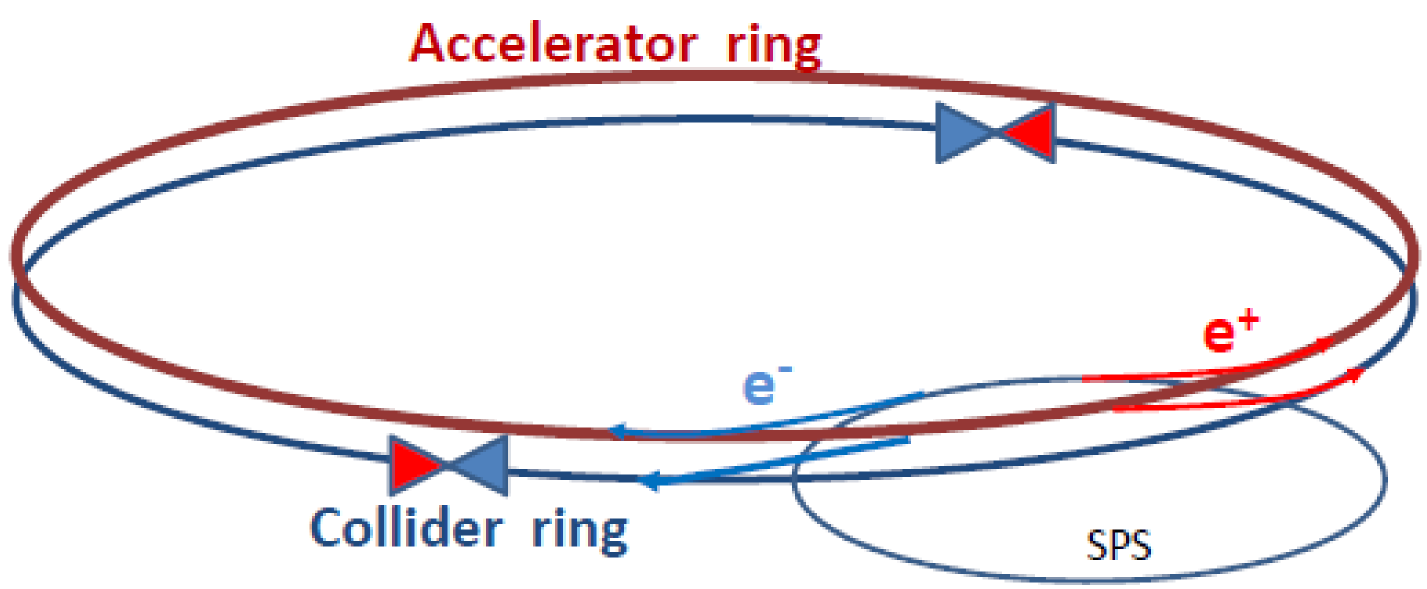
from A.Blondel et al., arXiv:1112.2518

Luminosity is the challenge

LEP3 Study Proposal

- Collider ring
    - 2 x 120 GeV
    - 7 GeV SR-loss per turn
    - 4 bunches of $4{\times}10^{12}$ e^-
      50 MW loss per beam
    - τ_{beam} = 16 min
      determined by Bhabha scattering
- Top-up ring
    - fast ramping synchrotron chain; SPS and accelerator ring 44-120 GeV

A.Blondel et al., arXiv:1112.2518 and IPAC12, TUPPR078 and references therein



Parameters at the limit
– no energy margin
– concept of storage doubtful

Parameters and issues of LEP3

- beam dynamics studies and optics; HOM heating with large bunch currents and very small bunch lengths (<0.3cm), vertical emittance tuning, single-bunch charge limits, longitudinal effects associated with a Q_s of 0.35, low beta insertion with large momentum acceptance, parameter optimization, beam-beam effects, including beamstrahlung, and the top-up scheme;
- optics design and beam dynamics for the accelerator ring, and its ramping speed;
- the design and prototyping of a collider-ring dipole magnet, an accelerator-ring dipole magnet, and a low-beta quadrupole;
- 100 MW synchrotron radiation effects: damage considerations, energy consumption, irradiation effects on LHC and LEP3 equipment, associated shielding and cooling;
- SRF and cryogenics design and prototyping
- determining the optimum RF gradient as a compromise between cryo power and space, and the optimum RF frequency with regard to impedance, RF efficiency and bunch length;
- machine-detector interface, e.g. the integration of warm low-beta quadrupoles inside the ATLAS and CMS detectors

	LEP2	LHeC	LEP3
b. energy E_b [GeV]	104.5	60	120
circumf. [km]	26.7	26.7	26.7
beam current [mA]	4	100	7.2
#bunches/beam	4	2808	4
#$e-$/beam [10^{12}]	2.3	56	4.0
horiz. emit. [nm]	48	5	25
vert. emit. [nm]	0.25	2.5	0.10
bending rad. [km]	3.1	2.6	2.6
part. number J_ε	1.1	1.5	1.5
mom. c. α_c [10^{-5}]	18.5	8.1	8.1
SR p./beam [MW]	11	44	50
β^*_x [m]	1.5	0.18	0.2
β^*_y [cm]	5	10	0.1
σ^*_x [μm]	270	30	71
σ^*_y [μm]	3.5	16	0.32
hourglass $F_{\rm hg}$	0.98	0.99	0.67
$E^{\rm SR}{}_{\rm loss}$/turn [GeV]	3.41	0.44	6.99
$V_{\rm RF,tot}$ [GV]	3.64	0.5	12.0
$\delta_{\rm max,RF}$ [%]	0.77	0.66	4.2
ξ_x/IP	0.025	N/A	0.09
ξ_y/IP	0.065	N/A	0.08
f_s [kHz]	1.6	0.65	3.91
$E_{\rm acc}$ [MV/m]	7.5	11.9	20
eff. RF length [m]	485	42	606
$f_{\rm RF}$ [MHz]	352	721	1300
$\delta^{\rm SR}{}_{\rm rms}$ [%]	0.22	0.12	0.23
$\sigma^{\rm SR}{}_{z,\rm rms}$ [cm]	1.61	0.69	0.23
L/IP[10^{32}cm^{-2}s^{-1}]	1.25	N/A	107
number of IPs	4	1	2
beam lifetime [min]	360	N/A	16
$\Upsilon_{\rm BS}$ [10^{-4}]	0.2	0.05	10
n_γ/collision	0.08	0.16	0.60
$\Delta E^{\rm BS}$/col. [MeV]	0.1	0.02	33
$\Delta E^{\rm BS}{}_{\rm rms}$/col. [MeV]	0.3	0.07	48

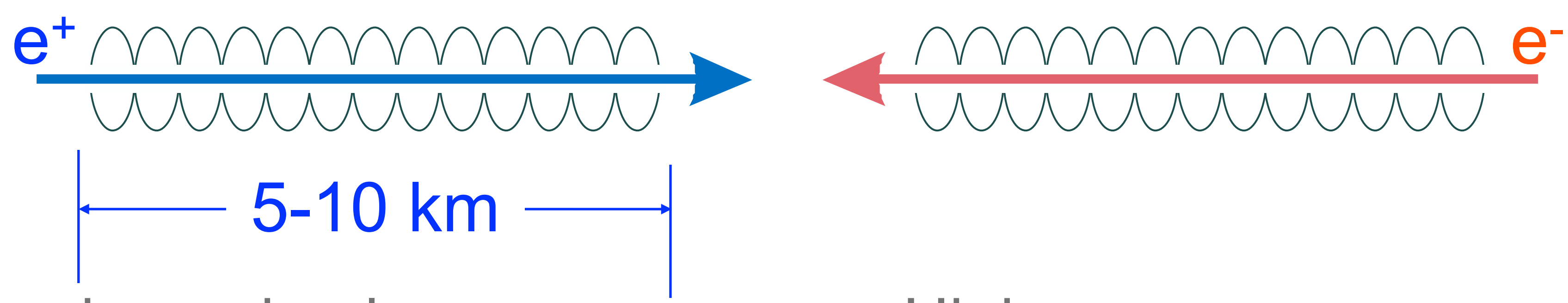
from IPAC12 paper

Some remarks on circular e^+e^- collider

- It would be possible to collide e^+e^- in the LEP tunnel at $\sqrt{s}$=240 GeV
  - Luminosity is the challenge
    - Synchrotron radiation losses of 7 GeV/turn
      - Radiation fluctuations necessitate voltage of 10 GV or more
      - large momentum acceptance required (5% or so)
    - cw-mode of SRF cavities necessitates an enormous cryoplant (~50 MW)
  - Beam stability
    - Beamstrahlung at the interaction point is critical
  - Power budget
    - 100 MW radiated

not extendible

Scheme for a Linear Collider



- Particle bunch used only once
  - extreme focussing
  - repetition rate
  - high gradient
- High power
  - Beam stability
    - Realistic treatment of beam power and heat
    - dimensions of collider

	LEP	ILC
$\sigma_x \times \sigma_y$	130×6 [μm²]	500×5 [nm²]
$N^* f_{rep}$	4×11 kHz	3000×5 Hz

While

A Possible Apparatus for Electron-Clashing Experiments (*).

M. Tigner

Laboratory of Nuclear Studies. Cornell University - Ithaca, N.Y.

Nuovo Cimento 37 (1965) 1228

While the storage ring concept for providing clashing-beam experiments ([1]) is very elegant in concept it seems worth-while at the present juncture to investigate other methods which, while less elegant and superficially more complex may prove more tractable.

has been proposed almost 50 years ago only one has been built and operated: SLC

with moderate design parameters
(from todays perspective)

Luminosity

Collider luminosity is approximately given by

$$\mathcal{L} = \frac{n_b N^2 f_{\mathrm{rep}}}{A} H_D$$

where:

$$\begin{aligned} n_b &= \text{bunches/train} \\ N &= \text{particles per bunch} \\ f_{\mathrm{rep}} &= \text{repetition frequency} \\ A &= \text{beam cross section at IP} \\ H_D &= \text{beam} - \text{beam enhancement factor} \end{aligned}$$

for Gaussian beams

$$\mathcal{L} = \frac{n_b N^2 f_{\mathrm{rep}}}{4\pi\sigma_x\sigma_y} H_D$$

Luminosity – RF power

- using centre of mass energy

$$\mathcal{L} = \frac{(E_{\rm cm} n_b N f_{\rm rep}) N}{4\pi\sigma_x\sigma_y E_{\rm cm}} H_D$$

$$\begin{aligned} n_b N f_{\rm rep} E_{\rm cm} &= P_{\rm beams} \\ &= \eta_{\rm RF} P_{\rm RF} \end{aligned}$$

$$\mathcal{L} = \frac{\eta_{\rm RF} P_{\rm RF} N}{4\pi\sigma_x\sigma_y E_{\rm cm}} H_D$$

- Example

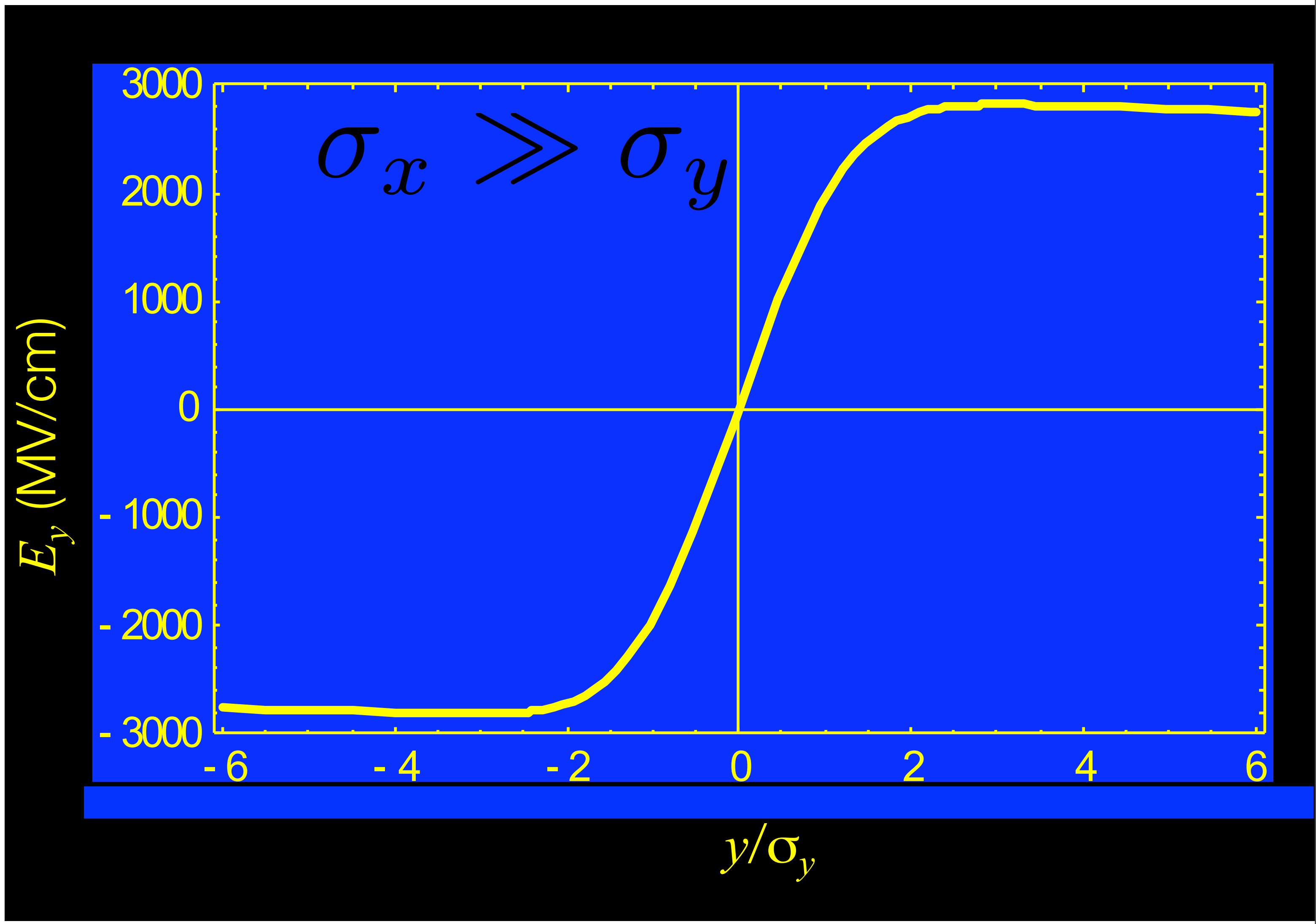
$$\left.\begin{aligned} E_{\rm cm} &= 500\,\mathrm{GeV} \\ N &= 10^{10} \\ n_b &= 100 \\ f_{\rm rep} &= 100\ (5)\,\mathrm{Hz} \end{aligned}\right\} P_{\rm beams} = 8\mathrm{MW}$$

- including efficiencies
  - RF to beam: 20-60%
  - Wall plug to RF: 30-40%

>100 MW AC needed to accelerate beams and achieve luminosity

Beam-Beam Interaction

- strong mutual focusing of beams (pinch) gives rise to luminosity enhancement H_D
- As e$^\pm$ pass through intense field of opposing beam, they radiate hard photons [beamstrahlung] and loose energy
- Interaction of *beamstrahlung* photons with intense field causes copious e^+e^- pair production [background]



Beam Beam Interaction at IP

Beam beam characterized by *Disruption* parameter:

$$D_{x,y} = \frac{2r_e N\sigma_z}{\gamma\sigma_{x,y}(\sigma_x+\sigma_y)} \approx \frac{\sigma_z}{f_{\mathrm{beam}}}$$

For storage rings f_{beam}~$\boldsymbol{\sigma}_z$ and $D_{x,y}$~1.

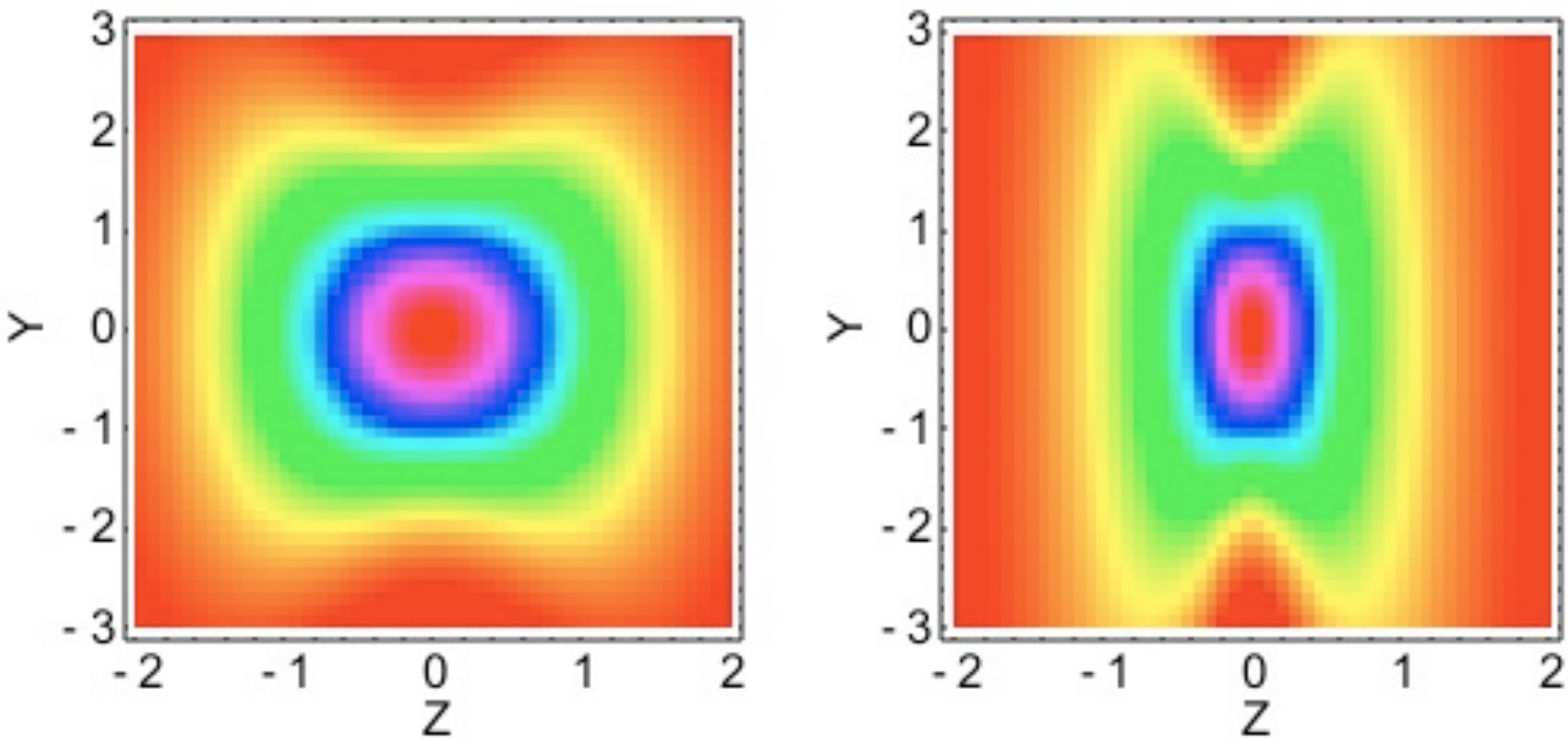
In a LC, D_y~10-20 and hence $f_{beam} < \boldsymbol{\sigma}_z$

Enhancement factor (typically H_D~2)

$$H_{D_{x,y}} = 1 + D_{x,y}^{1/4}\left(\frac{D_{x,y}^3}{1+D_{x,y}^3}\right)\left[\ln(\sqrt{D_{x,y}}+1) + 2\underbrace{\ln\left(\frac{0.8\beta_{x,y}}{\sigma_z}\right)}\right]$$

Hour glass effect

Hour-glass effect



β = "depth of focus"

reasonable lower limit for β is bunch length σ_z

Beamstrahlung

RMS relative energy loss

$$\delta_{BS} \approx 0.86 \frac{e r_e^3}{2 m_0 c^2} \left(\frac{E_{cm}}{\sigma_z} \right) \frac{N^2}{(\sigma_x + \sigma_y)^2}$$

Would like to make $\sigma_x \sigma_y$ <u>small</u> to maximise luminosity

BUT keep $(\sigma_x + \sigma_y)$ <u>large</u> to reduce δ_{BS}.

Trick: use "flat beams" with

$$\sigma_x \gg \sigma_y \qquad \delta_{BS} \propto \left(\frac{E_{cm}}{\sigma_z} \right) \frac{N^2}{\sigma_x^2}$$

Then choose σ_x to fix δ_{BS}, and make σ_y as small as possible to achieve high luminosity.

For most LC designs, δ_{BS} ~ 3-10%

Beamstrahlung

Returning to L scaling law, and ignoring H_D

$$\mathcal{L} \propto \frac{\eta_{\mathrm{RF}} P_{\mathrm{RF}}}{E_{CM}} \left(\frac{N}{\sigma_x}\right) \frac{1}{\sigma_y}$$

From flat-beam beamstrahlung

$$\frac{N}{\sigma_x} \propto \sqrt{\frac{\sigma_z \delta_{BS}}{E_{CM}}}$$

hence

$$\mathcal{L} \propto \frac{\eta_{\mathrm{RF}} P_{\mathrm{RF}}}{E_{\mathrm{cm}}^{3/2}} \frac{\sqrt{\delta_{\mathrm{BS}} \sigma_z}}{\sigma_y}$$

Small vertical beam size

$$\mathcal{L} \propto \frac{\eta_{\mathrm{RF}} P_{\mathrm{RF}}}{E_{\mathrm{cm}}^{3/2}} \frac{\sqrt{\delta_{\mathrm{BS}} \sigma_z}}{\sigma_y}$$

$$\sigma_y = \sqrt{\frac{\beta_y \epsilon_{n,y}}{\gamma}}$$

with $\varepsilon_{n,y}$ normalised vertical emittance and β_y the vertical β-function at the IP.

$$\mathcal{L} \propto \frac{\eta_{\mathrm{RF}} P_{\mathrm{RF}}}{E_{\mathrm{cm}}^{3/2}} \sqrt{\frac{\delta_{\mathrm{BS}} \gamma}{\epsilon_{n,y}}} \sqrt{\frac{\sigma_z}{\beta_y}} \propto \frac{\eta_{\mathrm{RF}} P_{\mathrm{RF}}}{E_{\mathrm{cm}}} \sqrt{\frac{\delta_{\mathrm{BS}}}{\epsilon_{n,y}}} \sqrt{\frac{\sigma_z}{\beta_y}}$$

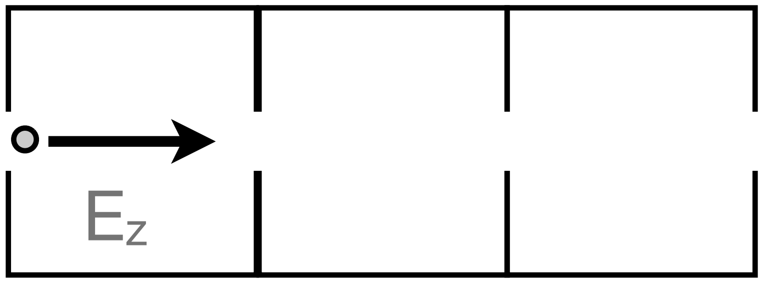
Optimised Scaling Law

$$\mathcal{L} \propto \frac{\eta_{\mathrm{RF}} P_{\mathrm{RF}}}{E_{\mathrm{cm}}} \sqrt{\frac{\delta_{\mathrm{BS}}}{\epsilon_{n,y}}} H_D \quad \text{for } \sigma_z \approx \beta_y$$

- For high luminosity
  - high RF-beam conversion efficiency
  - high RF power
  - small normalised vertical emittance
  - strong focussing at IP (small β_y and hence small σ_z!)
  - and could allow for larger beamstrahlung if willing to live with consequences

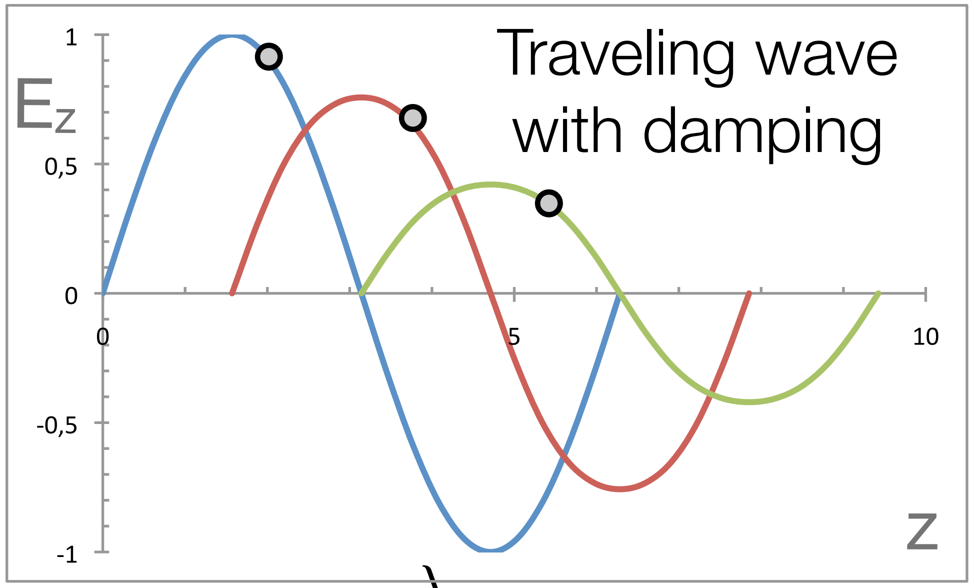
Concepts of rf acceleration

Resonator



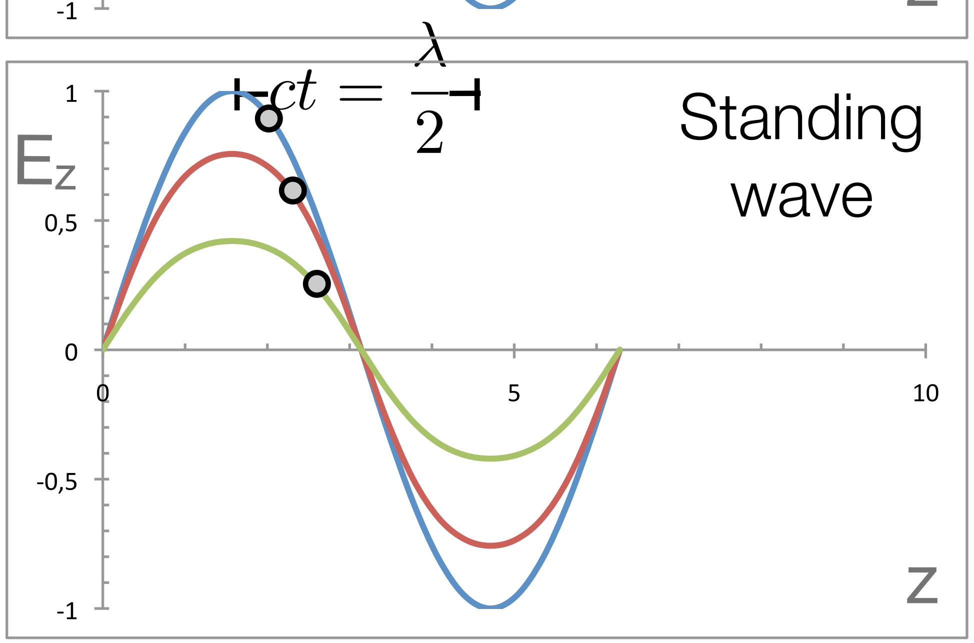
- Resonator required for
  - longitudinal component E_z
  - matching of phase velocity
- Two concepts
  - **Traveling wave** $$E_z = E_0 \cos(\phi)$$
    - Bunch (entirely) exhausts traveling wave during transit/acceleration;

CLIC



  - **Standing wave** $$E_z = E_0 \sin(\omega t + \phi) \sin(kz)$$ $$= E_0 \sin(kz + \phi) \sin(kz)$$
    - Particle bunch is accelerated by the mean value of the field; field is rather unaffected (large reservoir).

ILC



rf generation

- Klystrons
  - velocity modulation of an electron beam by an external field is translated into a density modulation of the electron beam in the clystron
  - rf field is extracted

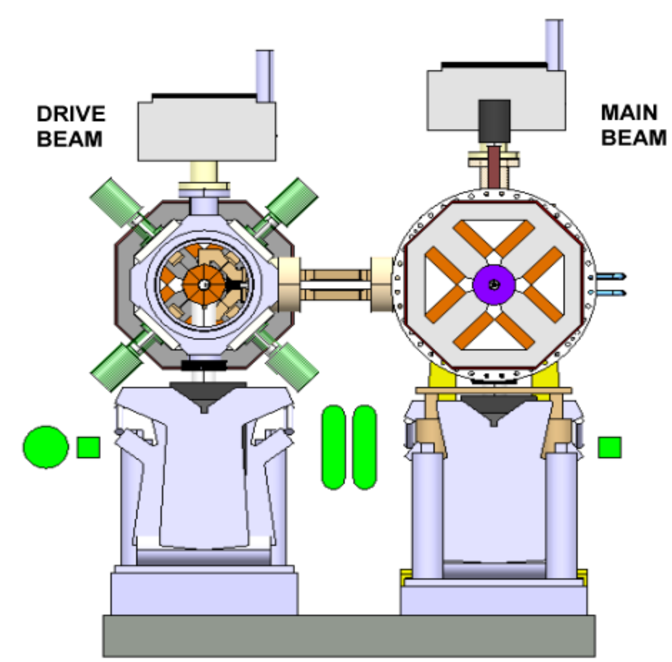
ILC

10 MW

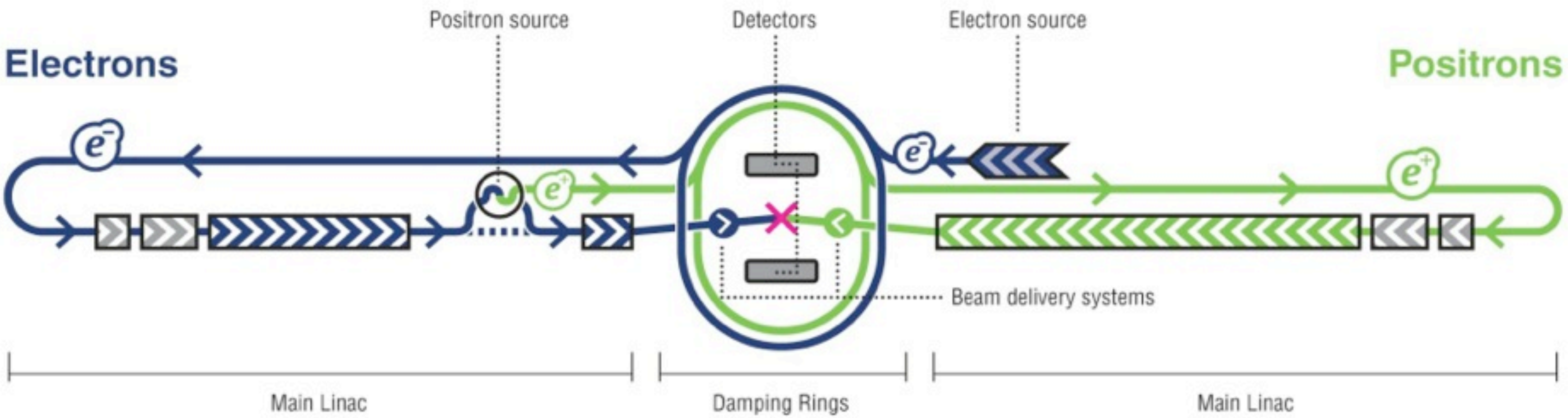
Thales CPI Toshiba

- Wakefield
  - field of moving charge is extracted from suitable resonant structures.

CLIC



ILC Layout (RDR version)



- Superconducting acceleration over a length of ~10 km
  - Nominal gradient: 31.5 MV/m
  - undulator based positron production

Global Design Effort (GDE) for the ILC

Americas

Labs

ANL
BNL
FNAL
JLAB
LANL
LBNL
LLNL
SLAC
TRIUMF

Universities/Institutes

Colorado Univ.
Cornell
FSU
Iowa Univ.
MSU
Notre Dame Univ.

Europe

labs

Budker
CEA/Saclay
CERN
CIEMAT
CNRS
STFC Daresubry Lab.
DESY
ESRF
GSI
INFN
JINR
LAL-Orsay
PSI

Universities/Institutes

Abertay Univ.
Berlin HU
Birmingham Univ.
Cambridge Univ.
Dundee Univ.
Durham
IFIC
IPJ
IPN-Orsay
IPPP Durham
Krakow
Lancaster Univ.
LAPP-Annecy
Legnaro
Liverpool Univ.
Manchester Univ.
Mannheim
Oxford Univ.
RHUL
Rostock

Asia

labs

BARC
IHEP
IUAC
KEK
RRCAT
Tsinghua Univ.
VECC

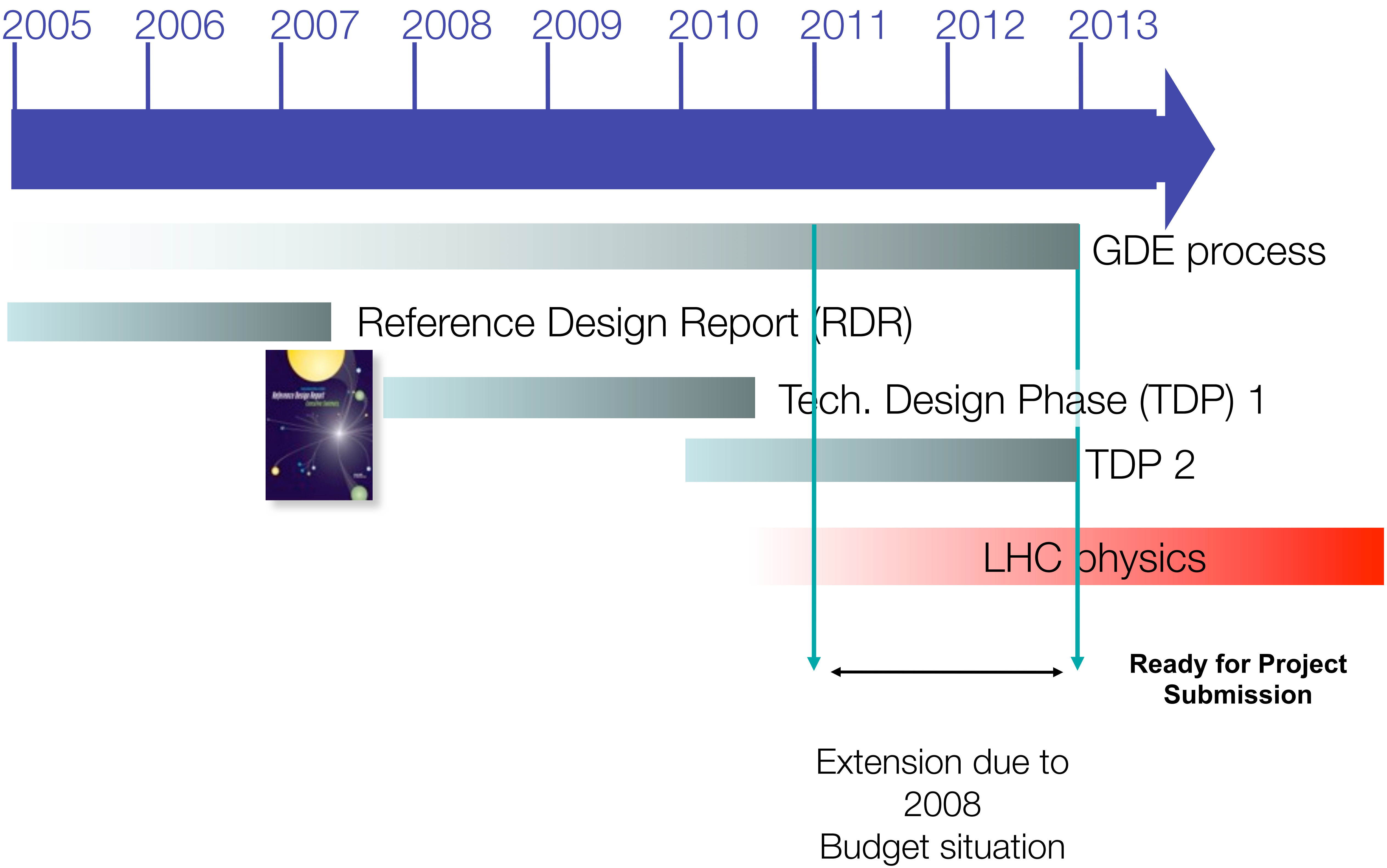
Universities/Institutes

Hiroshima Univ.
KNU
Nagoya Univ.
PAL
TIFR
Tohoku Univ.
Tokyo Univ.
Univ. Delhi

3 regions
16 countries
76 institutes

as of RDR

GDE ILC timelines



GDE approaching its original goals

2007

2011

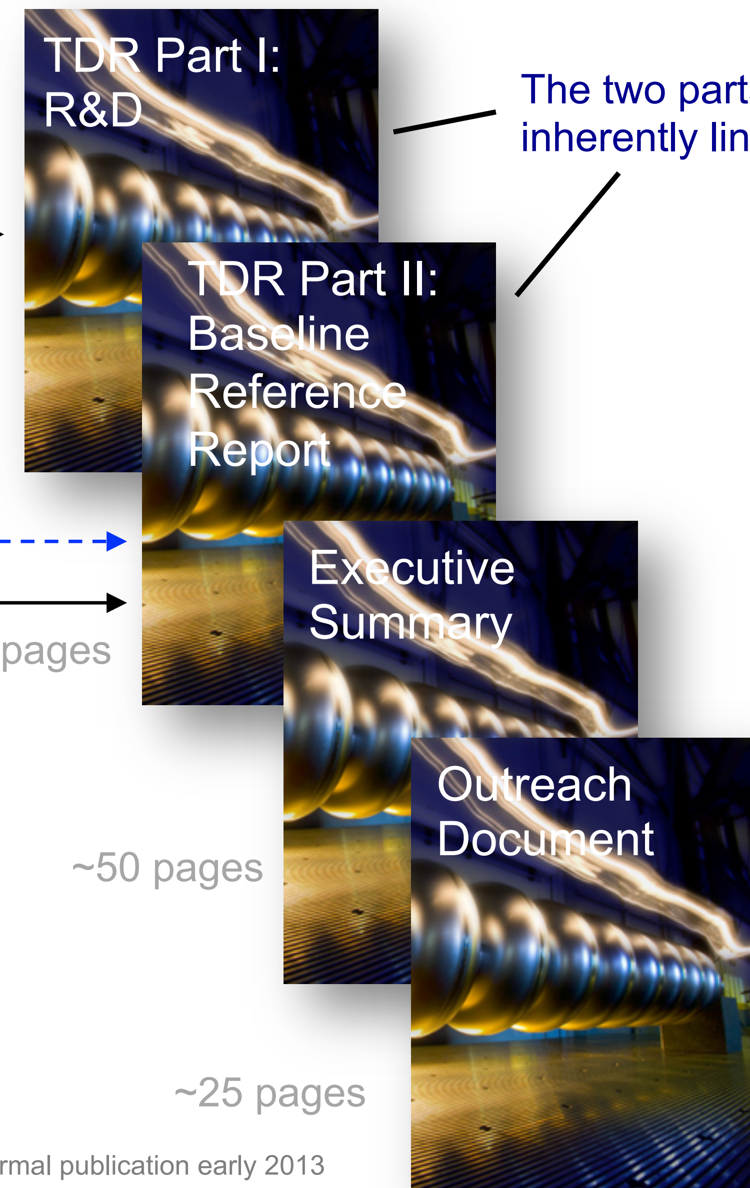
2013*

ILC Technical Progress Report
(“*interim report*”)

AD&I

Technical Design Report

~250 pages



The two parts are
inherently linked

~300 pages

~50 pages

~25 pages

Reference Design Report

* end of 2012 – formal publication early 2013

Priorities during Technical Design Phase

Risk Mitigating R&D	• SCRF Technology (e.g. gradient) • Damping ring electron cloud • …
Beam Test Facilities	• ATF / ATF 2 (KEK) • CesrTA (Cornell) • TTF/FLASH (DESY) • …
Machine Design / Cost	• CFS / Value Engineering • Accelerator Design & Integration

Global SCRF Technology

Implicit Goal

Develop expertise and infrastructure for 1.3 GHz 9-cell cavities in all 3 regions

This has been achieved

Global SCRF Technology: Asia

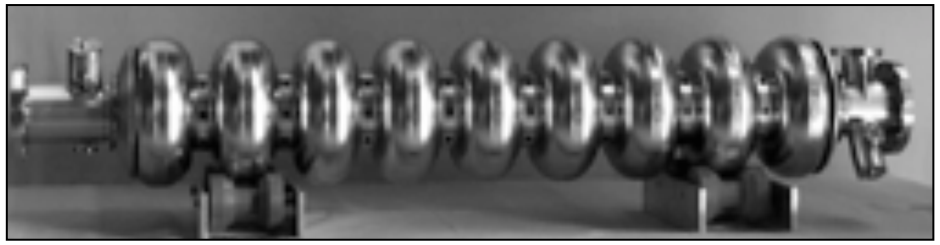
Global SCRF Technology: America

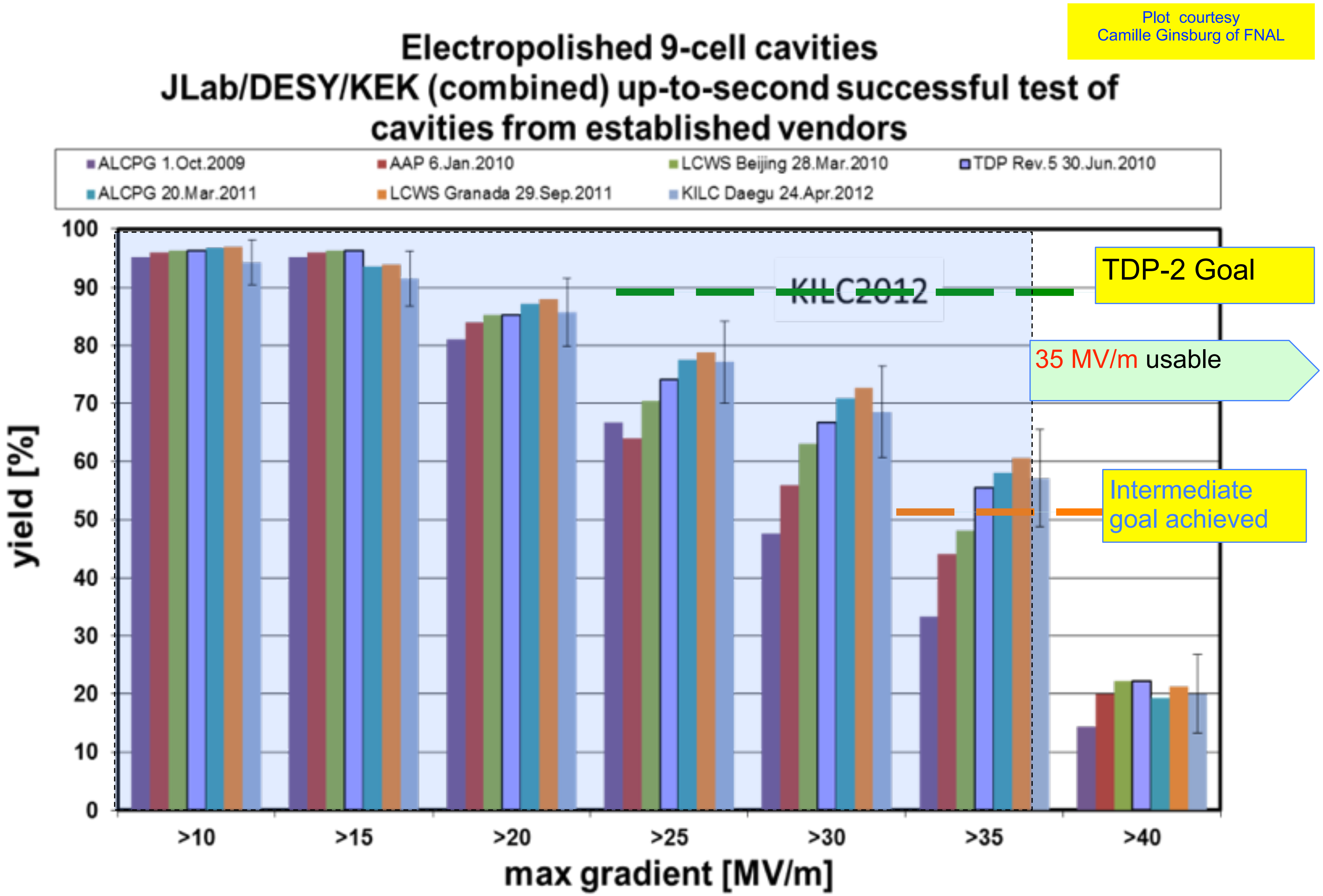
Global SCRF Technology: Europe

Major R&D goals for Technical Design

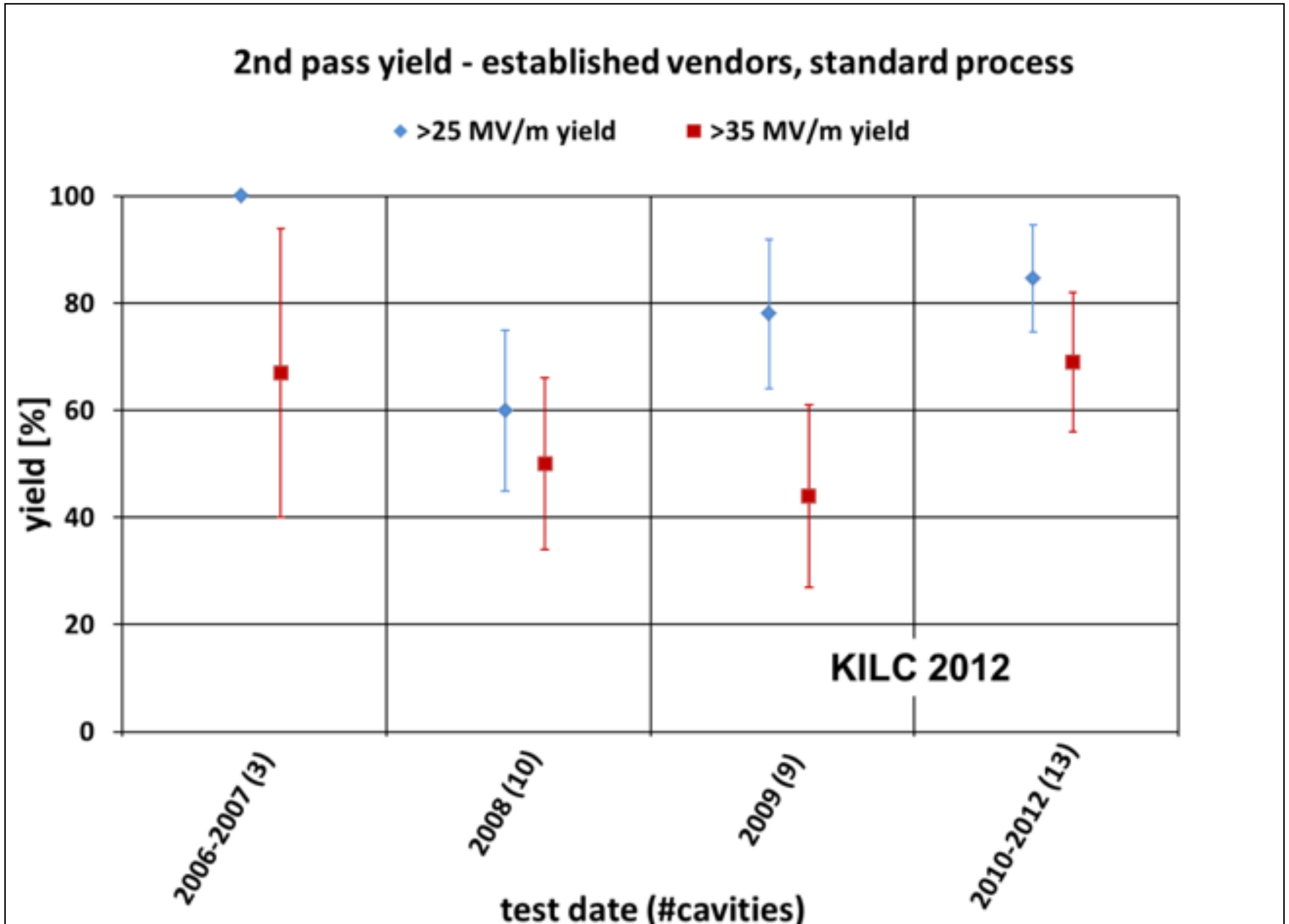
- SCRF
  - High Gradient R&D - globally coordinated program to demonstrate gradient by 2010 with 50%yield; improve yield to 90% by TDR (end 2012)
  - Manufacturing: plug compatible design; industrialisation, etc.
  - Systems tests: FLASH; plus NML (FNAL), STF2 (KEK) post-TDR
- Test Facilities
  - ATF2 - Fast Kicker tests and Final Focus design/performance
    Delayed due to EARTHQUAKE RECOVERY
  - CesrTA - Electron Cloud tests to establish damping ring parameters/design and electron cloud mitigation strategy
  - FLASH – Study performance using ILC-like beam and cryomodule (systems test)
    Future STF (KEK), NML (Fermilab)

Cavity Yield



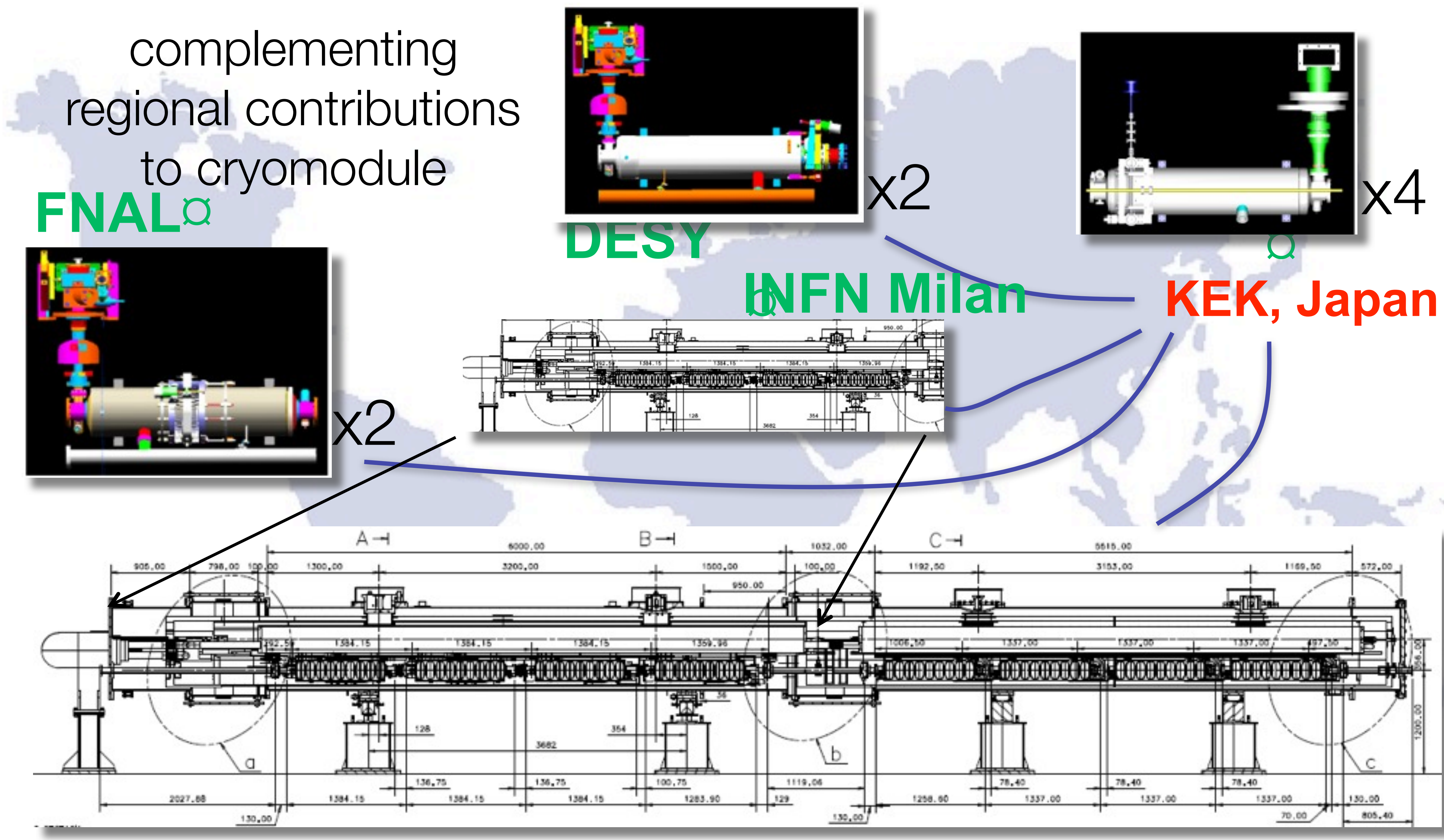


Differential yield



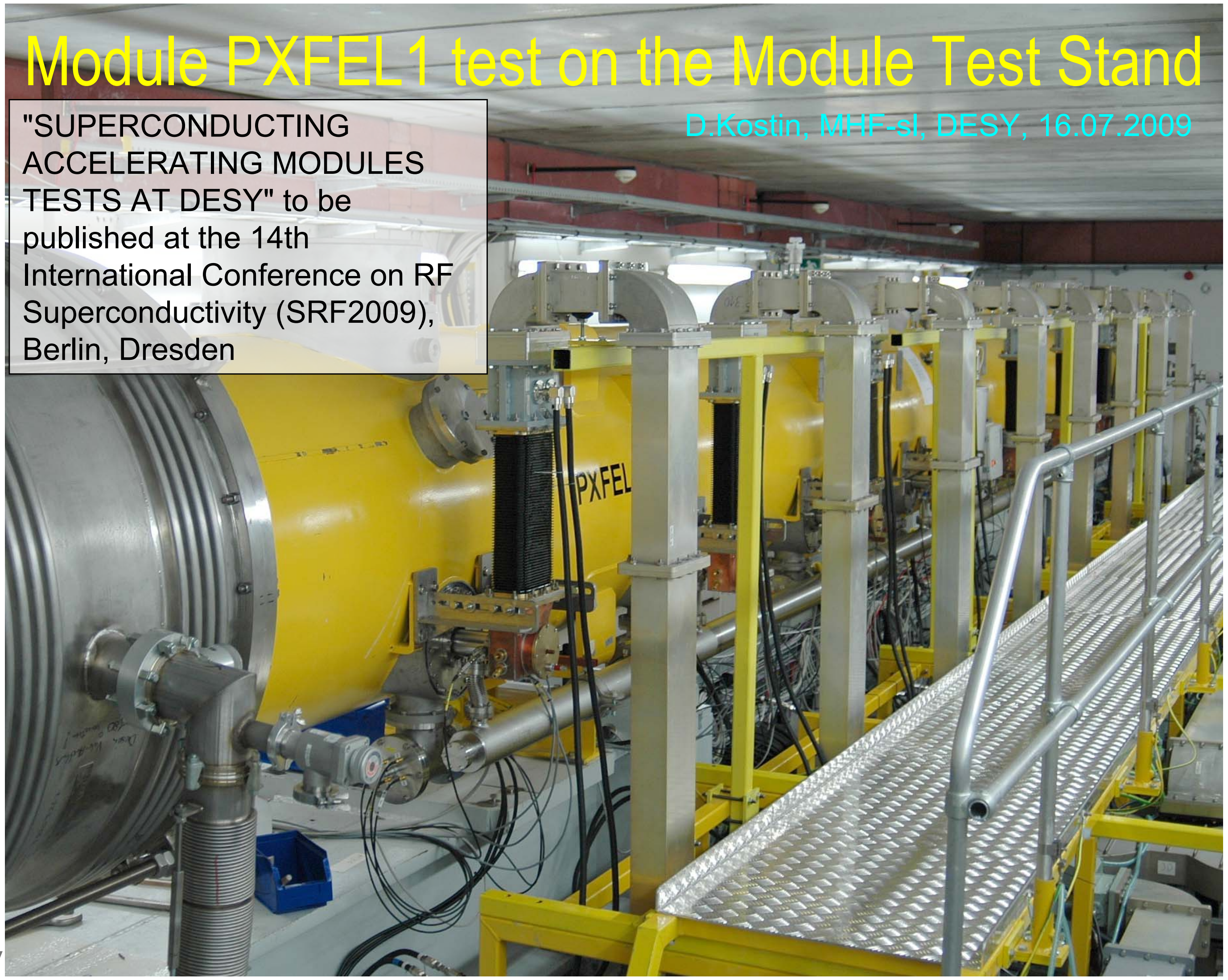
more statistics soon to come from European XFEL

S1-Global Collaboration

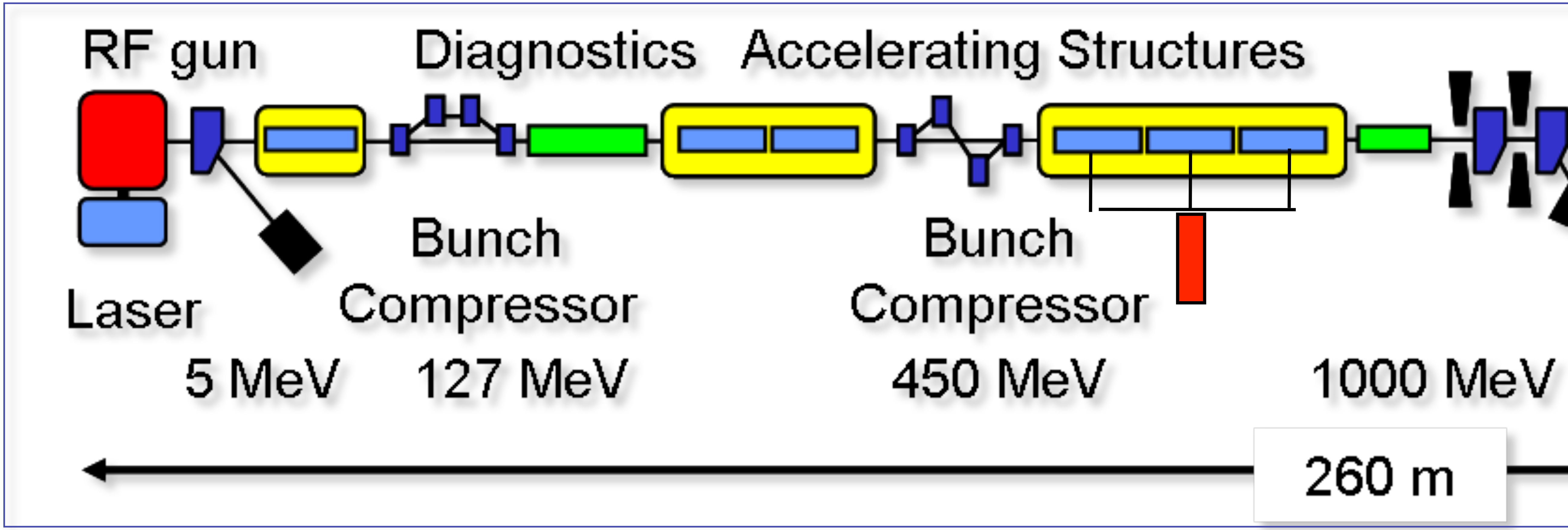


Test of FLASH Module / first XFEL prototype

- Cavity test in 2009:
  34.75 MV/m
- Cavities in module
  32.5 MV/m
- Operation at FLASH at 30 MV/m
  and 10 Hz
- Increased FLASH energy to 1.2 GeV
- Collaboration IHEP/Beijing, CEA-IRFU/Saclay, IN2P3-LAL/Orsay, INFN/Milano, CIEMAT/Madrid and DESY



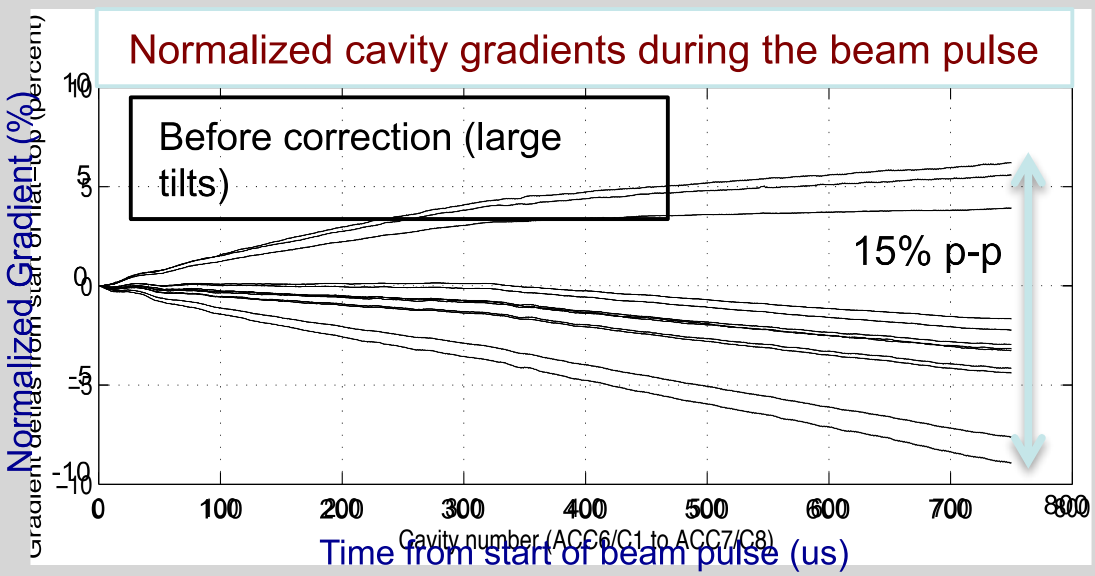
9mA Experiments in TTF/FLASH

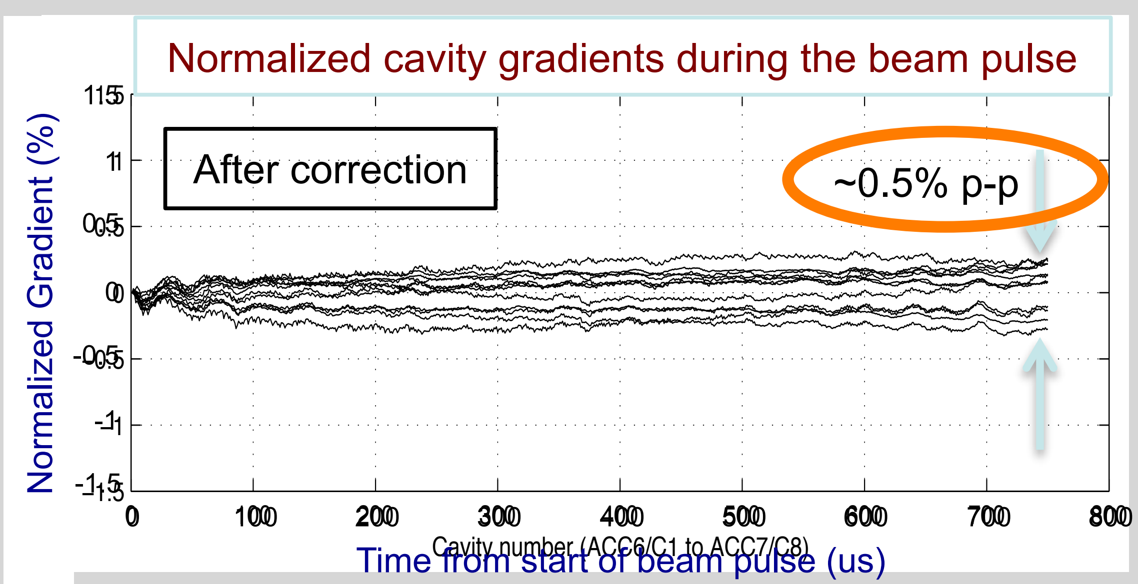


		XFEL X-Ray Free-Electron Laser	ilc	FLASH design	FLASH experiment
Bunch Ladung	nC	1	3.2	1	3
# bunches		3250*	2625	7200*	2400
Pulslänge	µs	650	970	800	800
Strom	mA	5	9	9	9

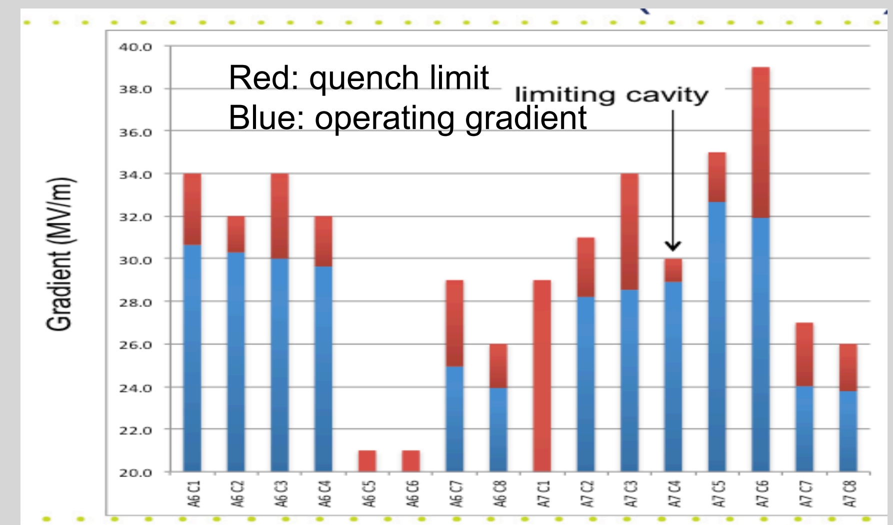
Recent tests at FLASH – Operation near Quench limit

Tailored cavity Loaded-Qs to cancel beam-loading induced gradient tilts





Operation at 380MeV on ACC67 (13 cavities)



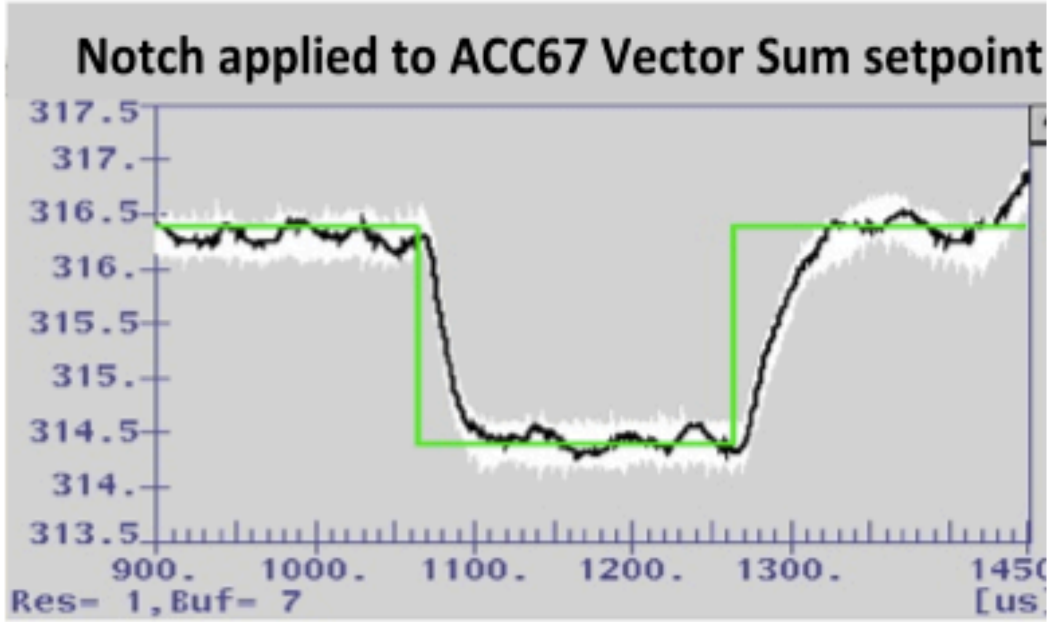
The limiting cavity is within 5% of quench

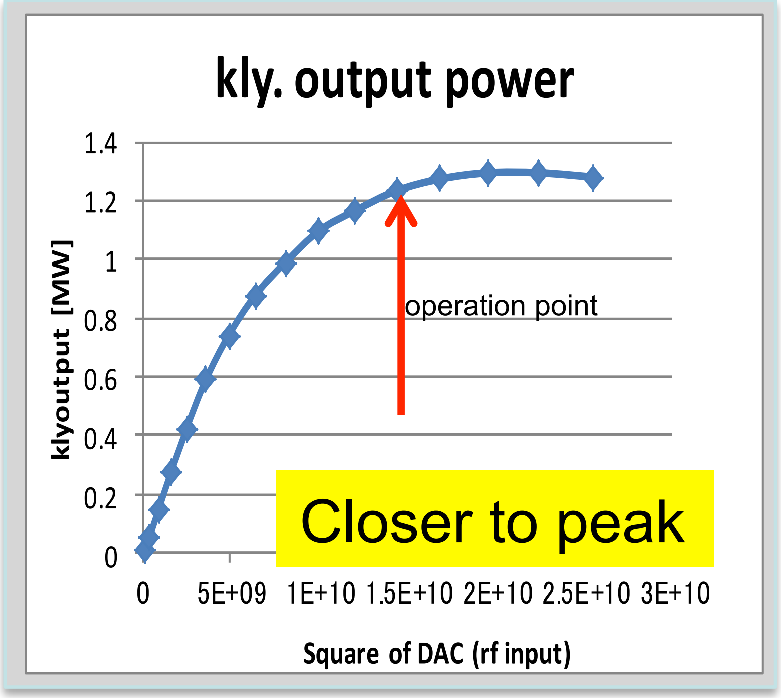
- Individual gradients flat to <<1% p-p
- Several cavities within 10% of quench
- ‘Crash test’: very rapid recovery of 800μs / 4.5mA after beam trip
- Ramped up current from ~zero to 4.5mA with ACC67 gradients approaching quench
- ‘Cavity gradient limiter’ to dynamically prevent quenching without turning off the rf

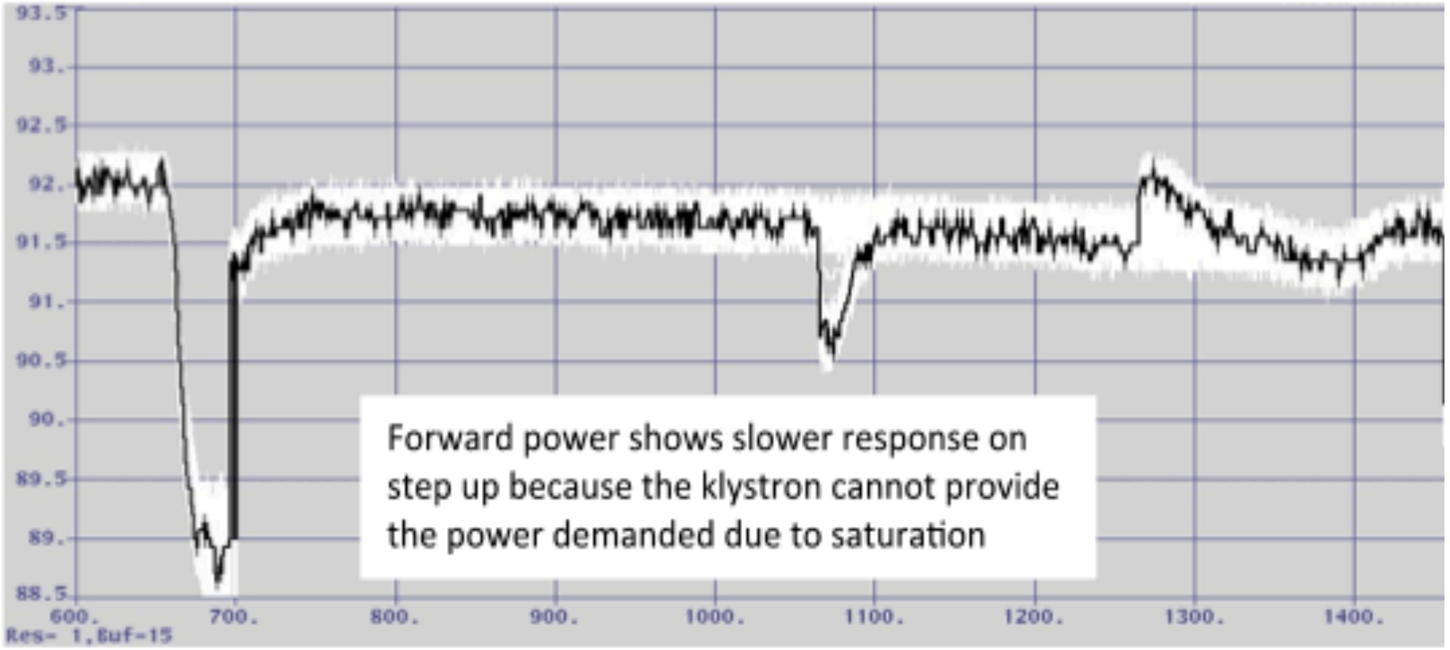
FALSH: Evaluating rf power overhead

- Klystron high voltage was reduced from 108KV to 86.5KV so that the rf output just saturated during the fill
- The required beam-on power ended up being ~7% below saturation

4.5 mA/800 μs train





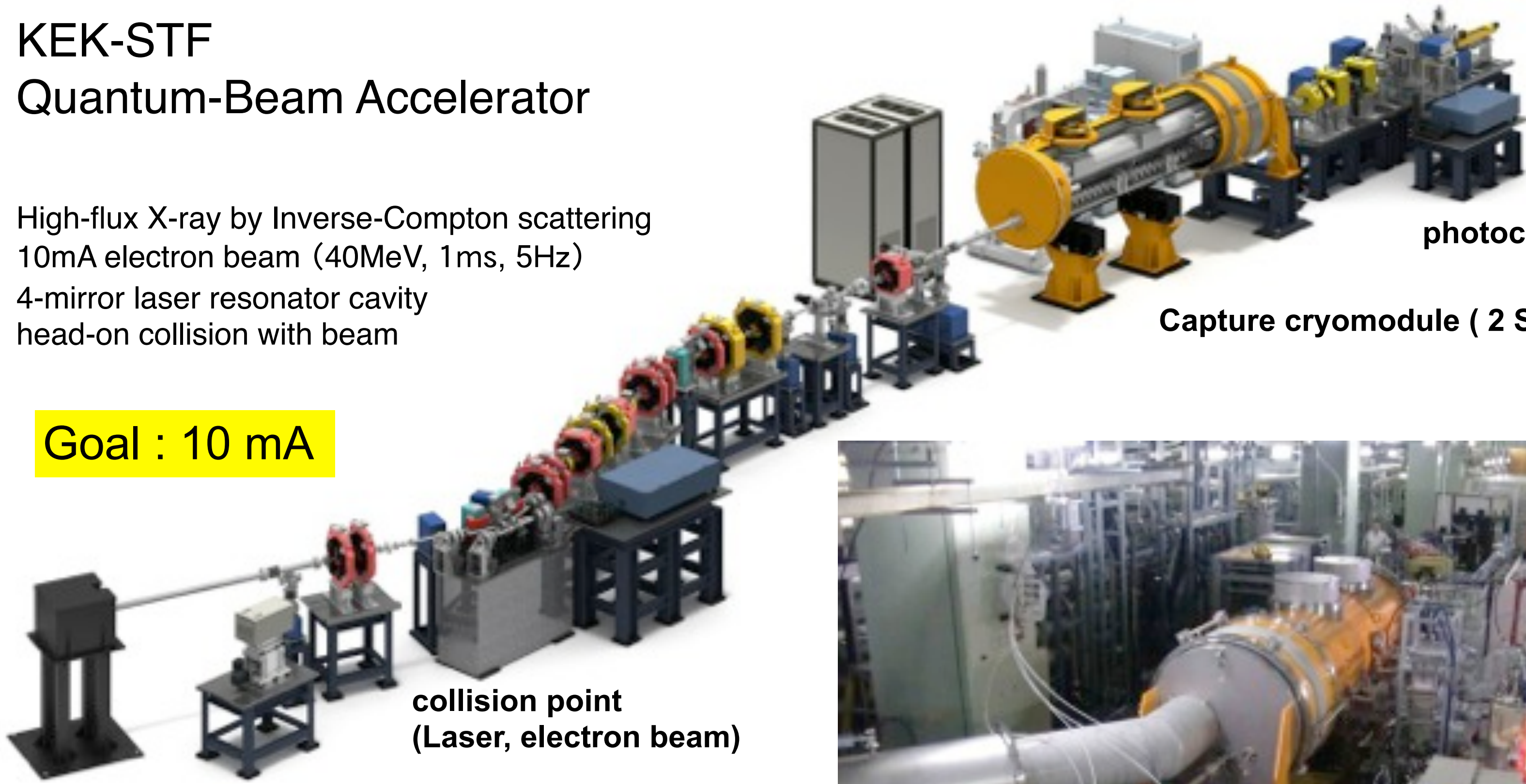


STF Quantum beam experiment at KEK

KEK-STF
Quantum-Beam Accelerator

High-flux X-ray by Inverse-Compton scattering
10mA electron beam（40MeV, 1ms, 5Hz）
4-mirror laser resonator cavity
head-on collision with beam

Goal : 10 mA

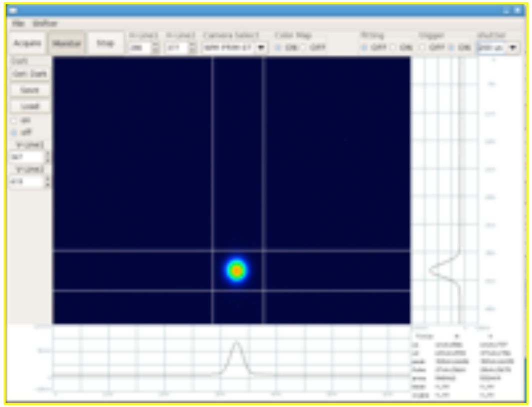


Target: 1.3 x 10^{10} photons/sec 1%bandwidth

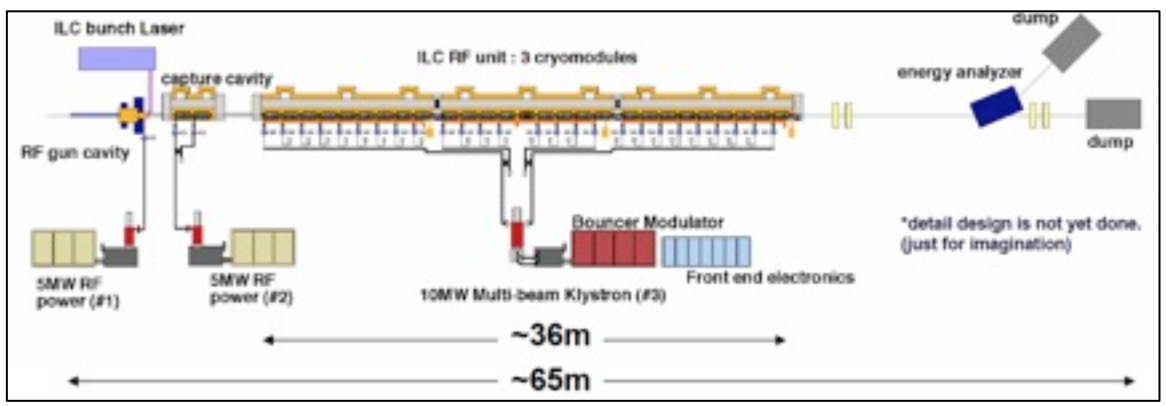
2012
Feb : cool-down started,
April : beam acceleration

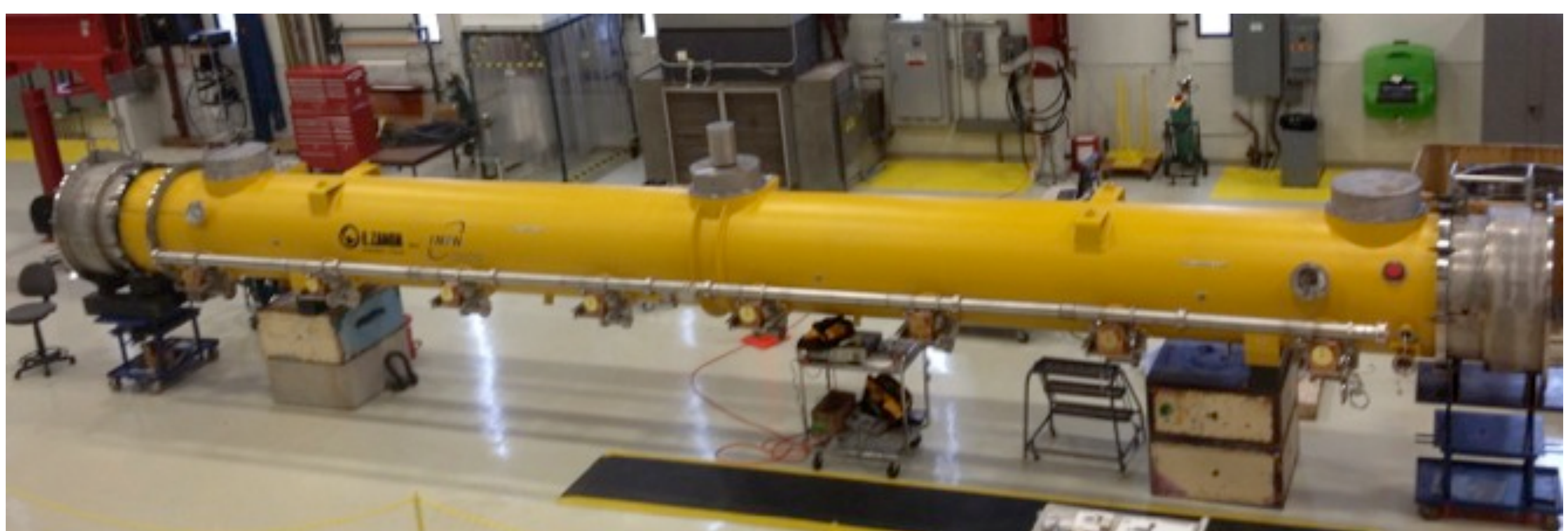
Beam acceleration (40 MV) and transport for 1 ms, successful !
April, 2012

shows the versatility of SCRF cavities: high current beam stable operation

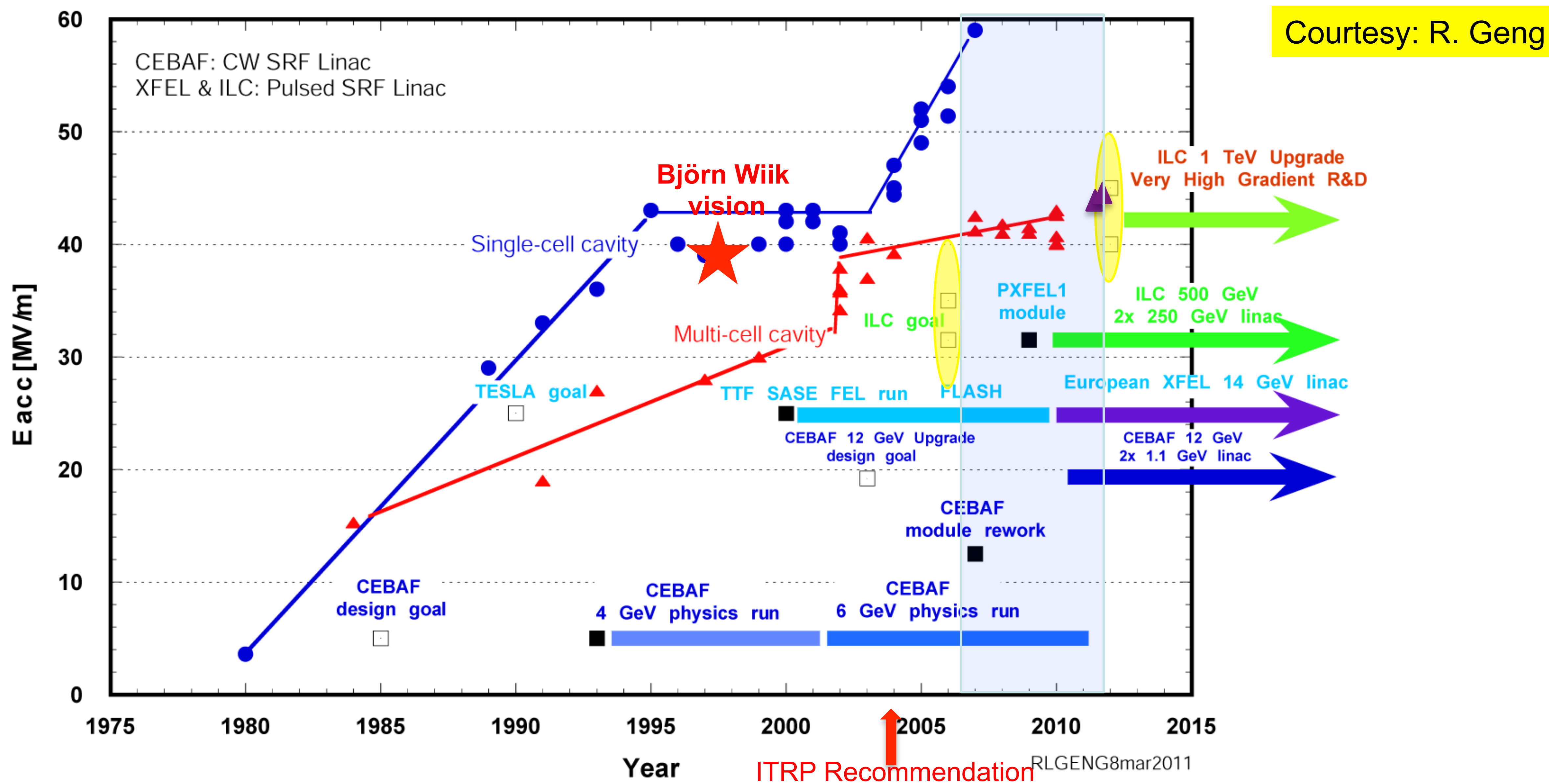


Beam Acceleration Test Plan at FNAL





Beyond ILC TDR



- Continued progress in SRF gradient : breakthrough of 45 MV/m in 1-cell, ~60 MV/m record; 45 MV/m in 9-cell
- GDE began in 2005: produce a design for ILC and coordinate worldwide R&D efforts
- New SRF Test Facilities in operation: STF at KEK and NML at Fermilab
- Upgrade of CEBAF to 12 GeV underway at Jefferson Lab (80 cavities)
- FLASH operation and construction of European XFEL underway (640 cavities)

2-cell cavity with end-group reached > 50 MV/m

Target

* Accelerate to 10 MeV

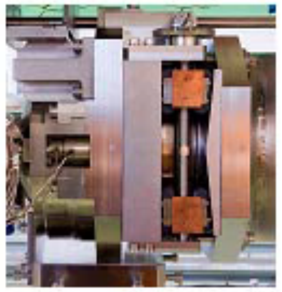
Require

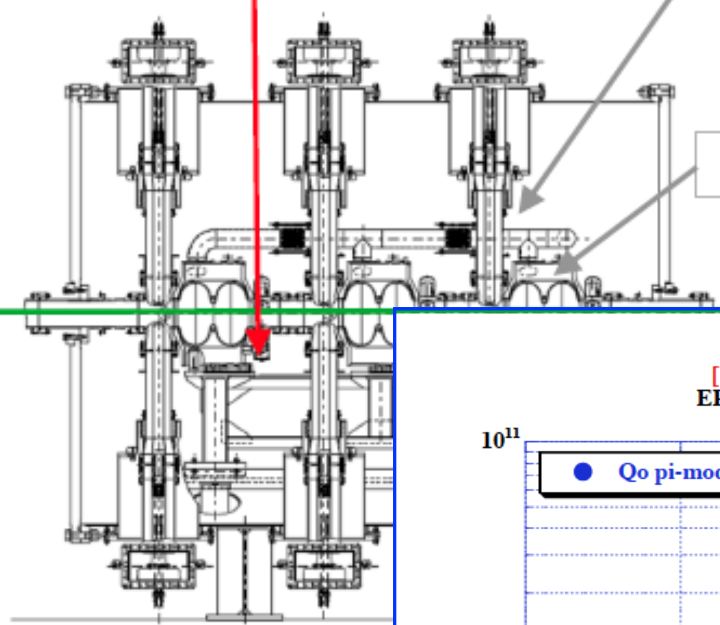
* 15 MV/m / cavity at CW

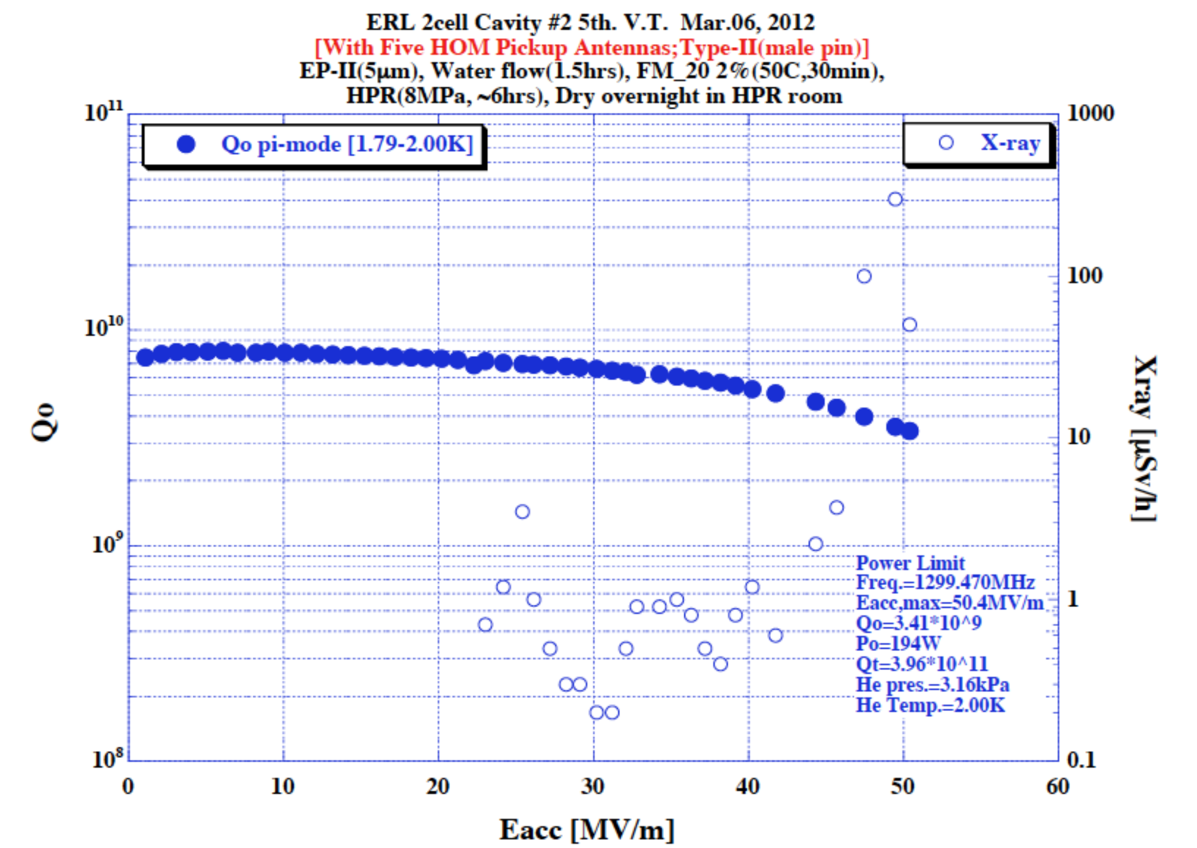
5 coaxial HOM couplers for one cavity

Input coupler (double feed) 167kW/coupler

Cavity : 3 x 2-cell cavities
Slide-Jack tuner and piezo tuner





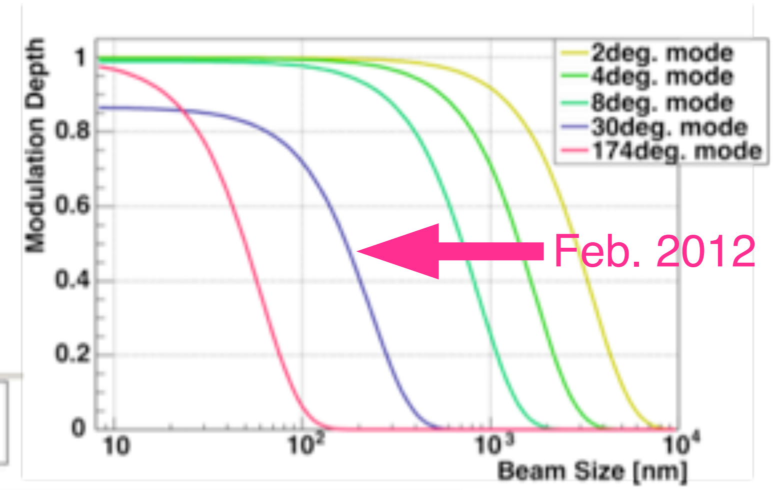


To be installed in
KEK cERL injection beam line

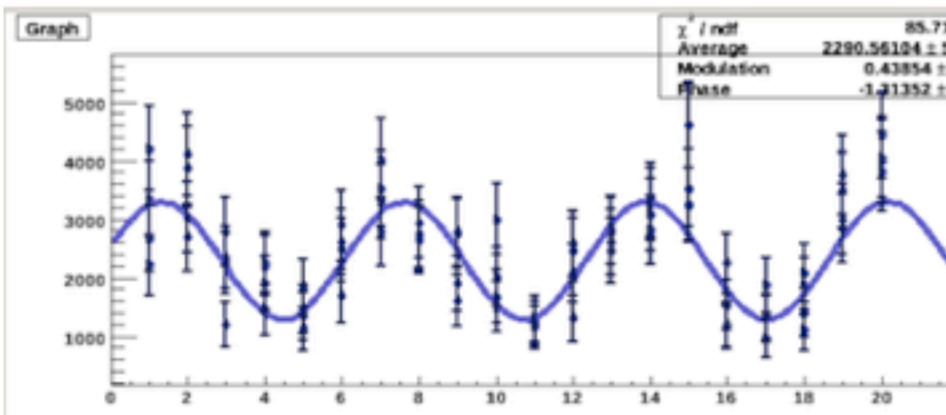
Accelerator Systems

- BDS
  - ATF recovery after “earth quake” in 2011
- Damping Ring
- e^+ source
- RTML and ML beam dynamics

ATF2 status after earthquake recovery



Commissioning of 30 deg mode



σ_y^* = 201 ± 4.4 (stat.) nm

M_{meas} = 0.429 ± 0.012 (stat.)

From 10 stable consecutive scans
30 deg, Feb 17, 2012
(10 β^*_x x 10 β^*_y optics)

largest M_{meas} = 0.522 ± 0.042 ←→ $\sigma_{y,meas}$ ~ 165 nm

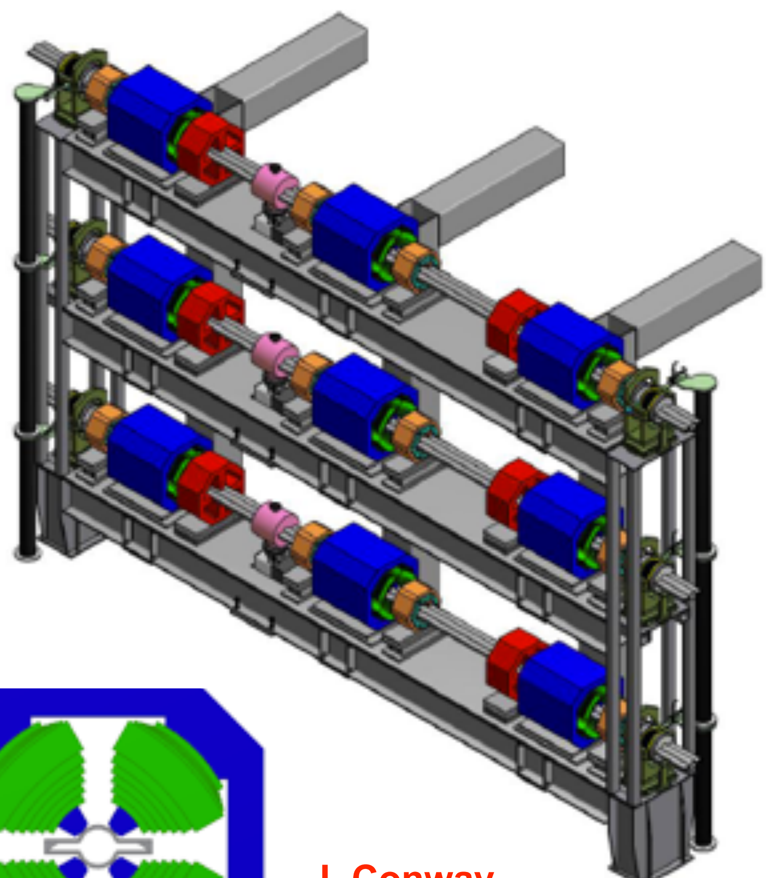
2/17: 30 deg	M	ΔM	σ_y^*	$\Delta\sigma_y^*$	avg E_{sig}/ ICT [GeV / 10^9e]
18:07	0.426	0.039	194.98	6.21	2.359
18:09	0.390	0.043	206.63	6.48	2.403
18:12	0.433	0.036	192.55	5.73	2.269
18:14	0.439	0.034	190.82	5.49	2.290
18:16	0.437	0.038	191.29	6.16	2.303
18:18	0.460	0.040	183.86	6.78	2.267
18:20	0.444	0.035	189.20	5.77	2.450
18:22	0.39	0.042	206.67	6.902	2.292
18:24	0.453	0.037	186.17	6.203	2.356
18:26	0.389	0.042	207.029	6.205	2.360

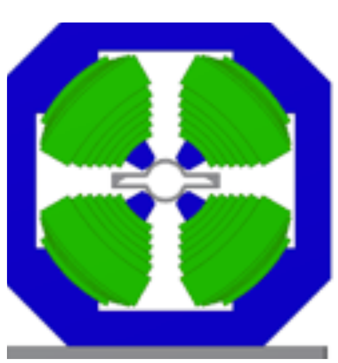
- *S/N : 4 – 5*
- *Signal jitter ~ 22%*
- *BG fluc. ~ 15%*

stable beam current

Damping rings

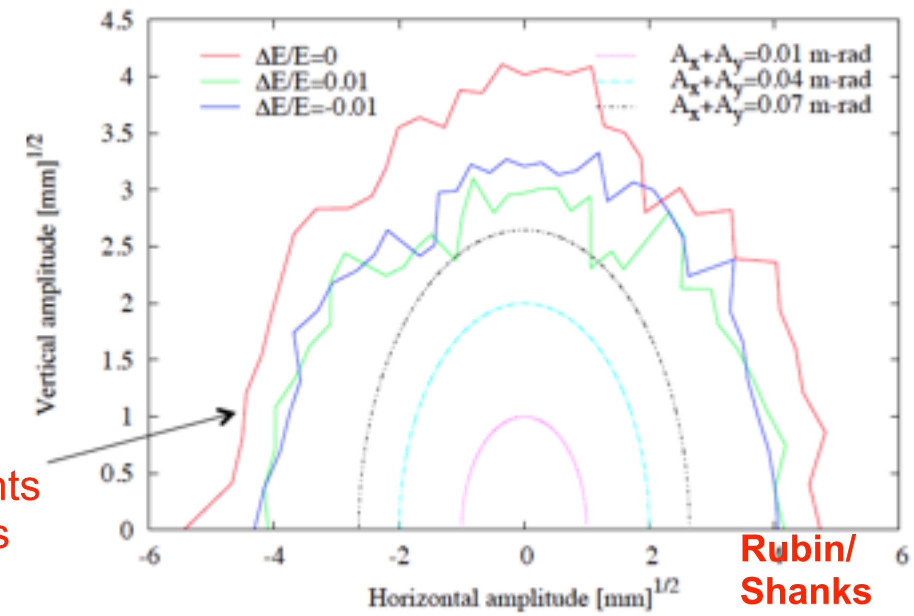
- DTC04 Lattice Evaluations
- Magnet Design & Layout Review





J. Conway
C. Spencer

DA with misalignments & field errors



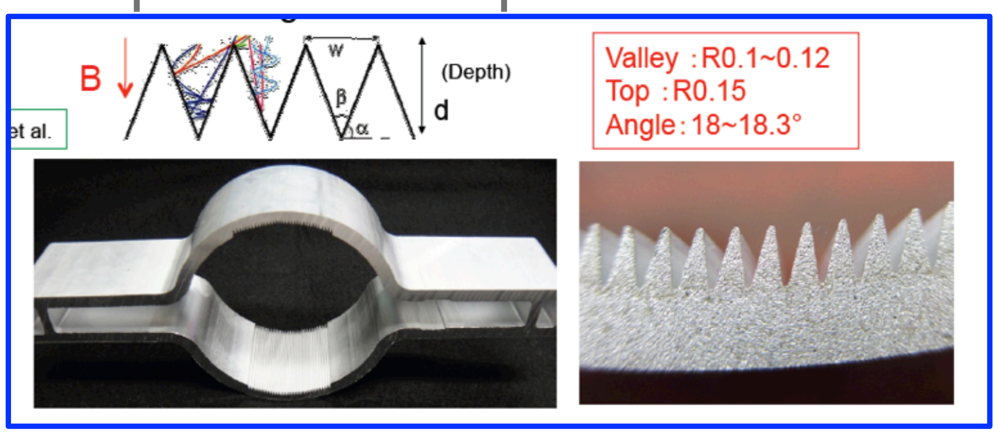
Rubin/ Shanks

Parameter	RMS
BPM – Differential resolution	2 µm
BPM – Absolute resolution	100 µm
BPM – Tilt	10 mrad
BPM button – Gain variation	1%
Quads + Sexts – Offset (H+V)	50 µm
Quads – Tilt	100 µrad
Dipole – Roll	100 µrad
Wiggler – Offset (V only)	200 µm
Wiggler - Roll	200 µrad

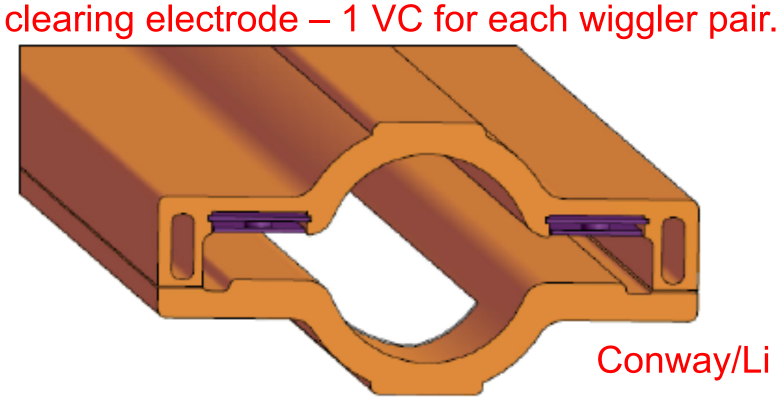
Ring Tolerances Evaluation for ε_y=2 pm using current LET Algos

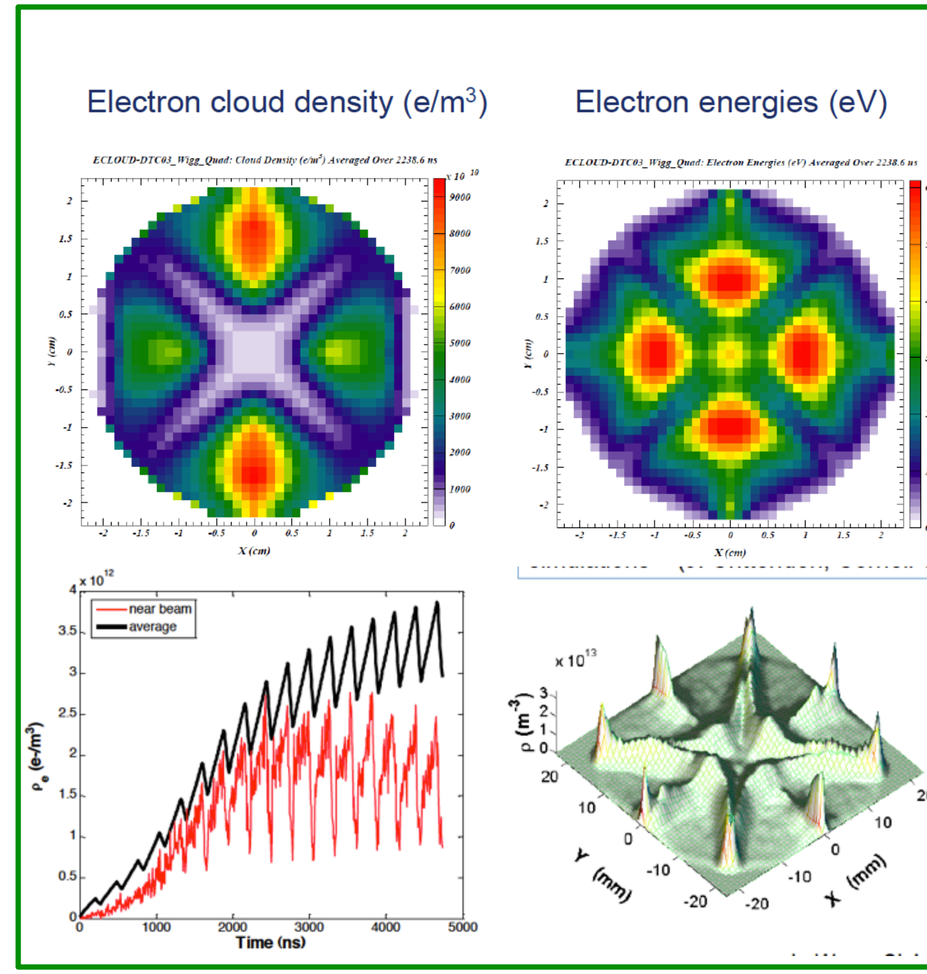
Damping rings cont'd

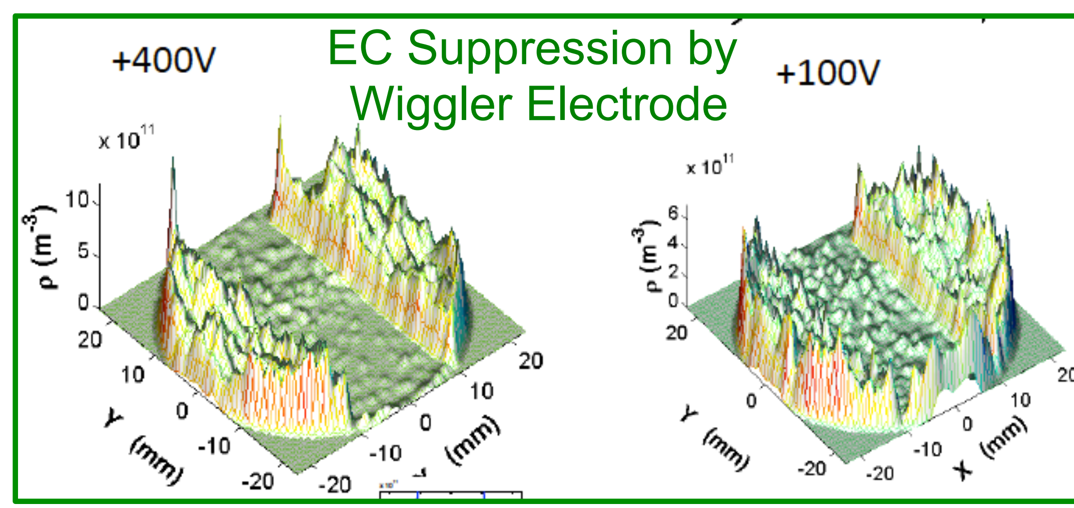
- EC Mitigations & Status
- Vacuum System Design/Costing
  - SuperKEKB VCs in production with similar designs to ILC DR
- SuperKEKB Dipole Chamber



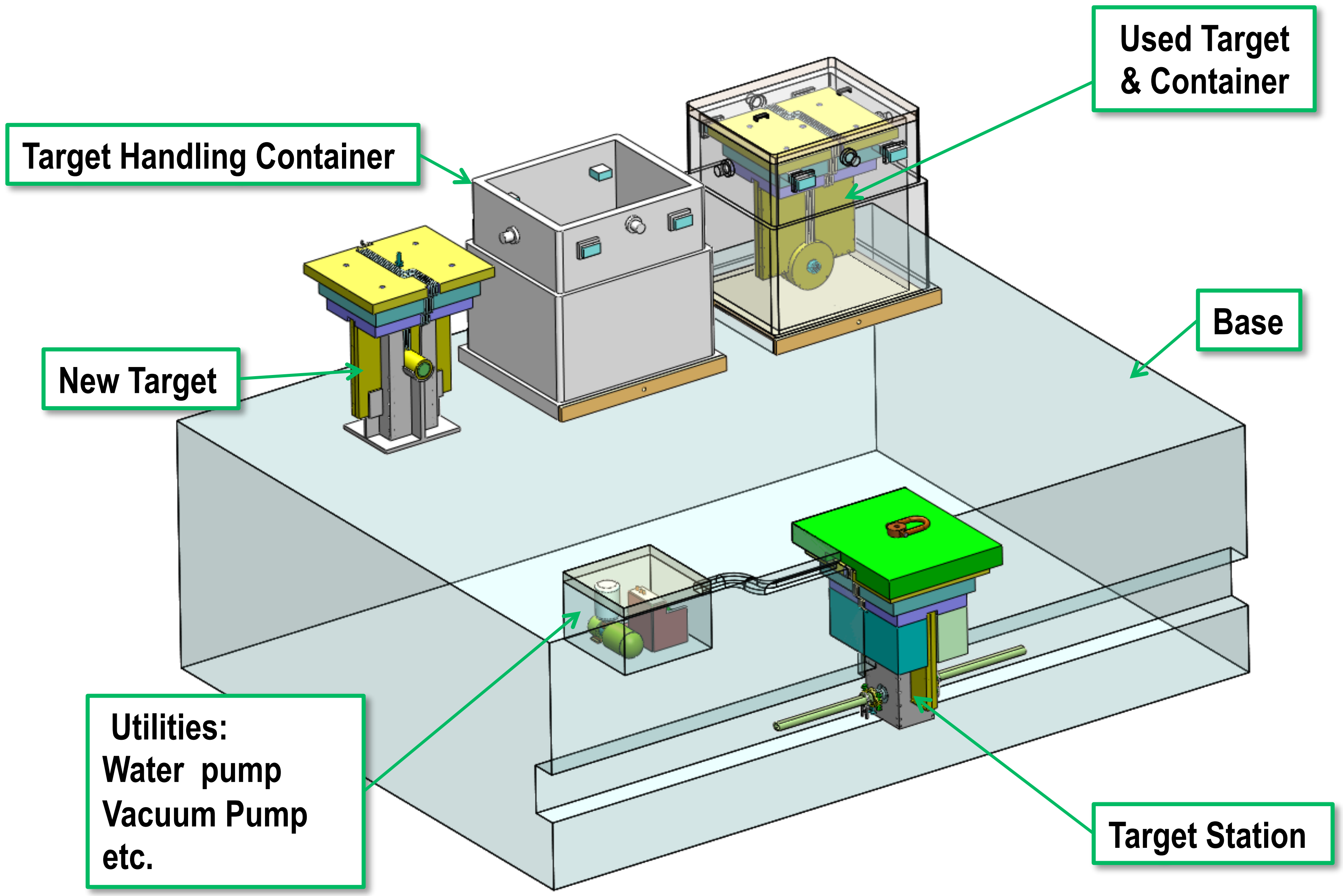
DR Wiggler chamber concept with thermal spray clearing electrode – 1 VC for each wiggler pair.





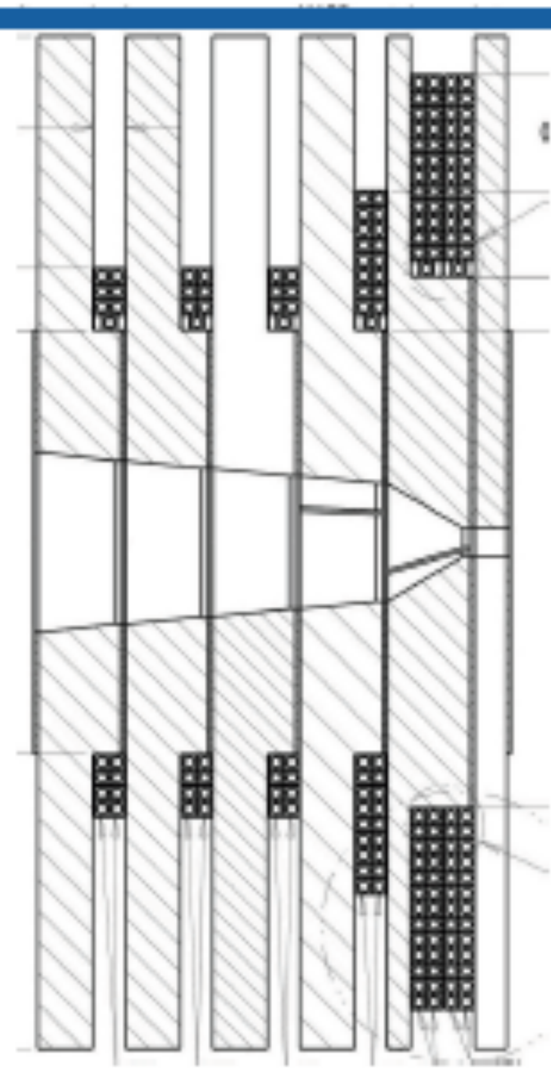


Layout for Remote Target Handling



Positron capture

Water cooling and room temperature greatly simplifies the design



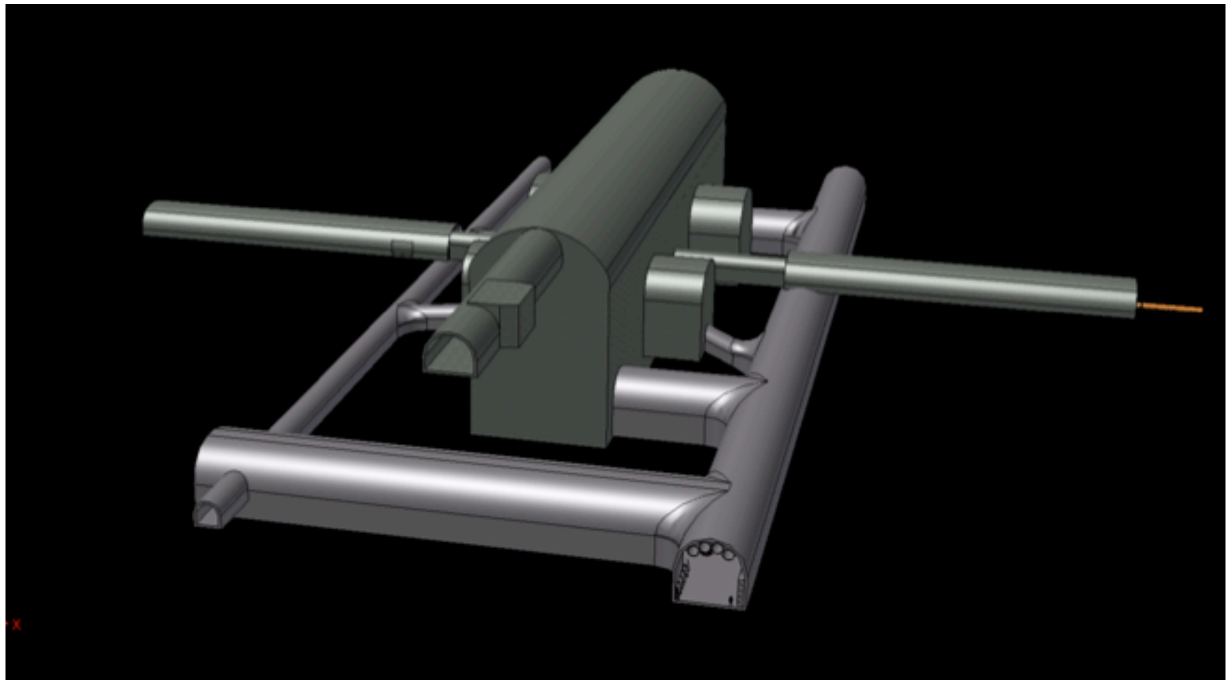
- Device sits in the vacuum
- All power and cooling connections move to the rim
  - Coils are kapton wound, hollow copper, water cooled
  - Plates are OFHC copper with water cooling pipes soldered in
  - Only metal in the high radiation areas
- Plates and coils stack and bolt together

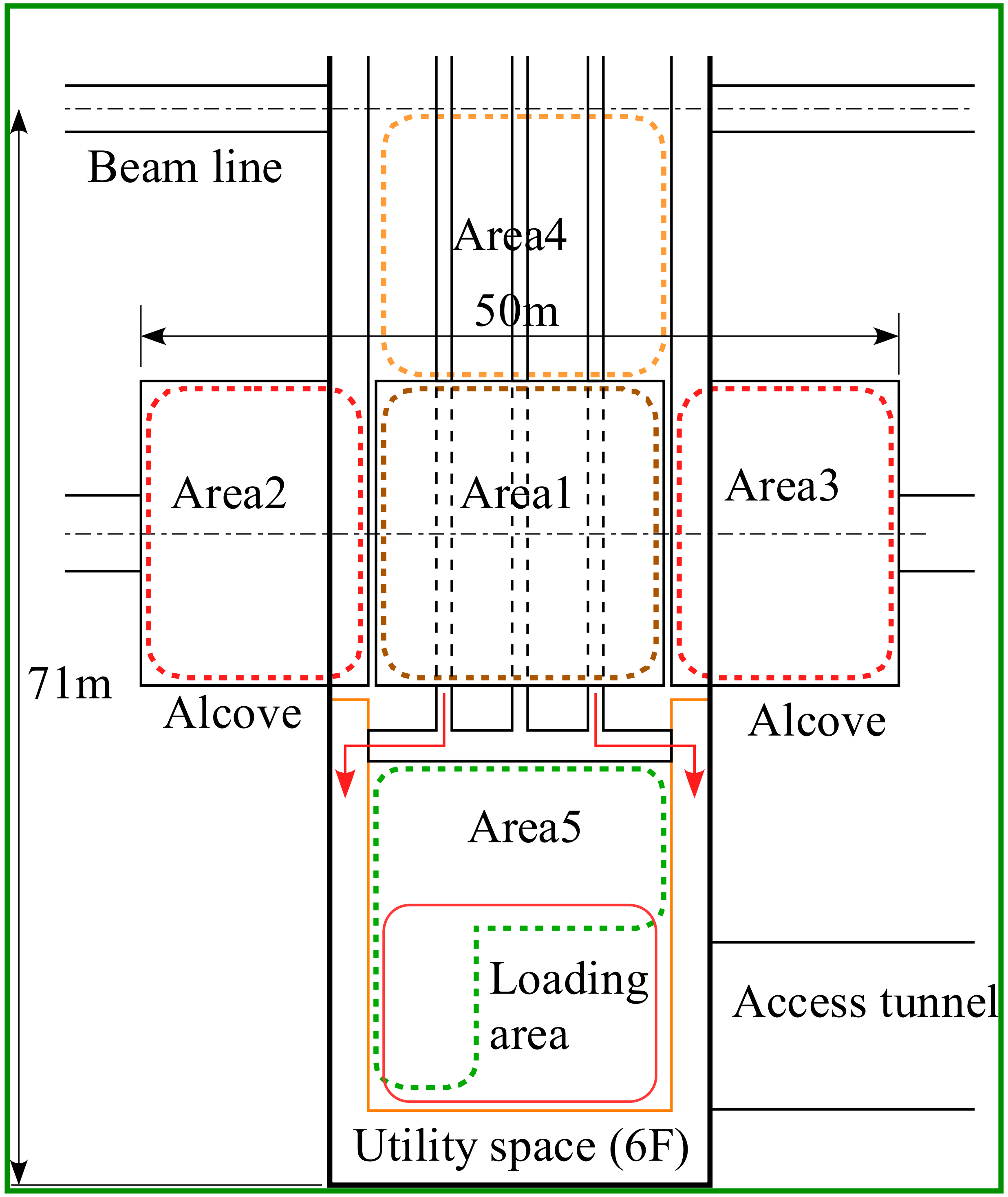
ILC Baseline parameters

Centre-of-mass energy	E_{CM}	GeV	200	230	250	350	500
Luminosity pulse repetition rate		Hz	5	5	5	5	5
Positron production mode			10 Hz	10 Hz	10 Hz	nom.	nom.
Bunch population	N	$\times 10^{10}$	2	2	2	2	2
Number of bunches	n_b		1312	1312	1312	1312	1312
Linac bunch interval	Δt_b	ns	554	554	554	554	554
RMS bunch length	σ_z	μm	300	300	300	300	300
Normalized horizontal emittance at IP	$\gamma\epsilon_x$	μm	10	10	10	10	10
Normalized vertical emittance at IP	$\gamma\epsilon_y$	nm	35	35	35	35	35
Horizontal beta function at IP	β_x^*	mm	16	14	13	16	11
Horizontal beta function at IP	β_y^*	mm	0.34	0.38	0.41	0.34	0.48
RMS horizontal beam size at IP	σ_x^*	nm	904	789	729	684	474
RMS horizontal beam size at IP	σ_y^*	nm	7.8	7.7	7.7	5.9	5.9
Vertical disruption parameter	D_y		24.3	24.5	24.5	24.3	24.6
Fractional RMS energy loss to beamstrahlung	δ_{BS}	%	0.65	0.83	0.97	1.9	4.5
Luminosity	L	$\times 10^{34}\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$	0.56	0.67	0.75	1.0	1.8
Fraction of L in top 1% E_{CM}	$L_{0.01}$	%	91	89	87	77	58
Electron polarisation	P_-	%	80	80	80	80	80
Positron polarisation	P_+	%	30	30	30	30	30
Electron relative energy spread at IP	$\Delta p/p$	%	0.20	0.19	0.19	0.16	0.13
Positron relative energy spread at IP	$\Delta p/p$	%	0.19	0.17	0.15	0.10	0.07

Detector Hall

- Cost
- Alignment
- Cryogenc systems

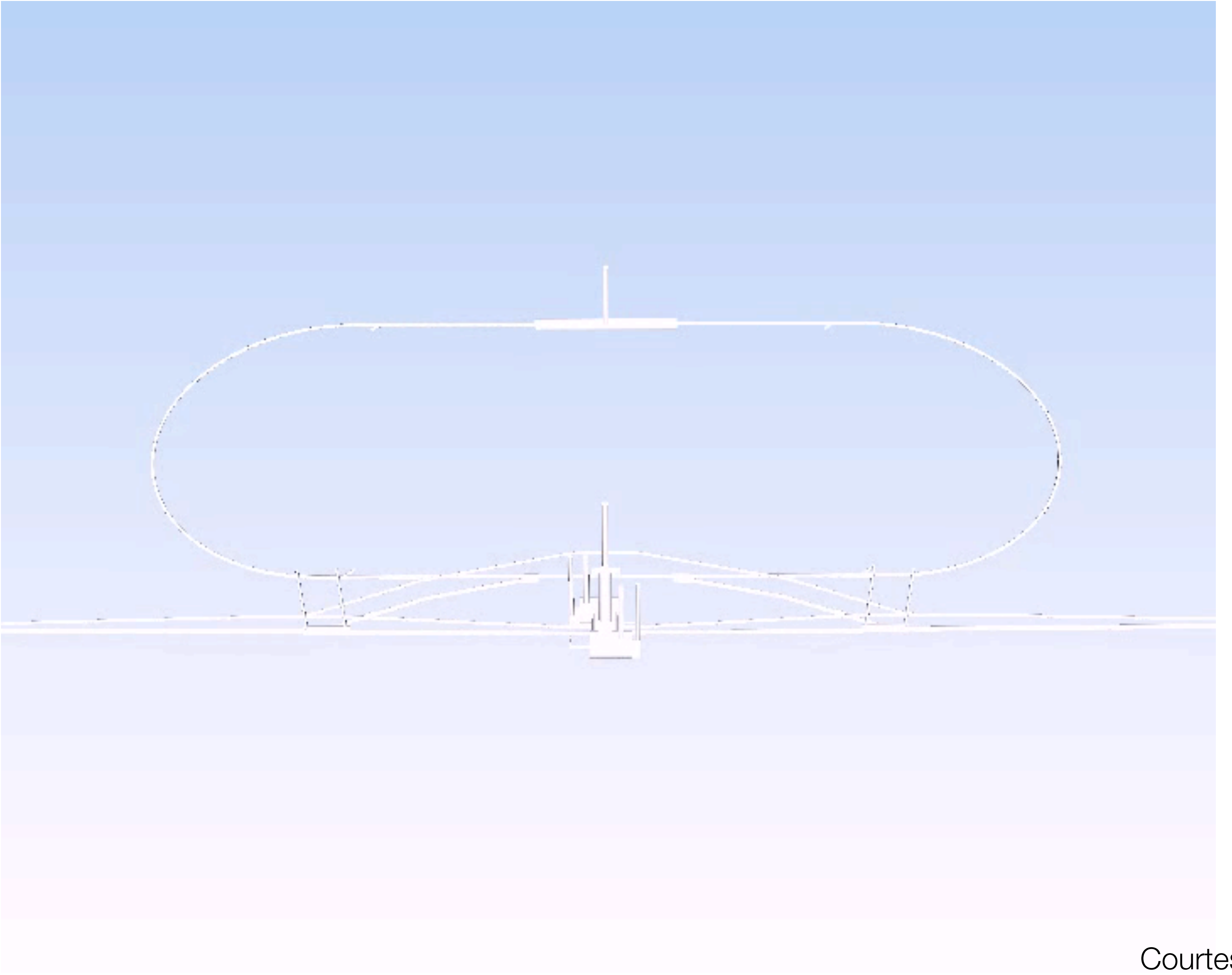




ILC Layout for TDR

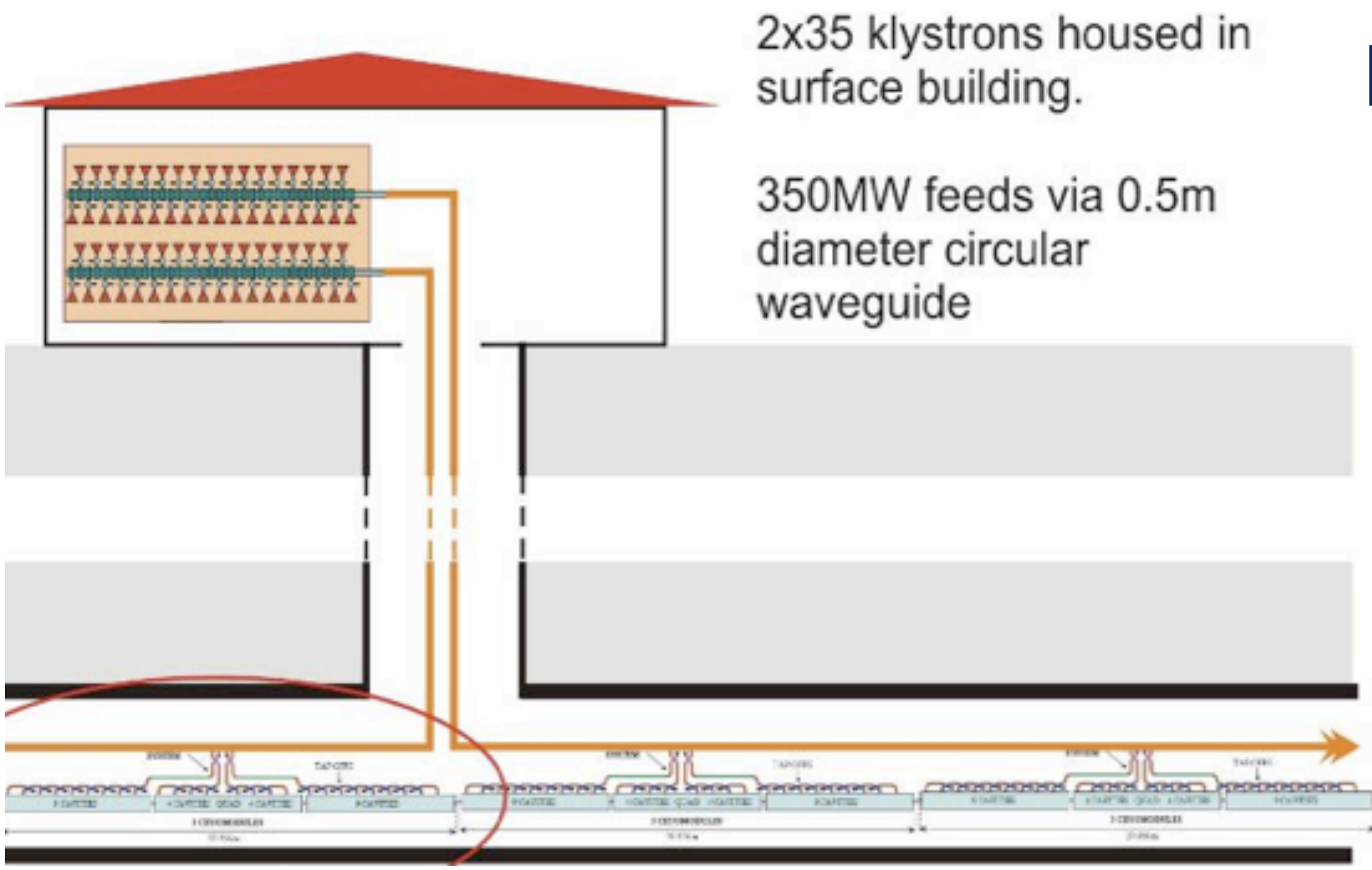
Courtesy B. List

ILC Layout for TDR

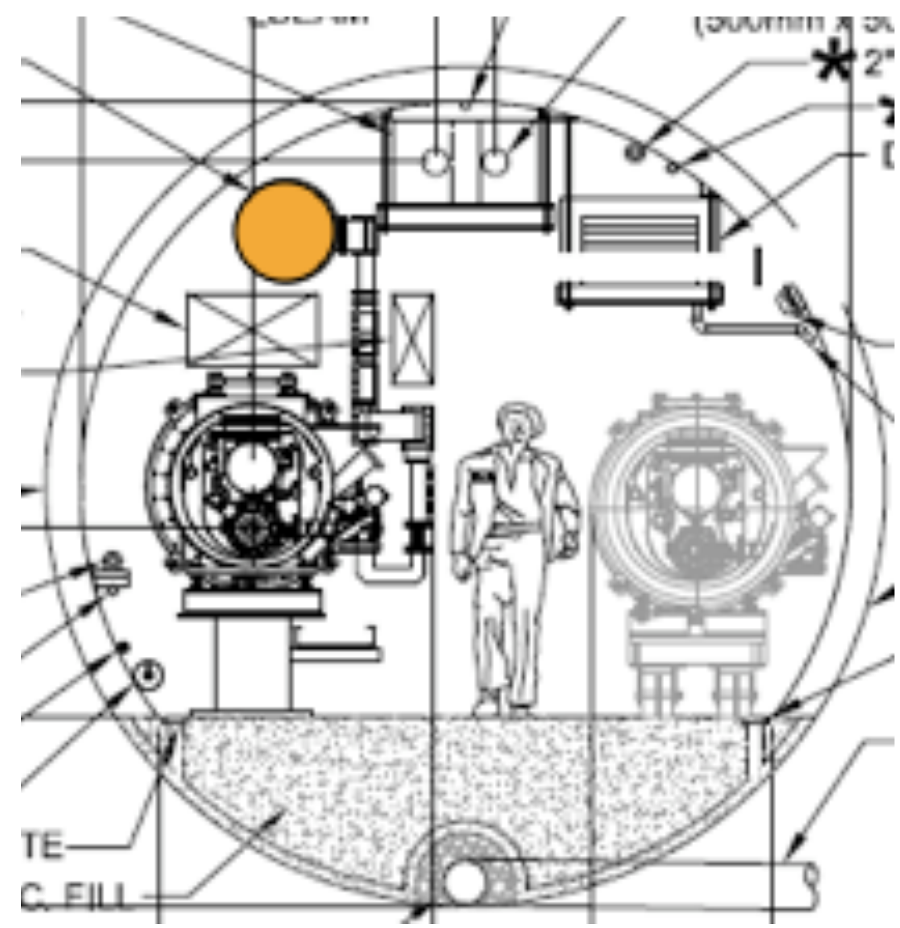


Courtesy B. List

rf distribution



Klystron Cluster Scheme (SLAC)

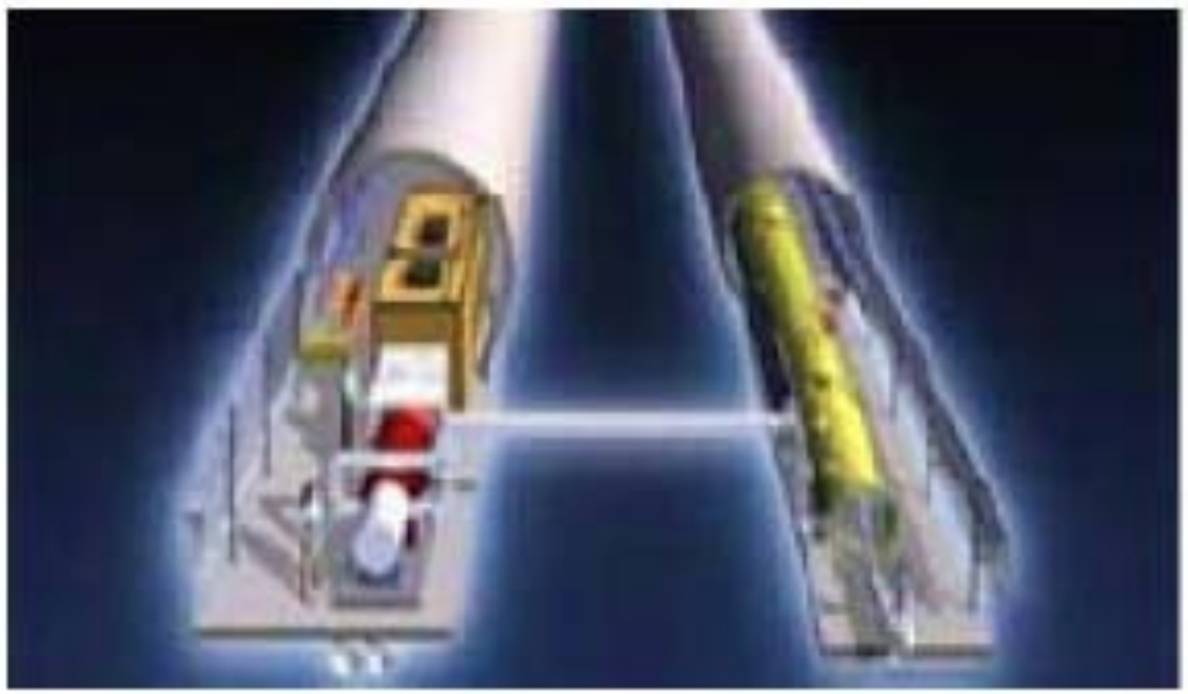


suitable for single tunnel layout

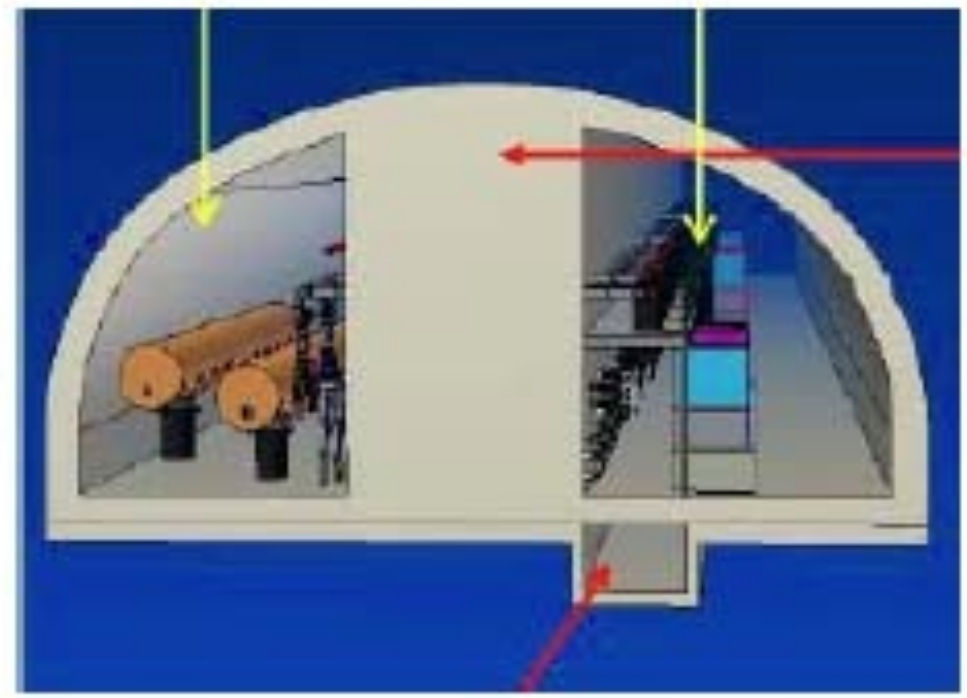
Two Japanese candidate sites

New tunnel shape - suitable for Japan

RDR two tunnel design (2007)

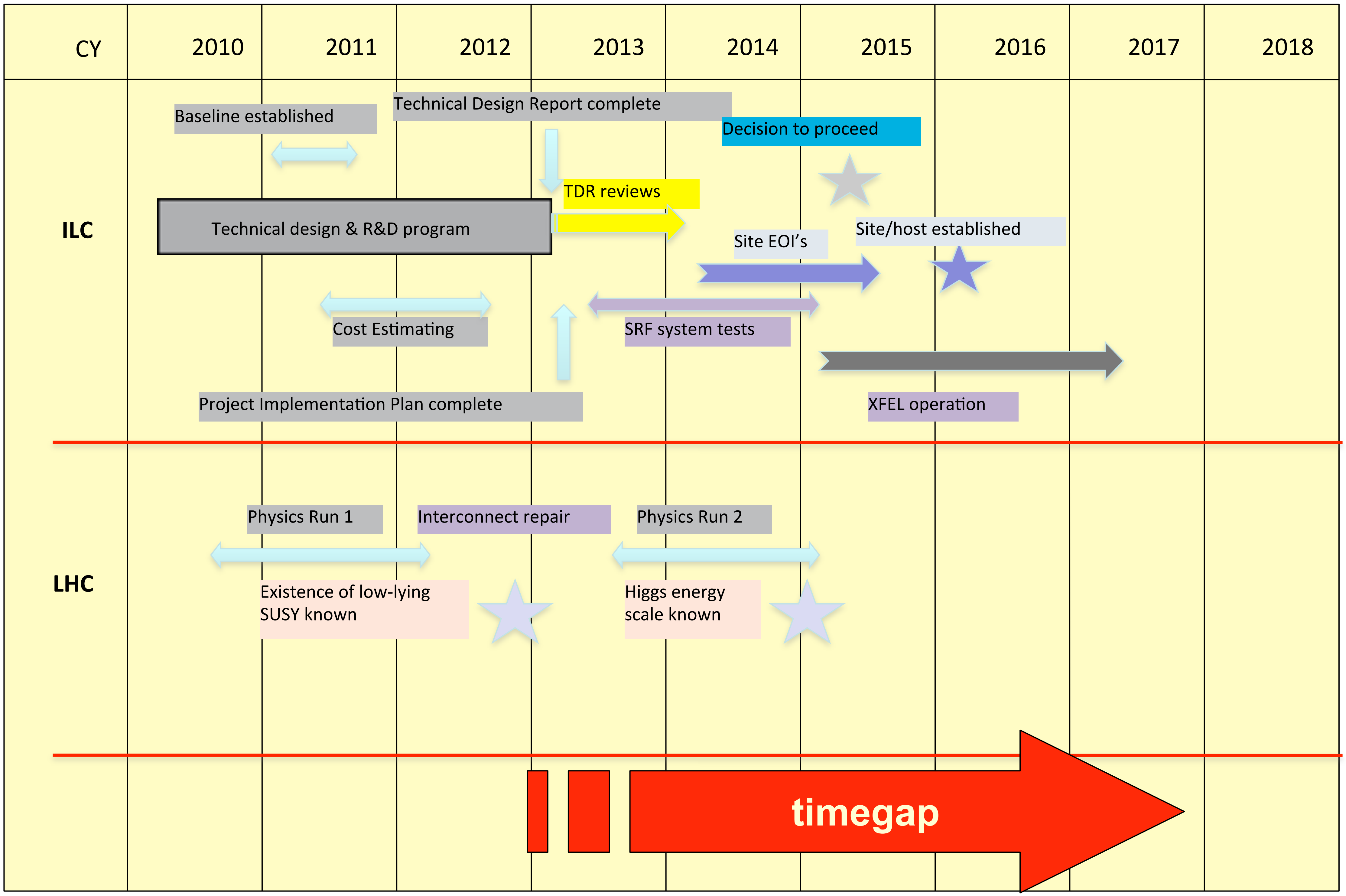


TDR mountain sites



- rf distribution à la TDR (similar to European XFEL)
    - 10 MW klystron attached to 2 cryomodules

ILC possible timelines



Summary ILC

- Design for a 500 GeV machine will be published by the end of 2012
    - $200 < \sqrt{s} < 500$ GeV with adequate luminosity
    - extendable to ~1 TeV,
      particularly with further progress in cavity gradient
    - including a cost update
        - not dissimilar to RDR value of 6.7bn ILCU (1 ILCU = $1 US on 1.1.2007)
        - GDE will use purchasing power index to relate exchange rate development in different regions

- Such a machine could be built today.