ILC:
The Machine

Brian Foster (Uni Hamburg/DESY/Oxford)

XXVI Lepton-Photon Symposium

San Francisco

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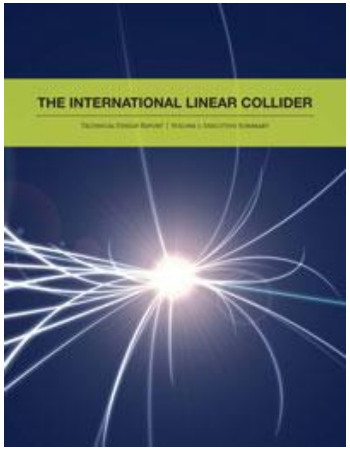
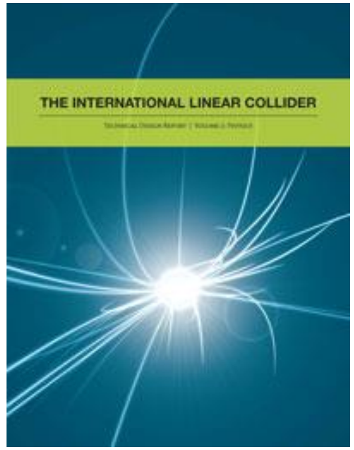
Acknowledgements & thanks – 100's of people whose work over > 10 years has brought the project to this stage; N. Walker in particular for preparing many slides for this talk.

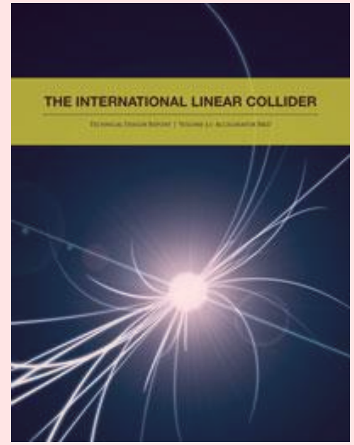
Unterstützt von / Supported by Alexander von Humboldt Stiftung/Foundation

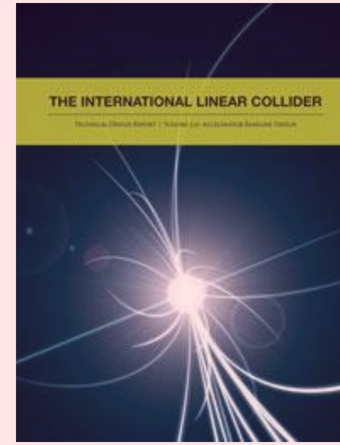
Introduction

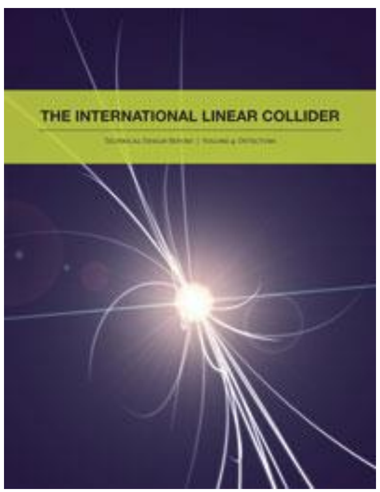
- On June 12th, ILC TDR was published in Worldwide Event.





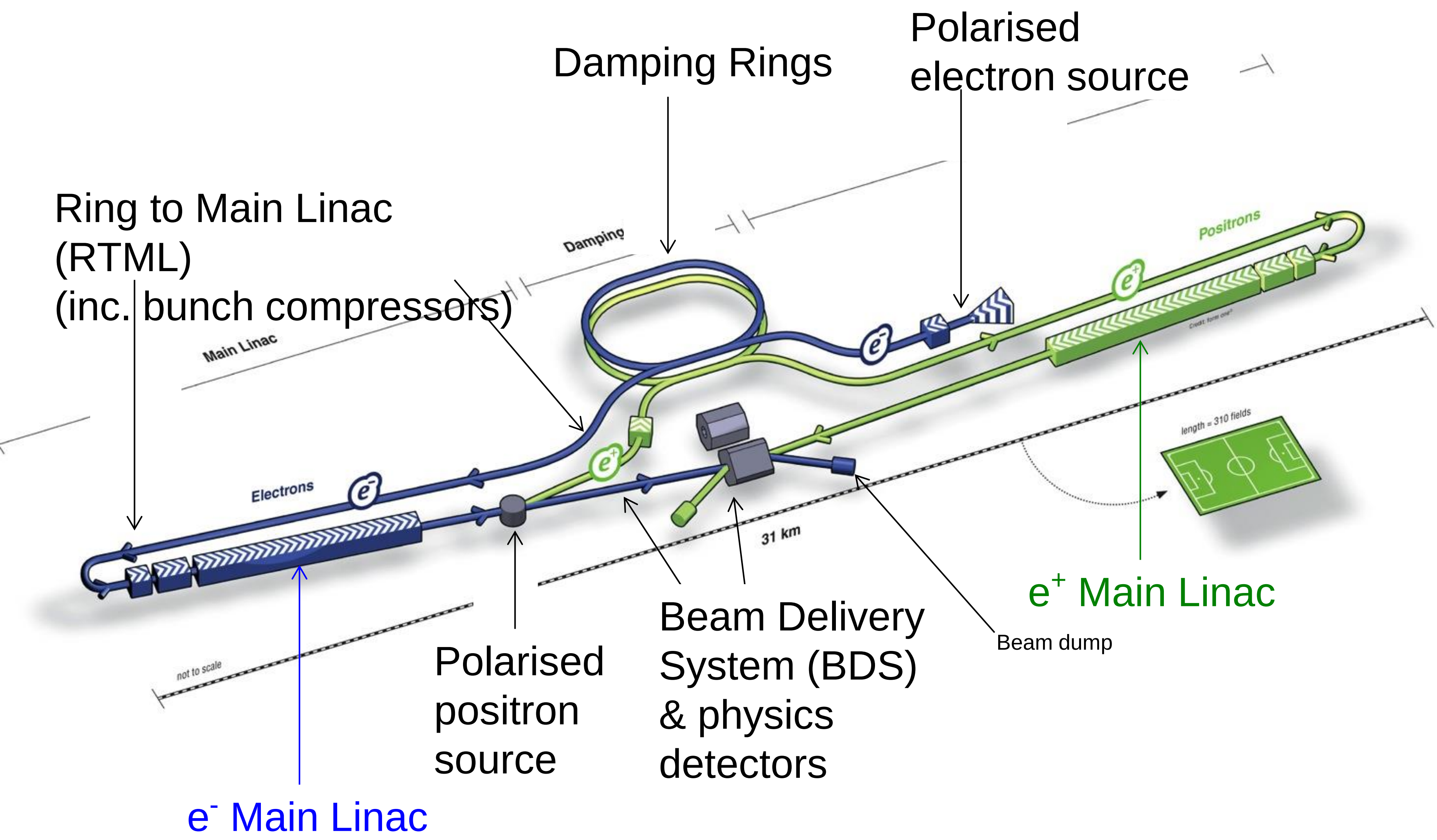






- I will attempt to summarise the machine part – 100s of person-years of work – in 25 minutes.

ILC Overview



not to scale

ILC Scheme | © www.form-one.de

500 GeV ILC Overview

Physics

Beam (interaction point)

structure)

Accelerator (general)

tiny emittances
nano-beams at IP
strong beam-beam

High-power high-current beams. Long bunch trains.
→ SCRF

Max. E_{cm}	500 GeV
Luminosity	1.8×10^{34} $cm^{-2}s^{-1}$
Polarisation (e-/e+)	80% / 30%
δ_{BS}	4.5%
σ_x / σ_y	574 nm / 6 nm
σ_z	300 μm
$\gamma\varepsilon_x$ / $\gamma\varepsilon_y$	10 μm / 35 nm
β_x / β_y	11 mm / 0.48 mm
bunch charge	2×10^{10}
Number of bunches / pulse	1312
Bunch spacing	554 ns
Pulse current	5.8 mA
Beam pulse length	727 μs
Pulse repetition rate	5 Hz
Average beam power	10.5 MW (total)
Total AC power	163 MW
(linacs AC power	107 MW)

SCRF Linac Technology

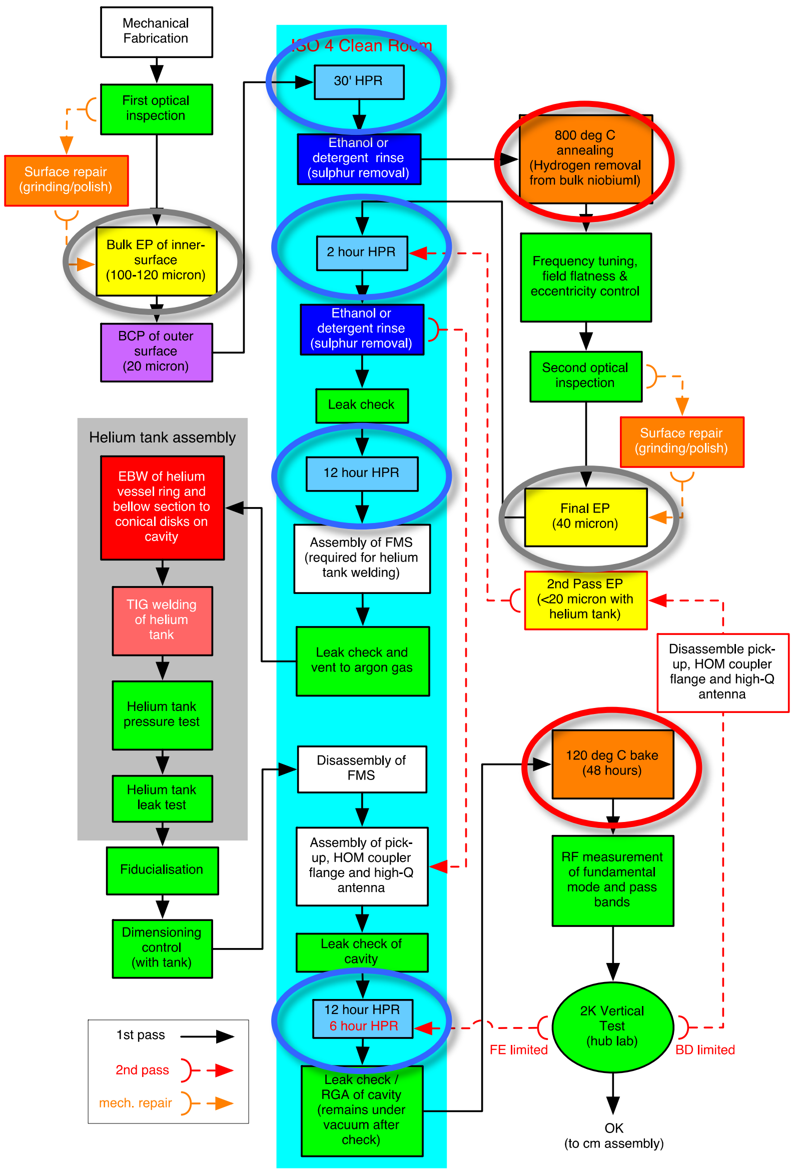
- solid niobium
- standing wave
- 9 cells
- operated at 2K (Lqd. He)
- 35 MV/m
- $Q_0 \geq 10^{10}$

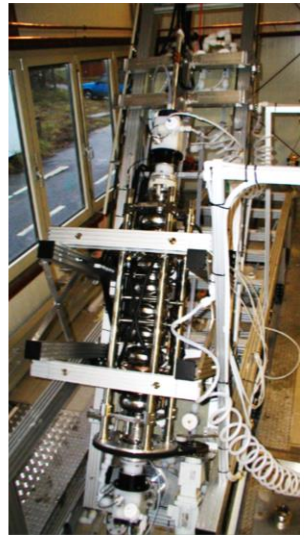
1.3 GHz Nb 9-cell Cavities	16,024
Cryomodules	1,855
SC quadrupole package	673
10 MW MB Klystrons & modulators	436 / 471*

* site dependent

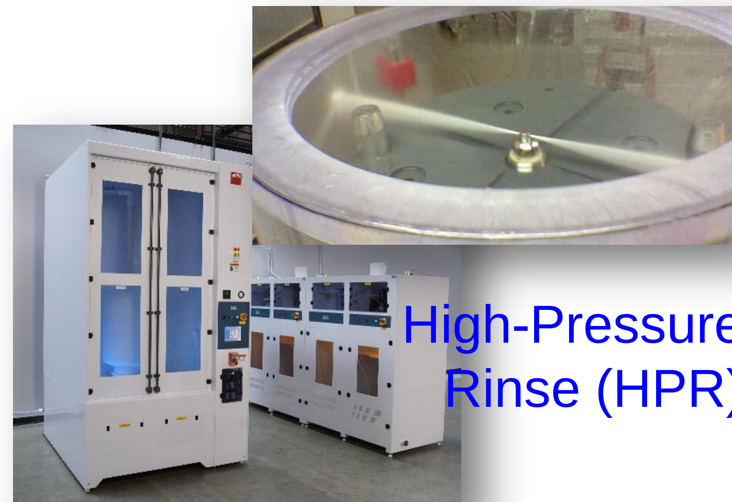
Approximately 20 years of R&D Worldwide → Mature technology

Road to High Performance





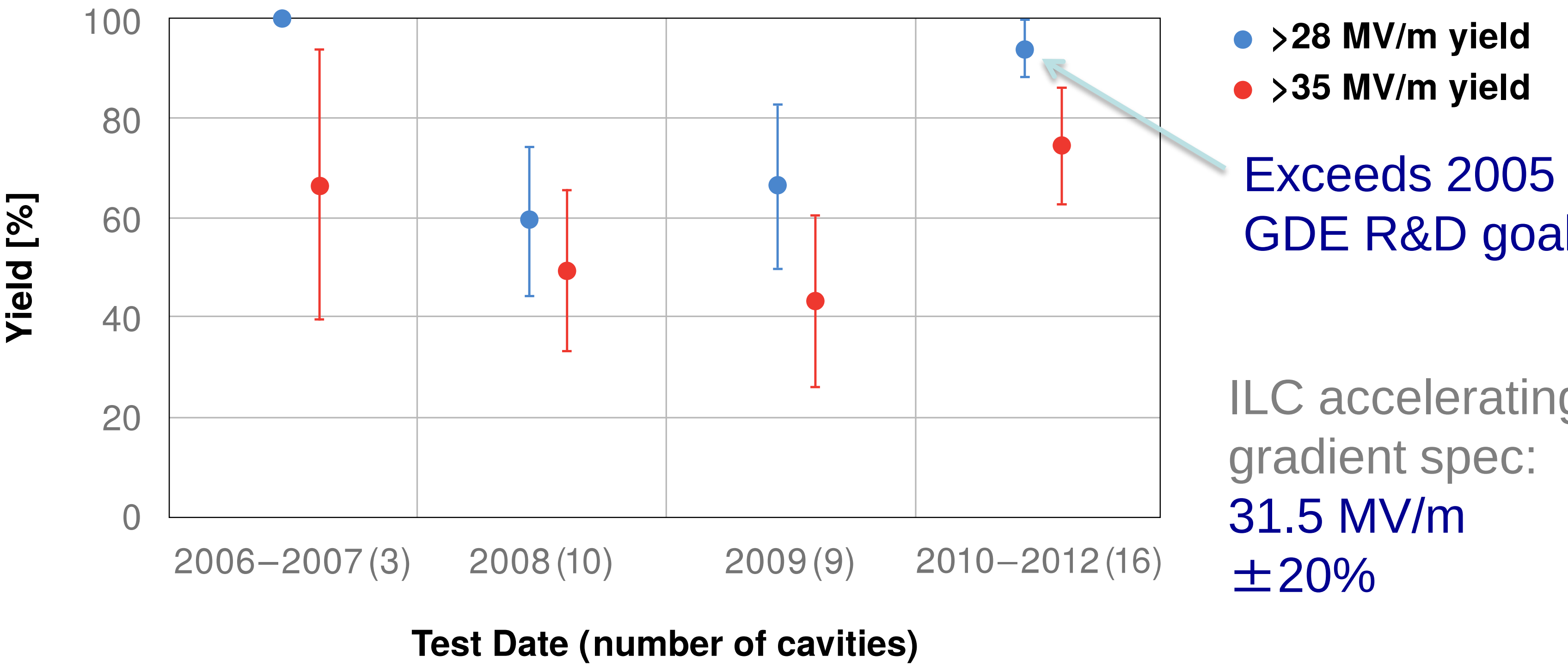
Electropolishing



High-Pressure Rinse (HPR)

800° C annealing and 120° C baking

Gradient performance worldwide

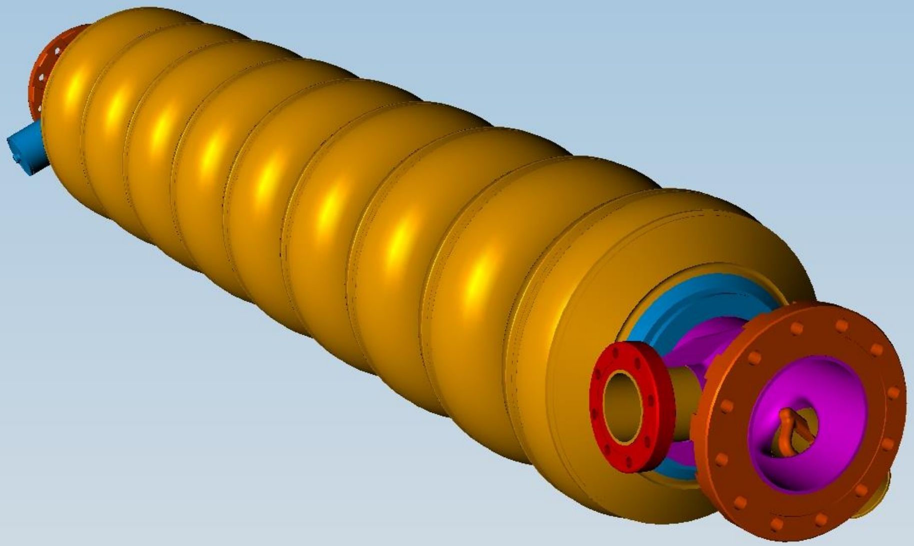


ILC accelerating gradient spec: 31.5 MV/m ±20%

GDE global database Asia – KEK; Europe – DESY; US – JLab, FNAL, ANL

Qualified cavity vendors Asia – 2; Europe – 2; US – 1

Cryomodule construction



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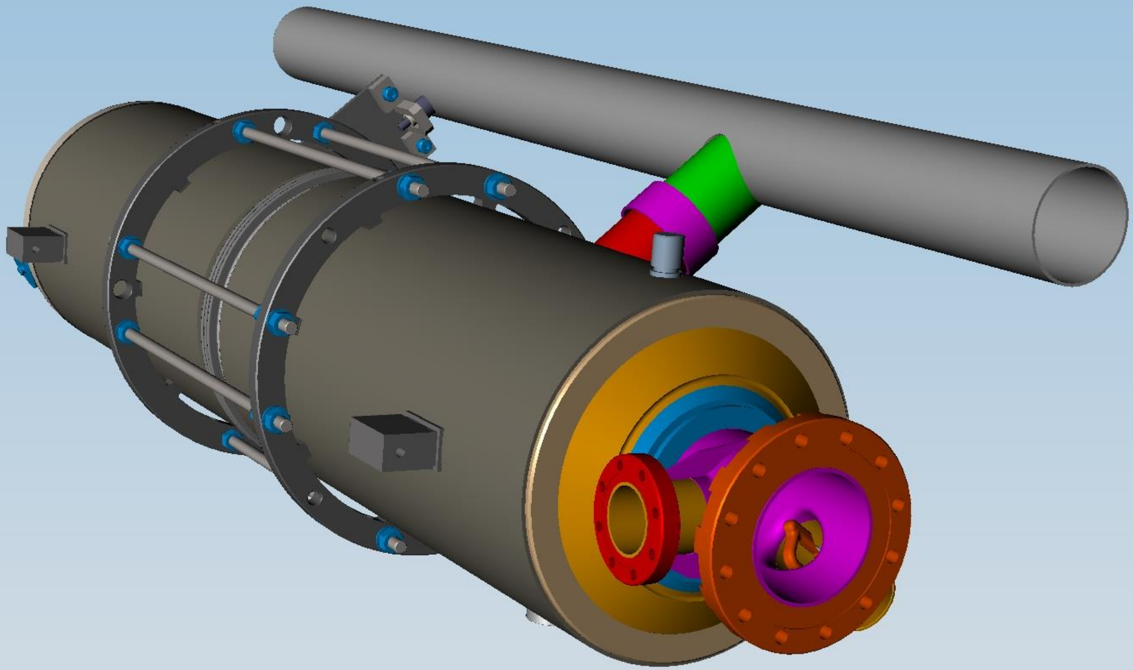

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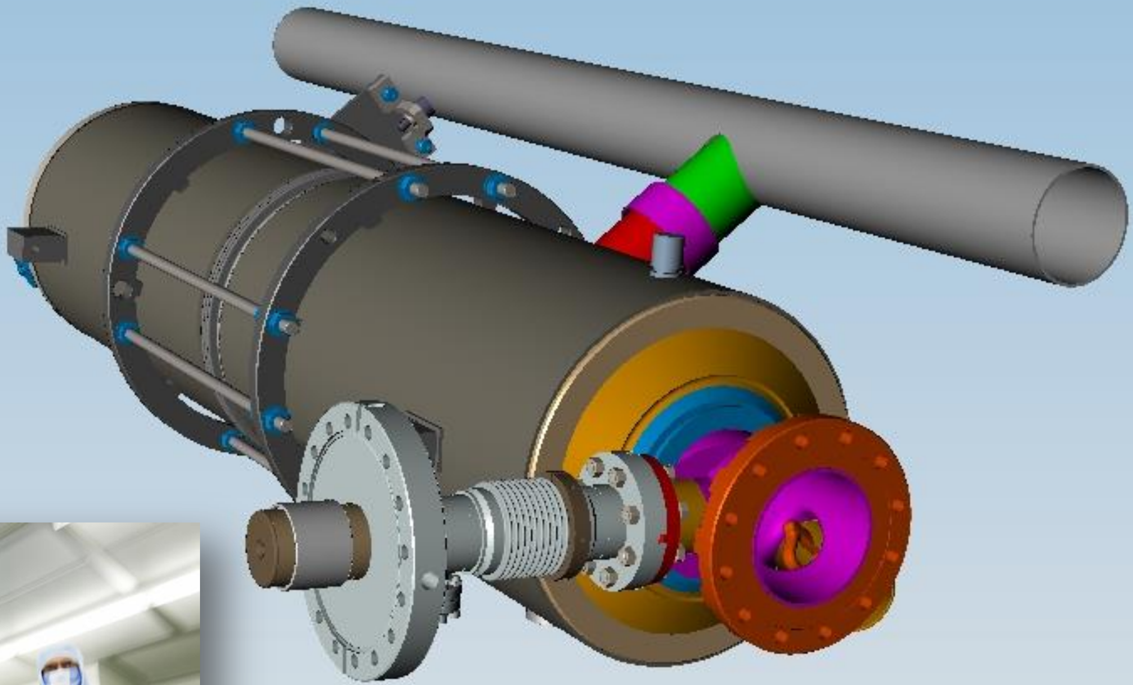

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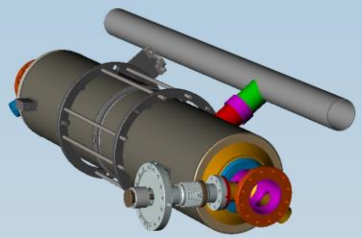

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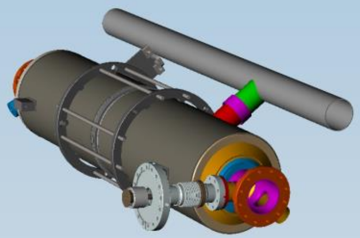

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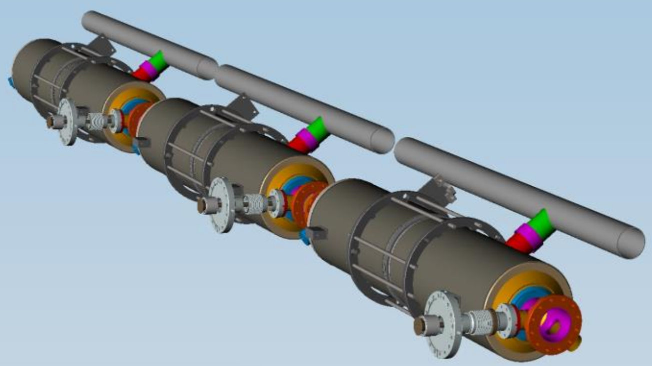

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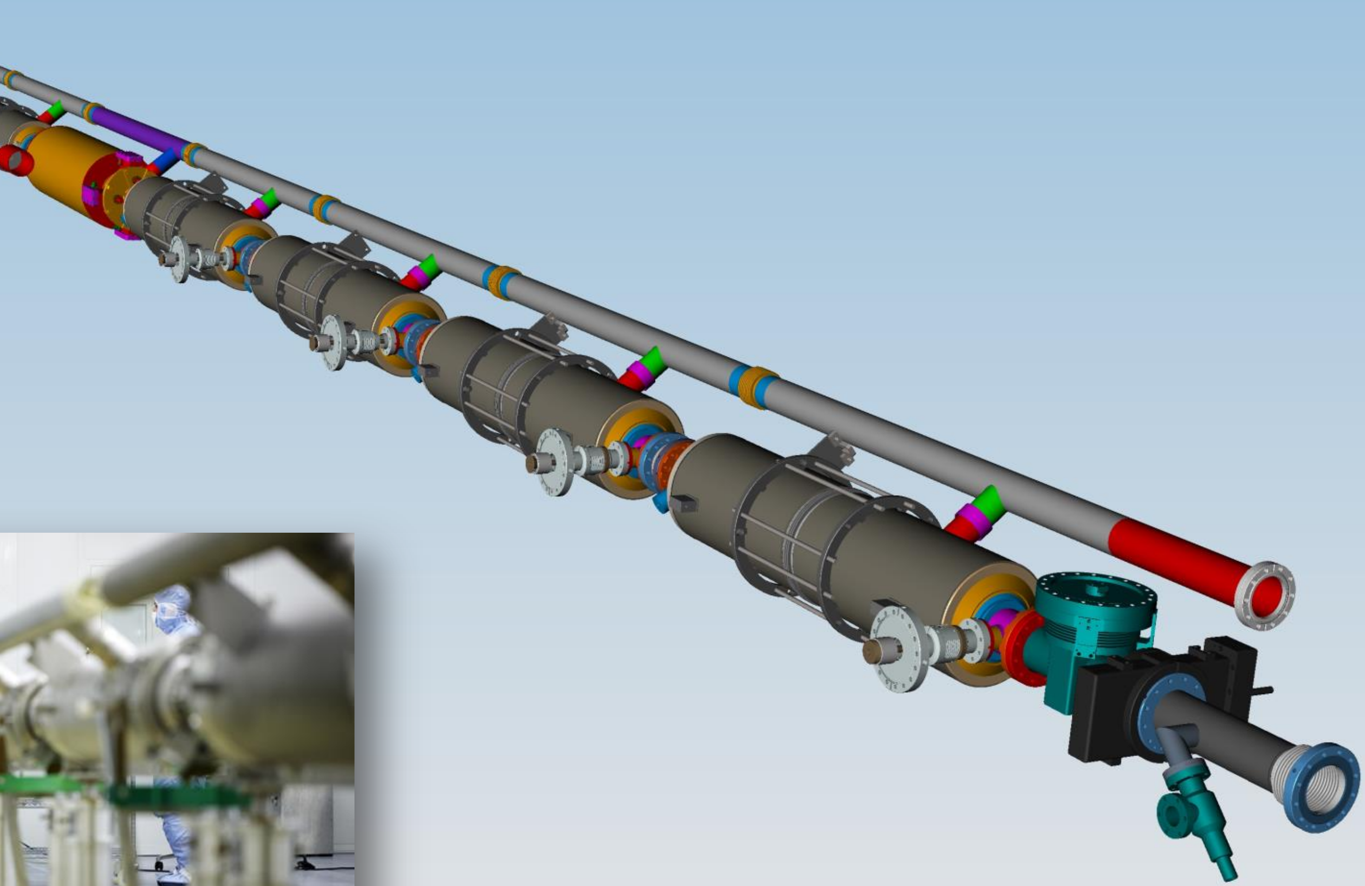

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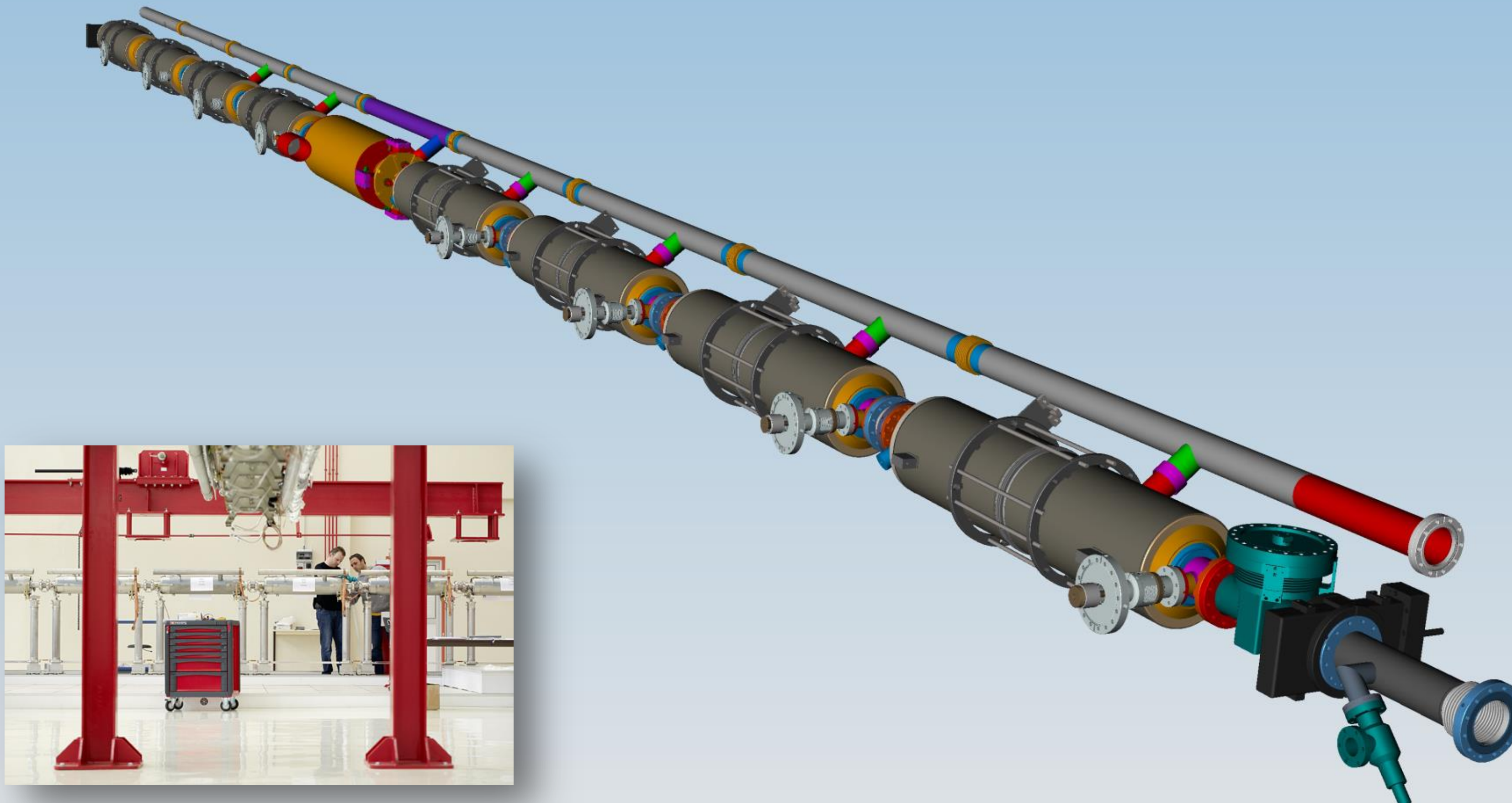

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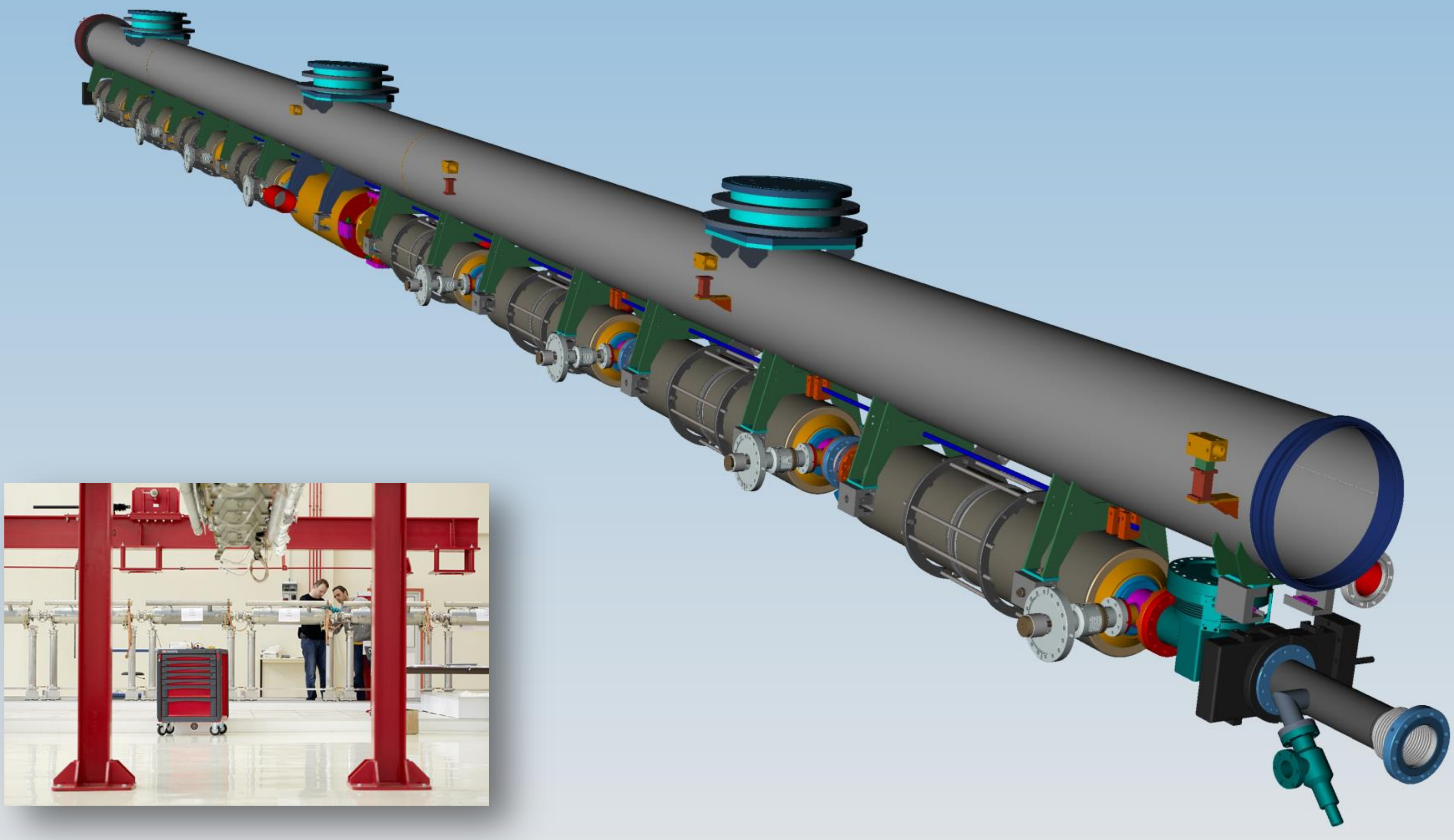

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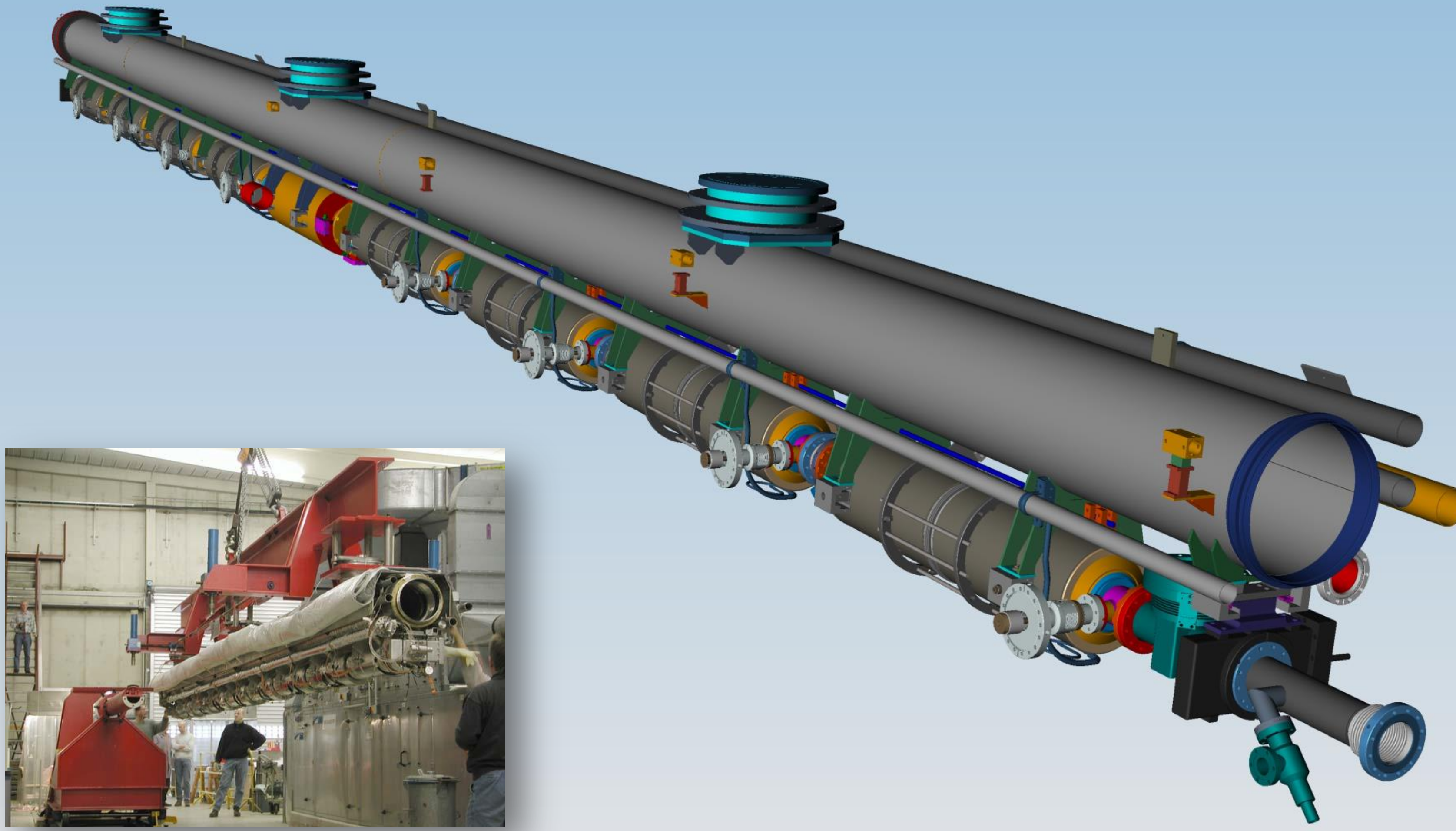
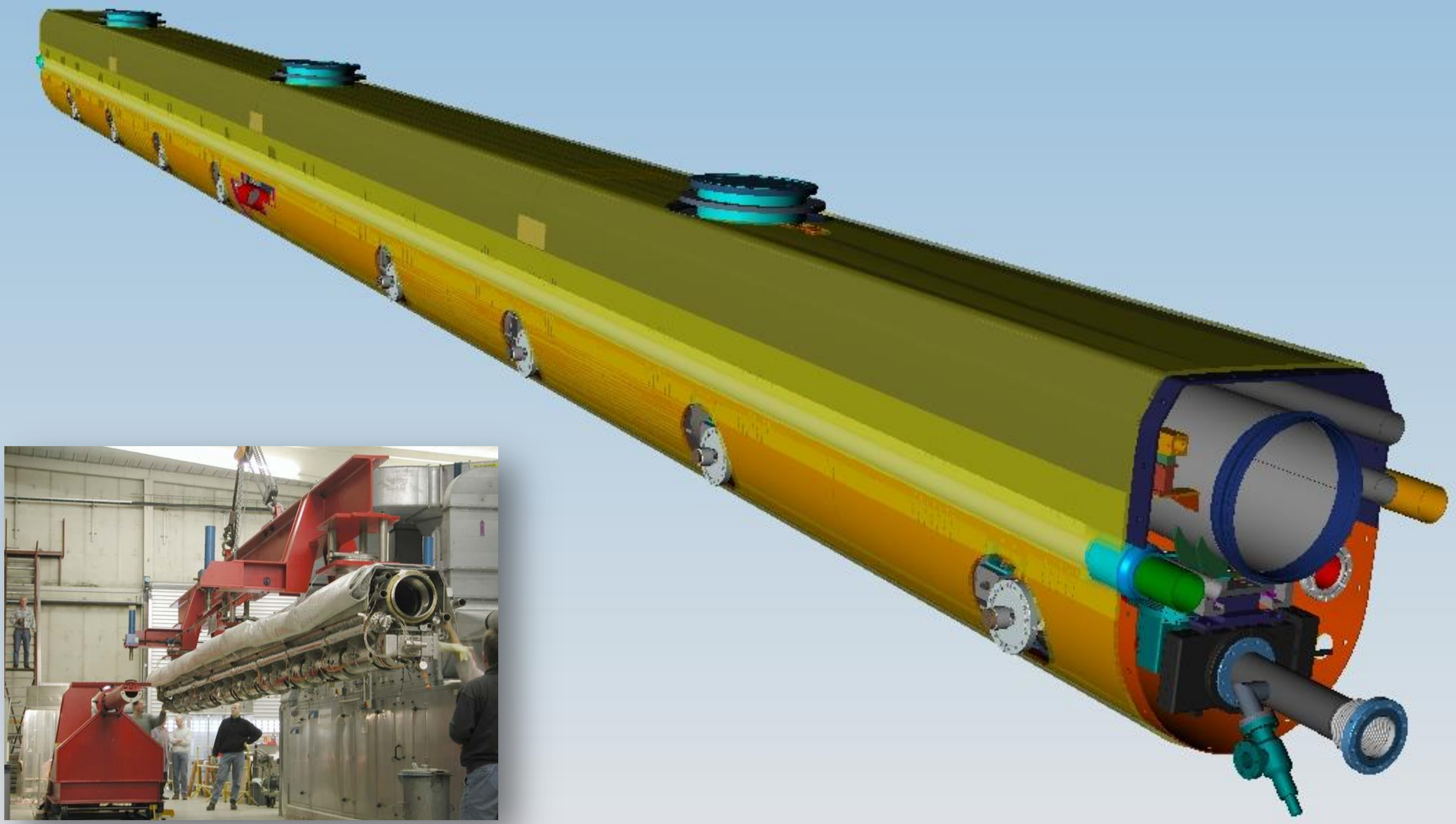


Cryomodule construction



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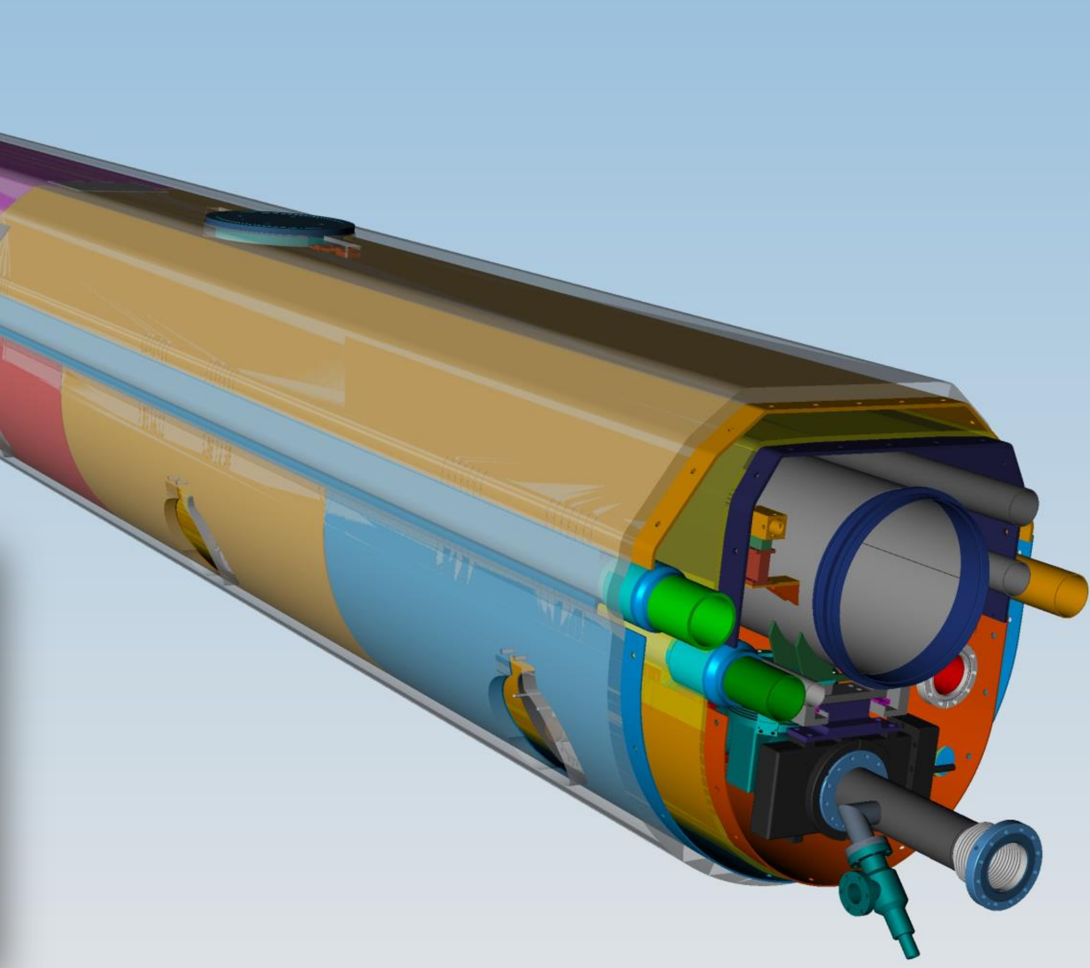

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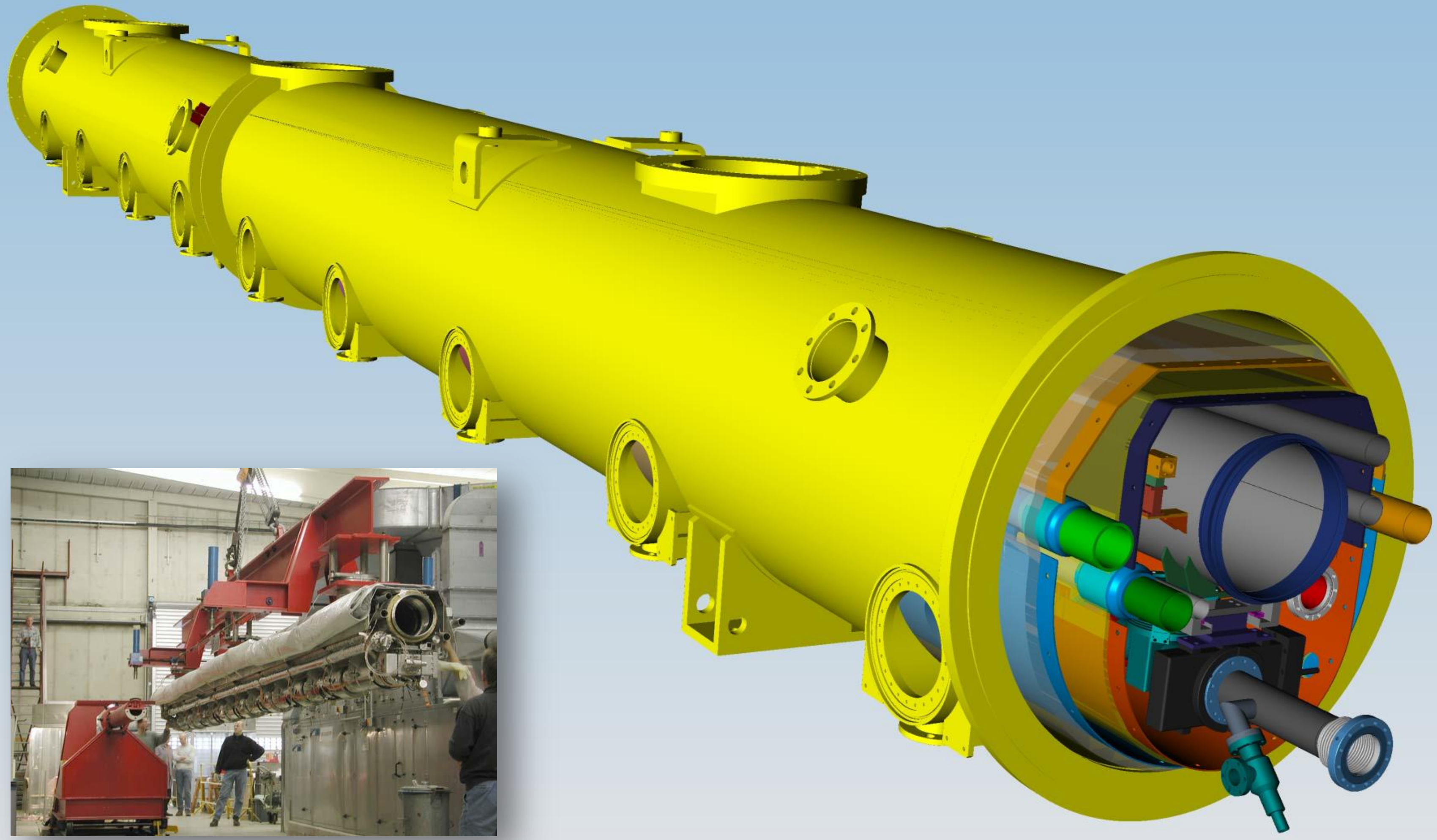

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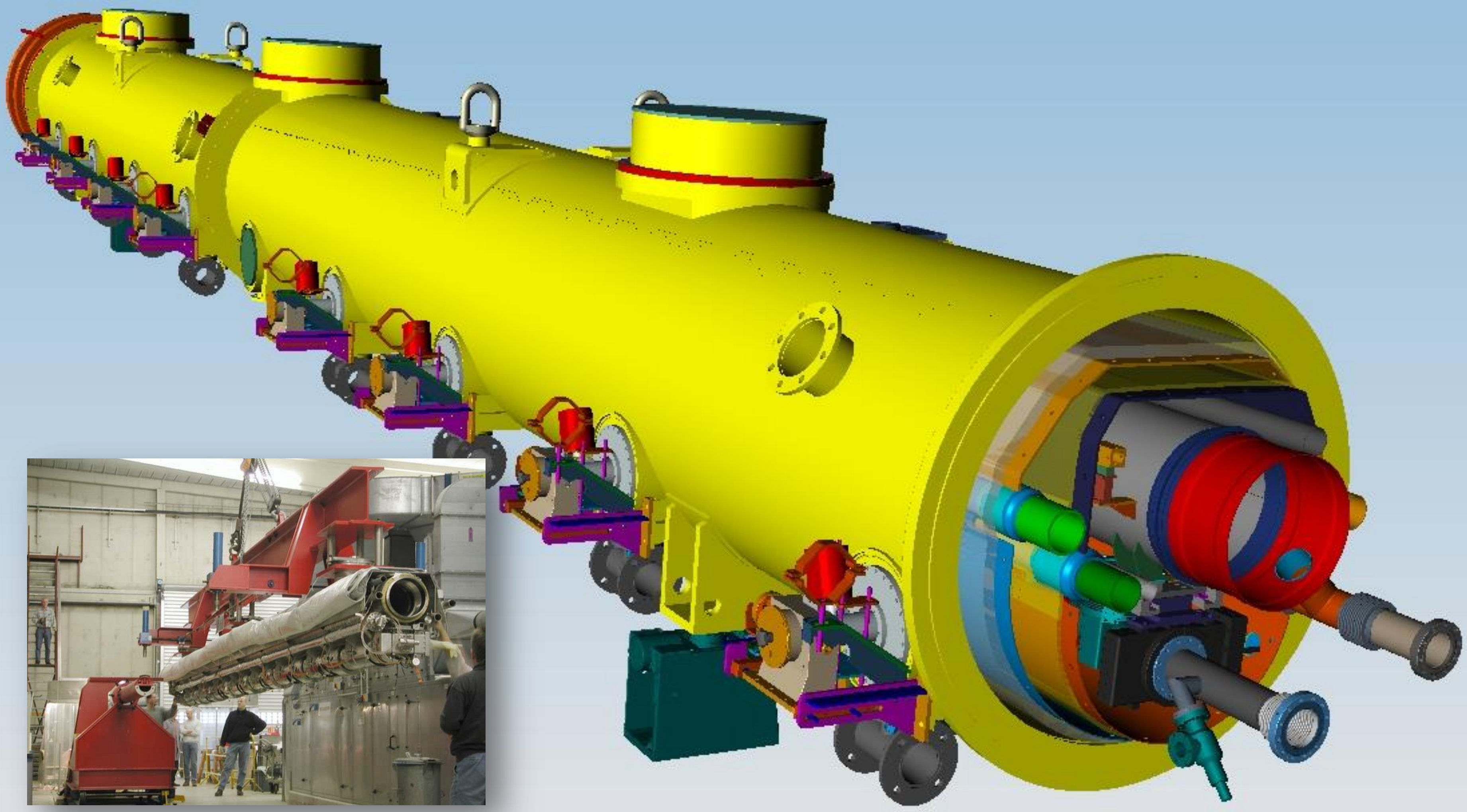
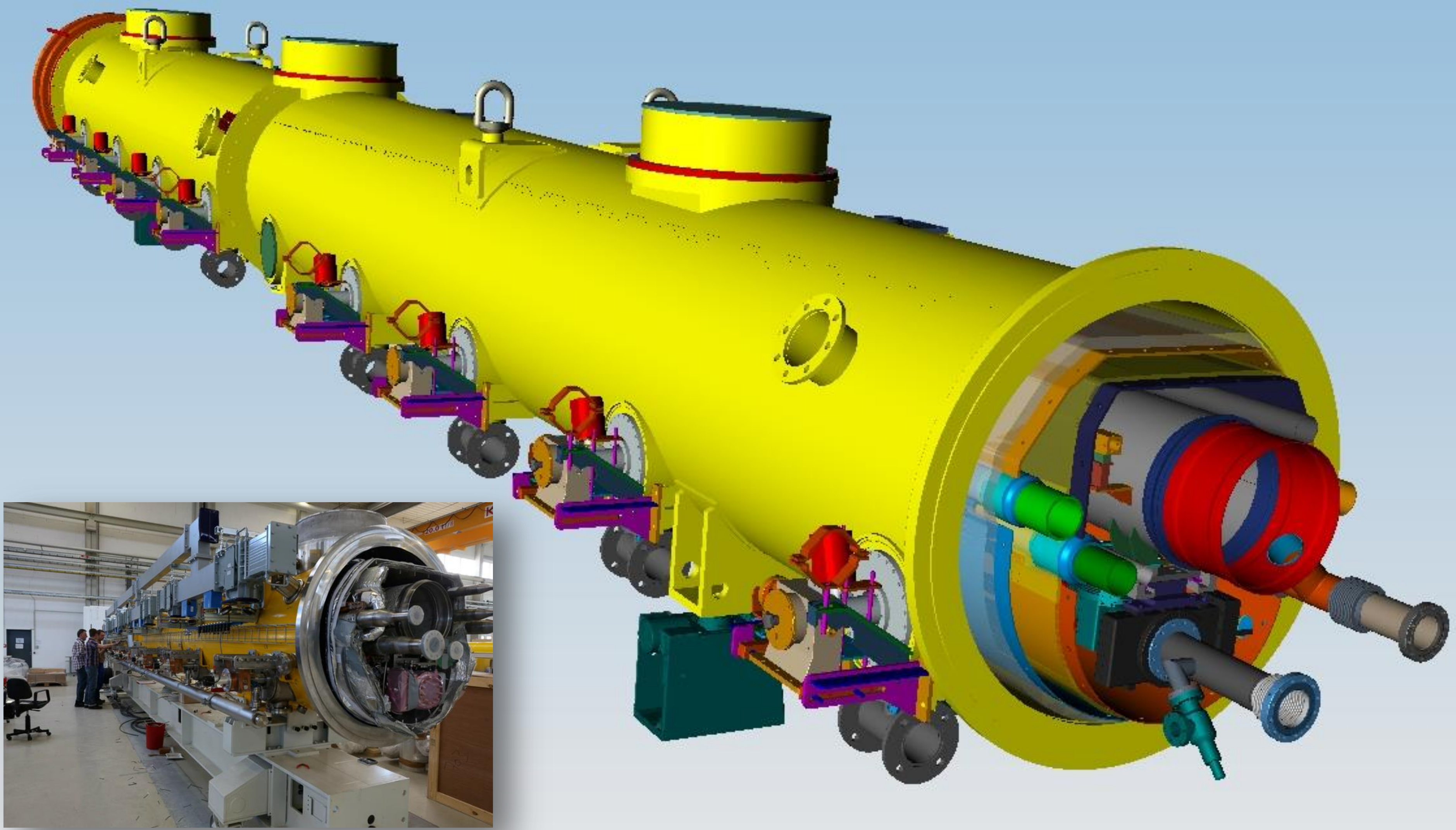
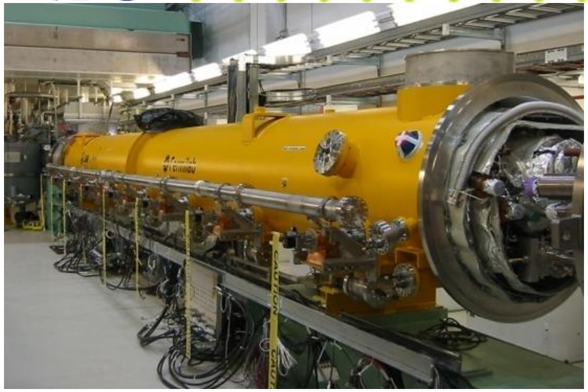


Cryomodule construction




shield wall removed
©Rey.Hori/KEK

Worldwide Cryomodule Development



CM1 at FNAL NML module test facility

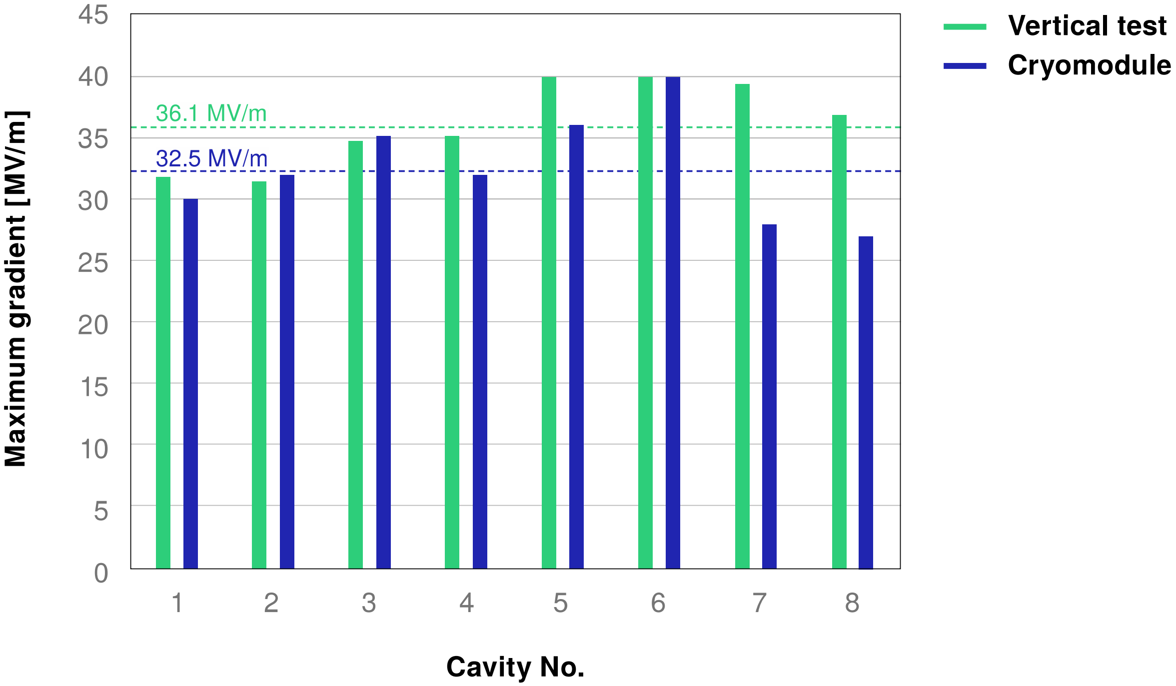
S1 Global at KEK SRF Test Facility (STF)

PXFEL 1 installed at FLASH, DESY, Hamburg

Worldwide Cryomodule Development

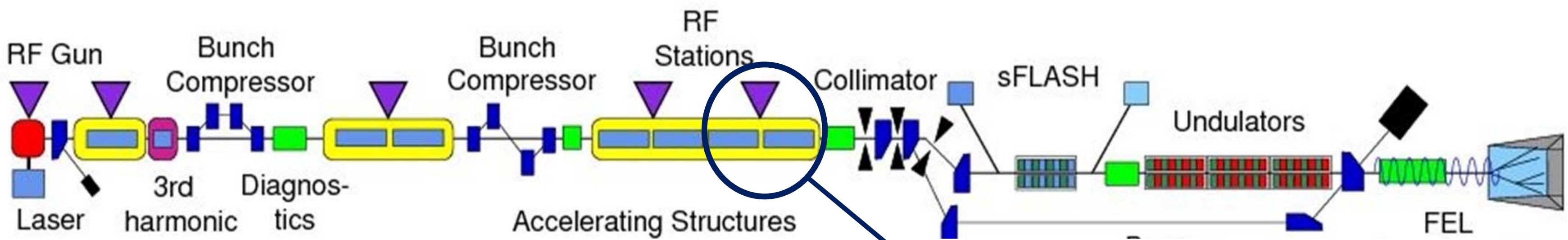
PXFEL 1 installed at FLASH, DESY, Hamburg

Worldwide Cryomodule Development

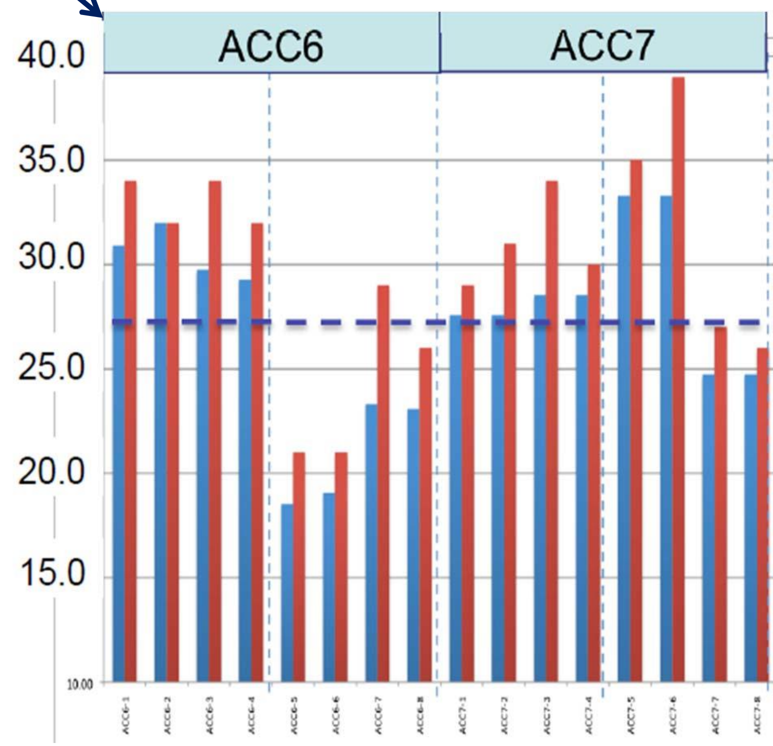


PXFEL 1 installed at FLASH, DESY, Hamburg

FLASH Achievements



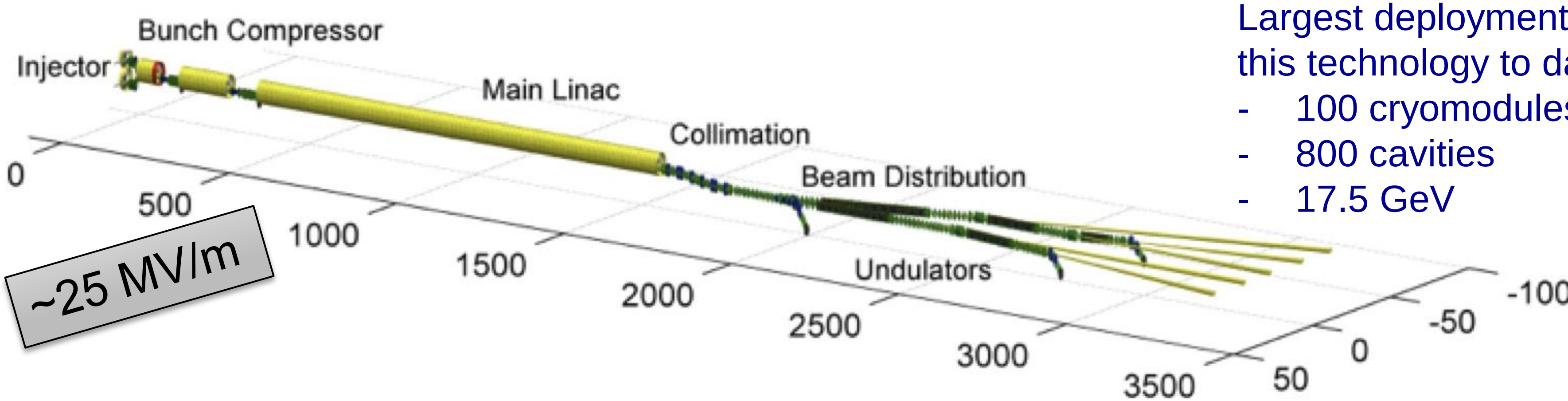
		XFEL	ILC (upg.)	FLASH design	9mA studies
Bunch charge	nC	1	3.2	1	3
# bunches		3250	2625	7200*	2400
Pulse length	μs	650	970	800	800
Current	mA	5	9	9	9



Many basic demonstrations:
- heavy beam loading with long bunch trains
- operation close to quench limits
- klystron overhead etc.

Development (LLRF & controls):
- tuning algorithms
- automation
- quench protection etc.

European XFEL @ DESY



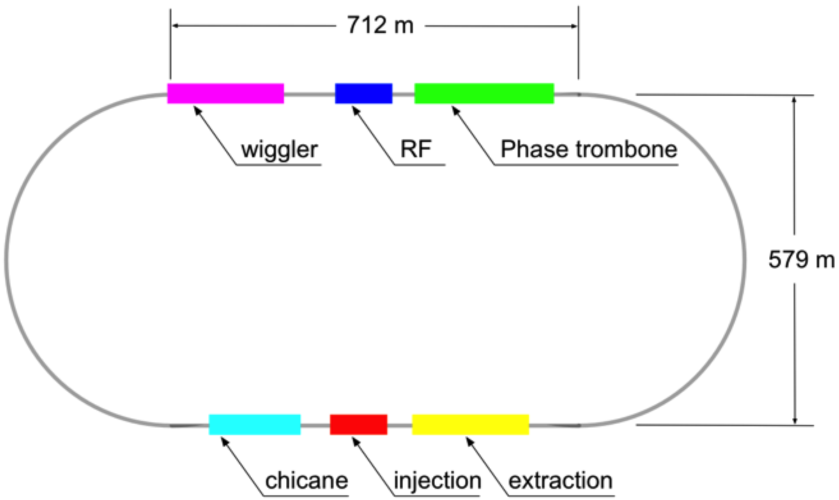
Largest deployment of this technology to date

- 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. Commissioning with beam 2nd half 2015

Damping Rings



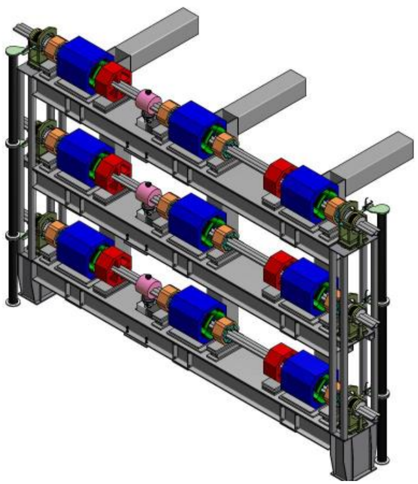
Circumference		3.2	km
Energy		5	GeV
RF frequency		650	MHz
Beam current		390	mA
Store time		200 (100)	ms
Trans. damping time		24 (13)	ms
Extracted emittance	x	5.5	µm
(normalised)	y	20	nm
No. cavities		10 (12)	
Total voltage		14 (22)	MV
RF power / coupler		176 (272)	kW
No.wiggler magnets		54	
Total length wiggler		113	m
Wiggler field		1.5 (2.2)	T
Beam power		1.76 (2.38)	MW

Values in () are for 10-Hz mode

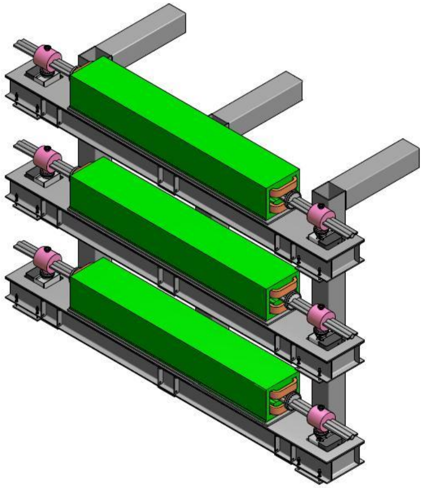
Positron ring (upgrade)

Electron ring (baseline)

Positron ring (baseline)



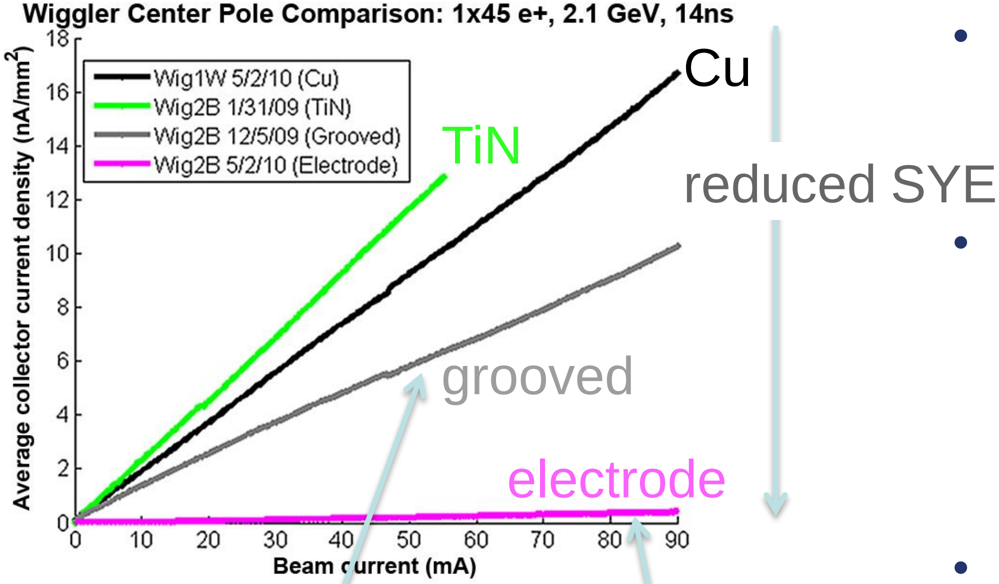
Arc quadrupole section

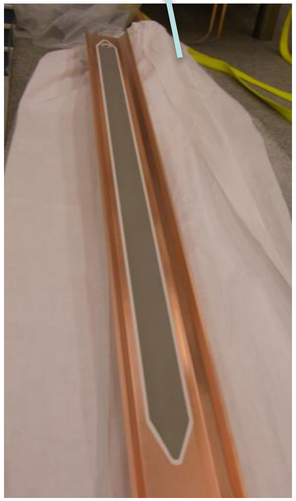


Dipole section

Many similarities to modern 3rd-generation light sources

DR: Critical R&D (Electron Cloud)

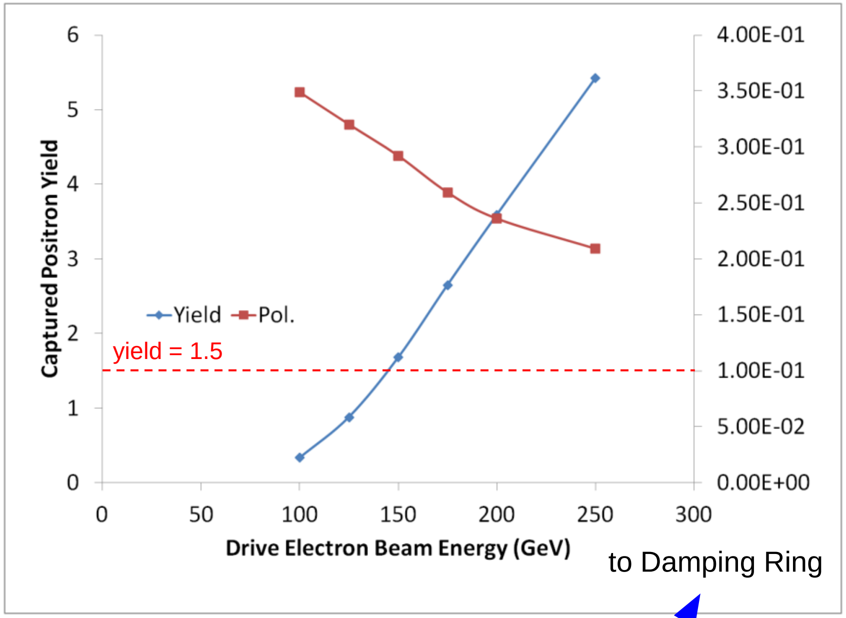


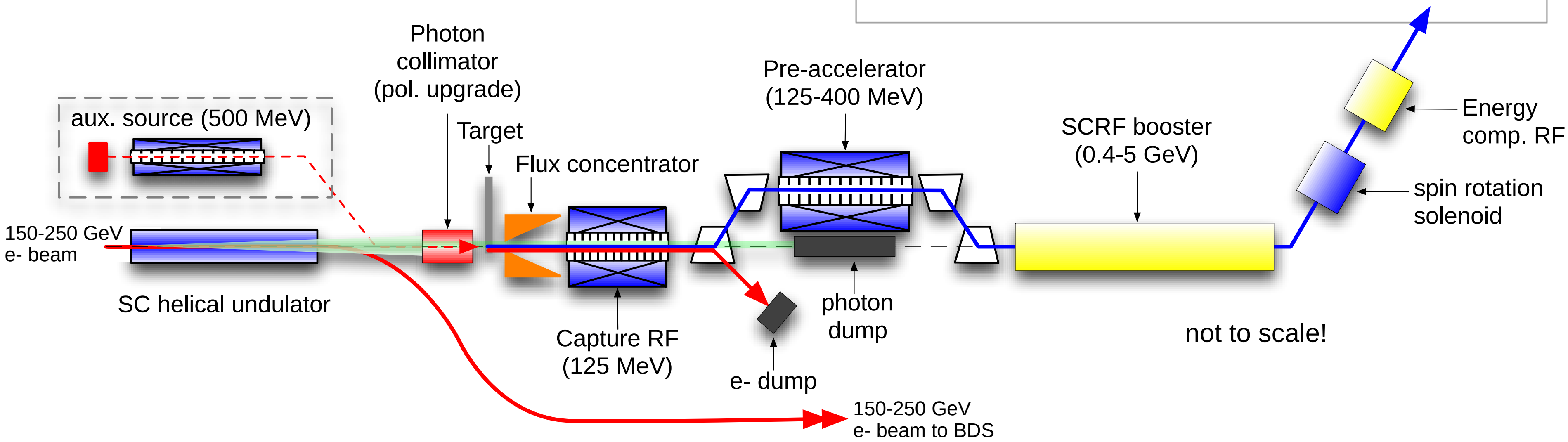


- Extensive R&D programme at CESR, Cornell (CesrTA)
- Instrumentation of wiggler, dipole and quad vacuum chambers for e-cloud measurements
  - RFA
- low emittance lattice
- Example: wiggler vacuum chamber
- Benchmarking of simulation codes
  - cloud build-up
  - beam dynamics (head-tail instabilities)

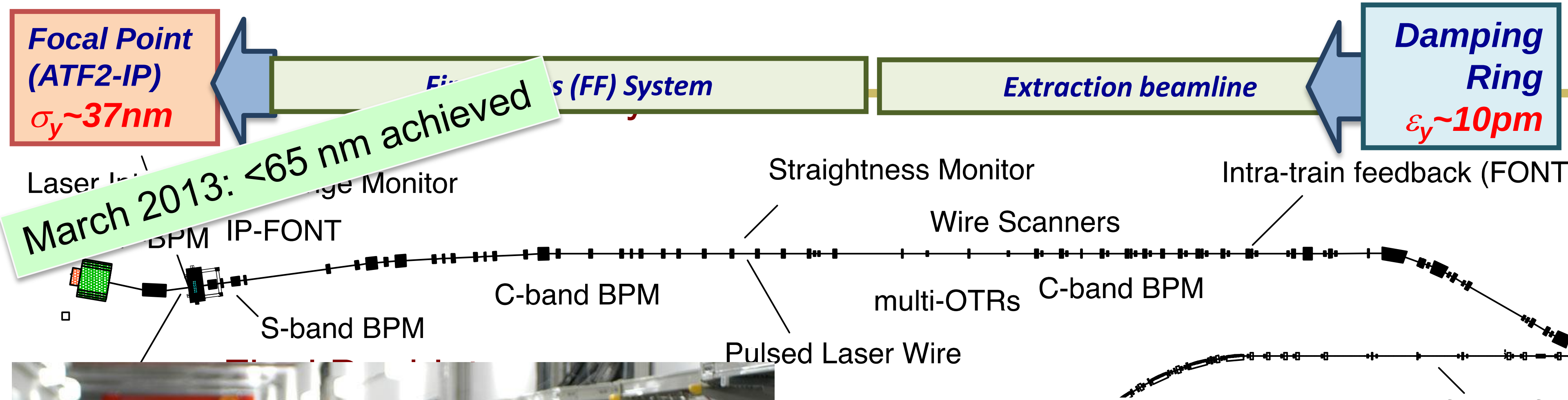
Positron Source

- located at exit of electron Main Linac
- 147m SC helical undulator
- driven by primary electron beam (150-250 GeV)
- produces ~30 MeV photons
- converted in thin target into e^+e^- pairs

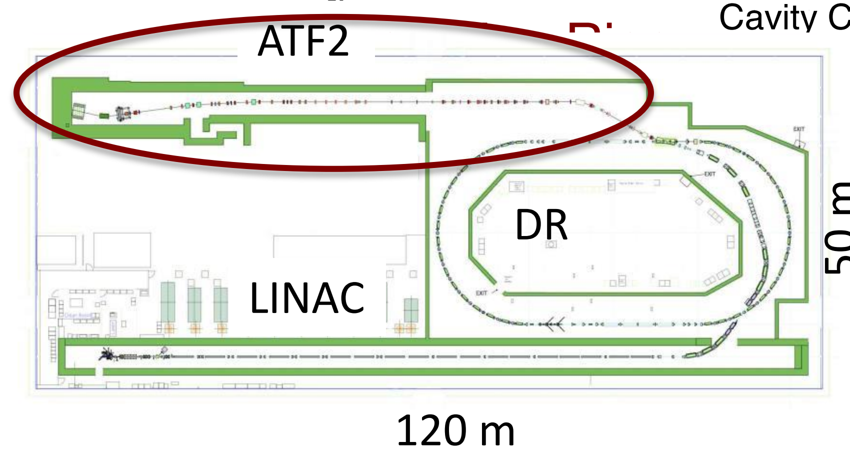




Final Focus R&D – ATF2

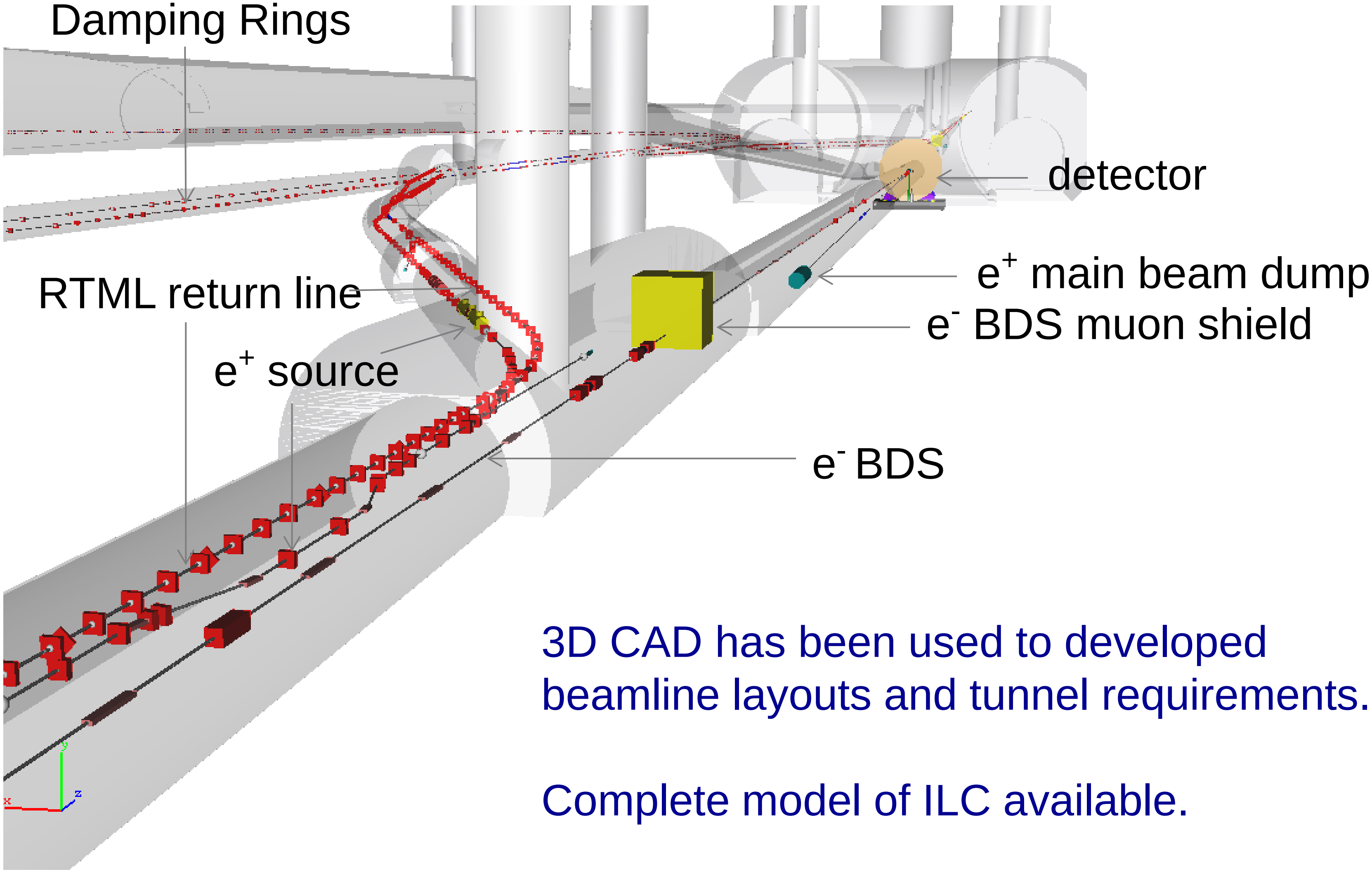


March 2013: <65 nm achieved



Formal international collaboration

Central Region Integration

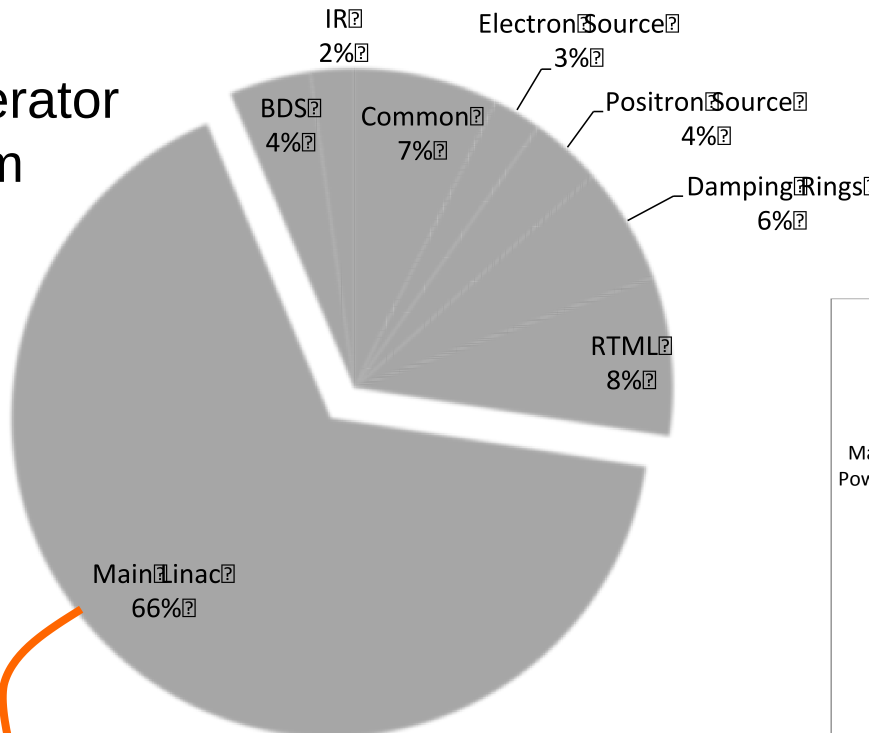


3D CAD has been used to developed beamline layouts and tunnel requirements.

Complete model of ILC available.

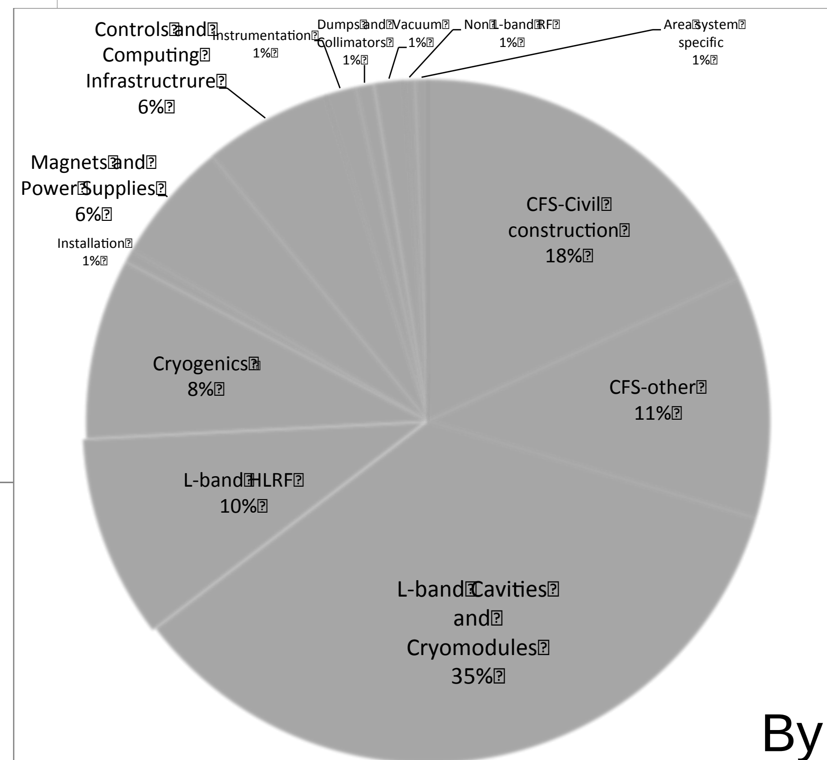
Cost

By accelerator system



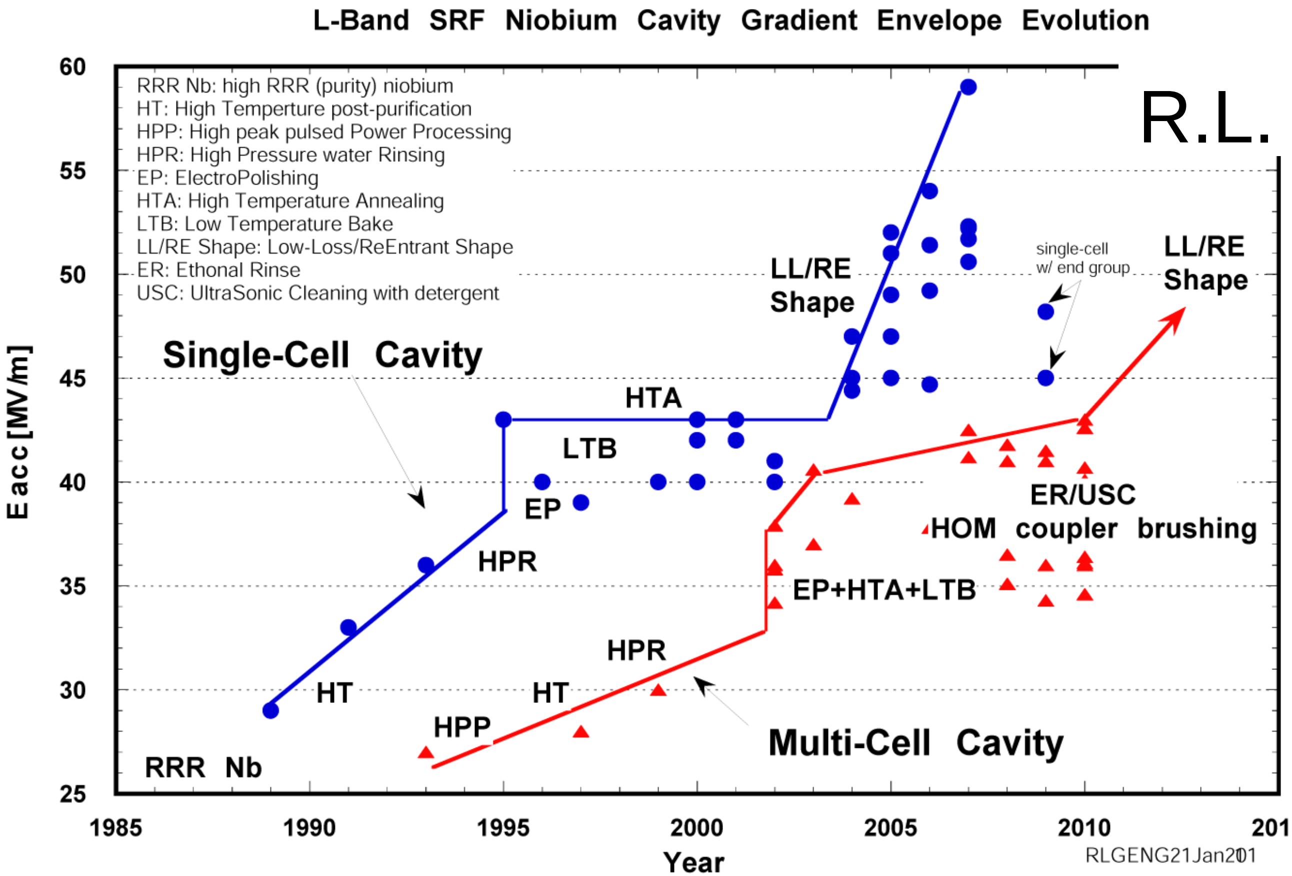
CFS-Civil construction	10%
CFS-other	6%
L-band Cavities and Cryomodules	32%
L-band HLRF	9%
Cryogenics	7%
Controls	2%
TOTAL Main Linac	**66%**

7.8 Billion ILCU
22.6 Million person-hours



By technical system

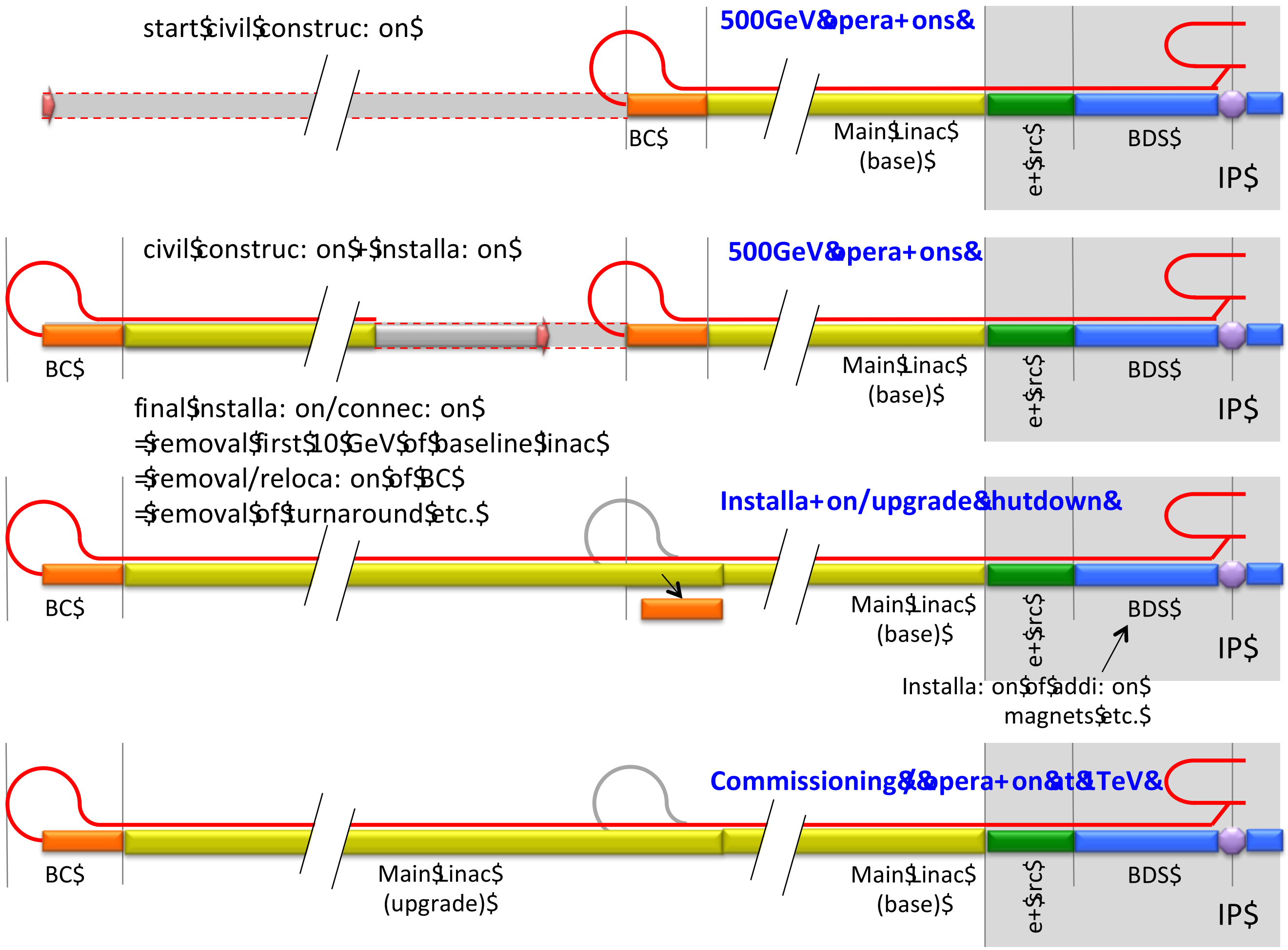
Upgrades - Increasing SCRF Gradient



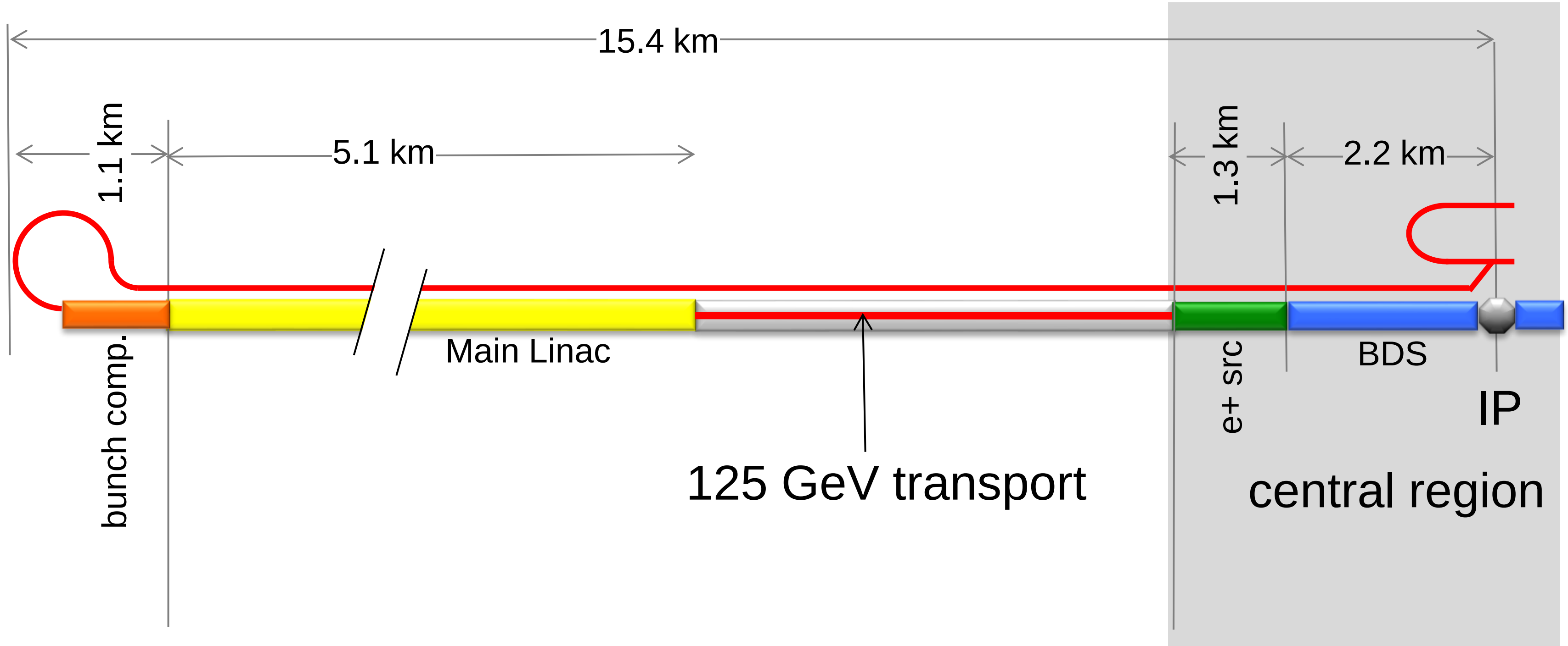
R.L. Geng

Understanding in gradient limits and inventing breakthrough solutions are responsible for gradient progresses. This has been a tradition in SRF community and rapid gradient progress continues. Up to 60 MV/m gradient has been demonstrated in 1-cell 1300 MHz Nb cavity. 45-50 MV/m gradient demonstration in 9-cell cavity is foreseen in next 5 years.

1 TeV Upgrade

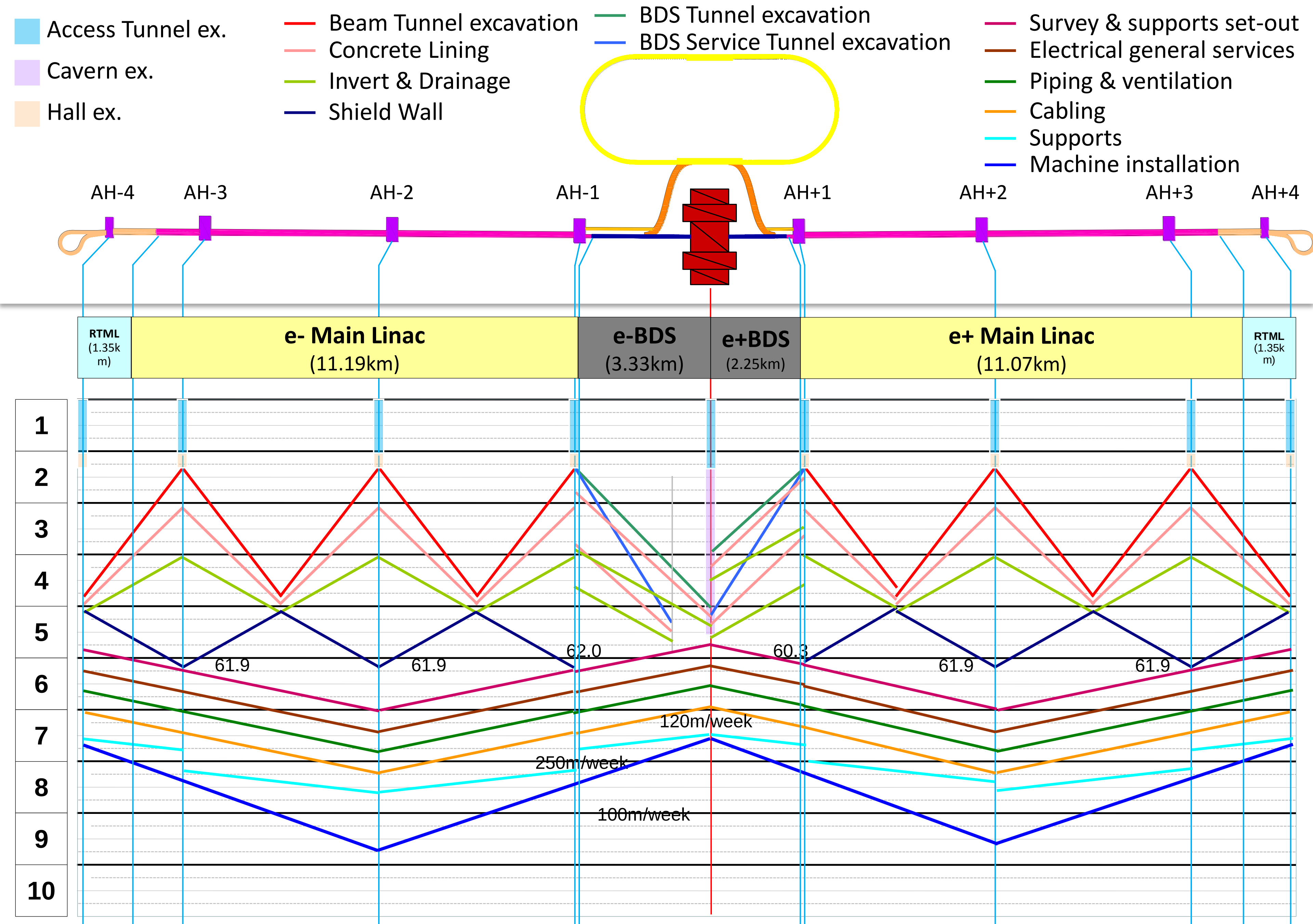


Initial Higgs Factory



Half the linacs
Full-length BDS tunnel & vacuum (TeV)
½ BDS magnets (instrumentation, CF etc)
5km 125 GeV transport line

quasi-adiabatic energy upgrade?


Access Tunnel ex.
Cavern ex.
Hall ex.
Beam Tunnel excavation
Concrete Lining
Invert & Drainage
Shield Wall
BDS Tunnel excavation
BDS Service Tunnel excavation
Survey & supports set-out
Electrical general services
Piping & ventilation
Cabling
Supports
Machine installation
AH-4
AH-3
AH-2
AH-1
AH+1
AH+2
AH+3
AH+4
RTML (1.35km)
e- Main Linac (11.19km)
e-BDS (3.33km)
e+BDS (2.25km)
e+ Main Linac (11.07km)
RTML (1.35km)
1
2
3
4
5
6
7
8
9
10
61.9
61.9
62.0
60.3
61.9
61.9
120m/week
250m/week
100m/week

Japanese Sites for ILC

- GDE-CFS group visited two sites, Oct., 2011.
- GDE EC visit in Jan. 2012.

Summary and Outlook

- Rarely has the next large project in particle physics had such a strong physics case on phenomena known to exist or been based on such mature technology.

- Japan, a major player in particle physics, is expressing growing interest in hosting the ILC. In doing so, very substantial new resources would enter the subject. The European Strategy welcomes this development; we hope the US will be similarly positive.

- The TDR is the evidence that the ILC can be built now within a carefully costed envelope based on real XFEL project costs.
- In the words of the last Chair of ILCSC, the ILC is “good to go”.

- We are at a crucial point - the ILC is a project whose time has come.

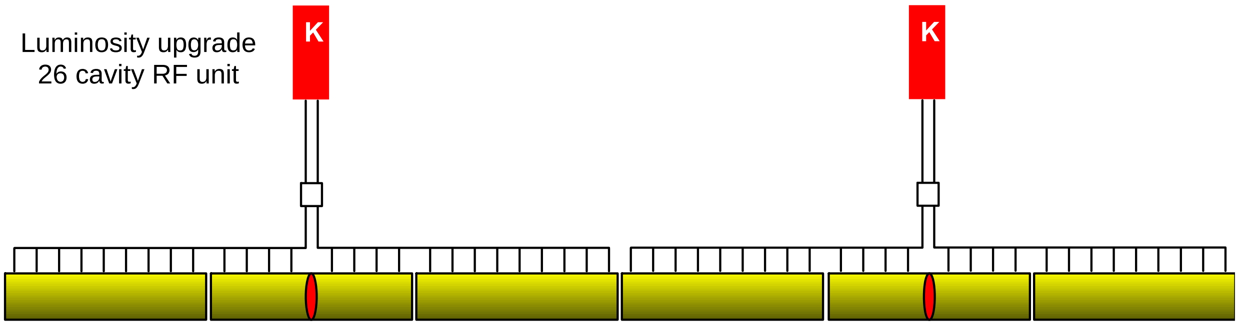
Backup slides

Luminosity Upgrade

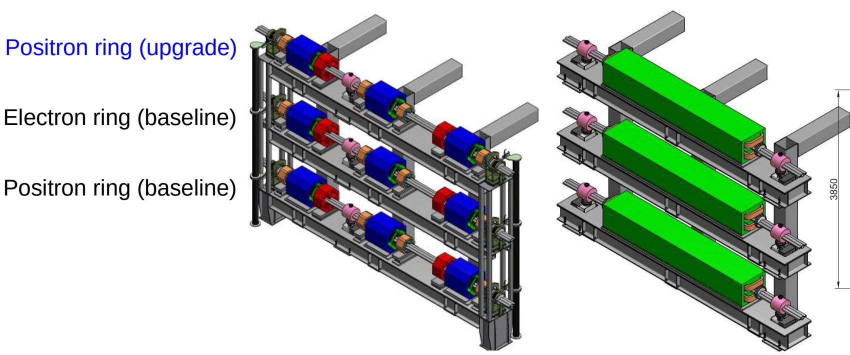
- Concept: increase n_b from 1312 → 2625
  - **Reduce linac bunch spacing 554 ns → 336 ns**
- Doubles beam power → $\times 2$ $L = 3.6 \times 10^{34}\ cm^{-2}s^{-1}$
- AC power: 161 MW → 204 MW (est.)
  - **shorter fill time and longer beam pulse results in higher RF-beam efficiency (44% → 61%)**

Luminosity Upgrade

Adding klystrons (and modulators)

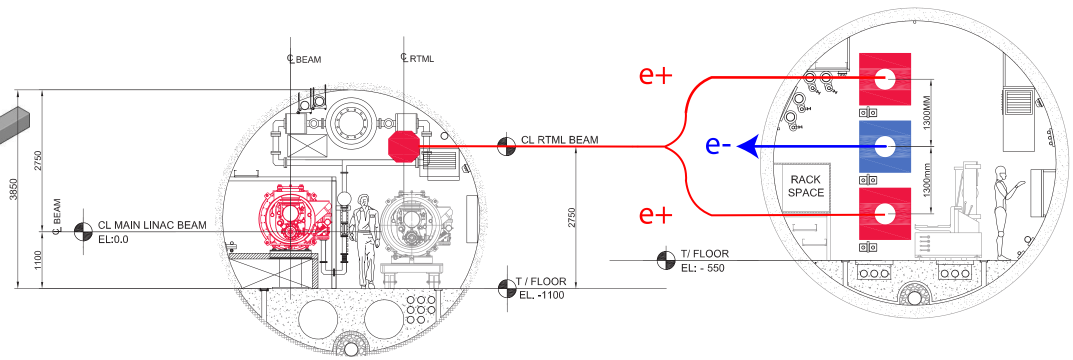


Damping Ring:



Arc quadrupole section

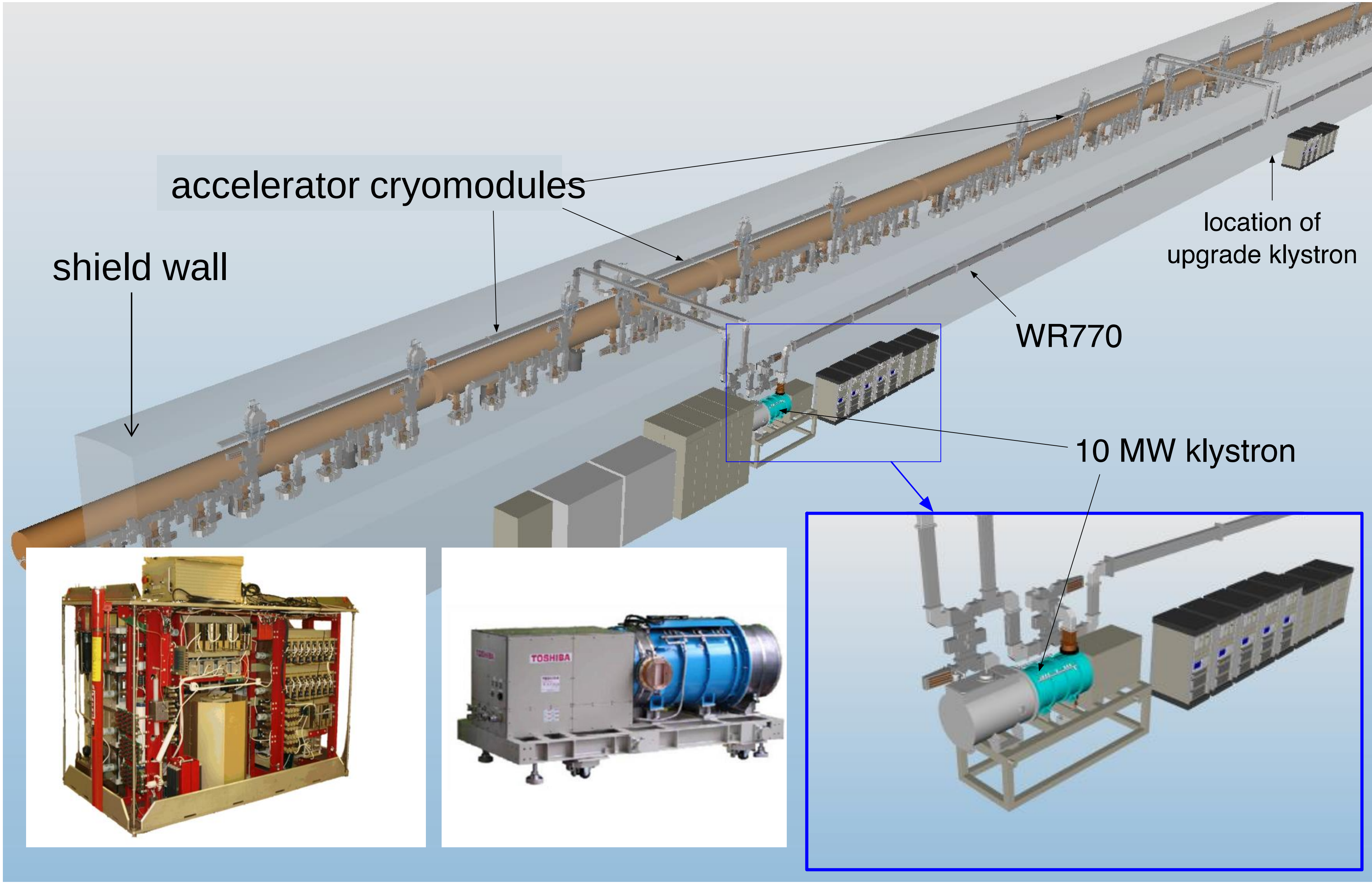
Dipole section



Main Linac Tunnel

Damping Ring Tunnel

RF Power Generation



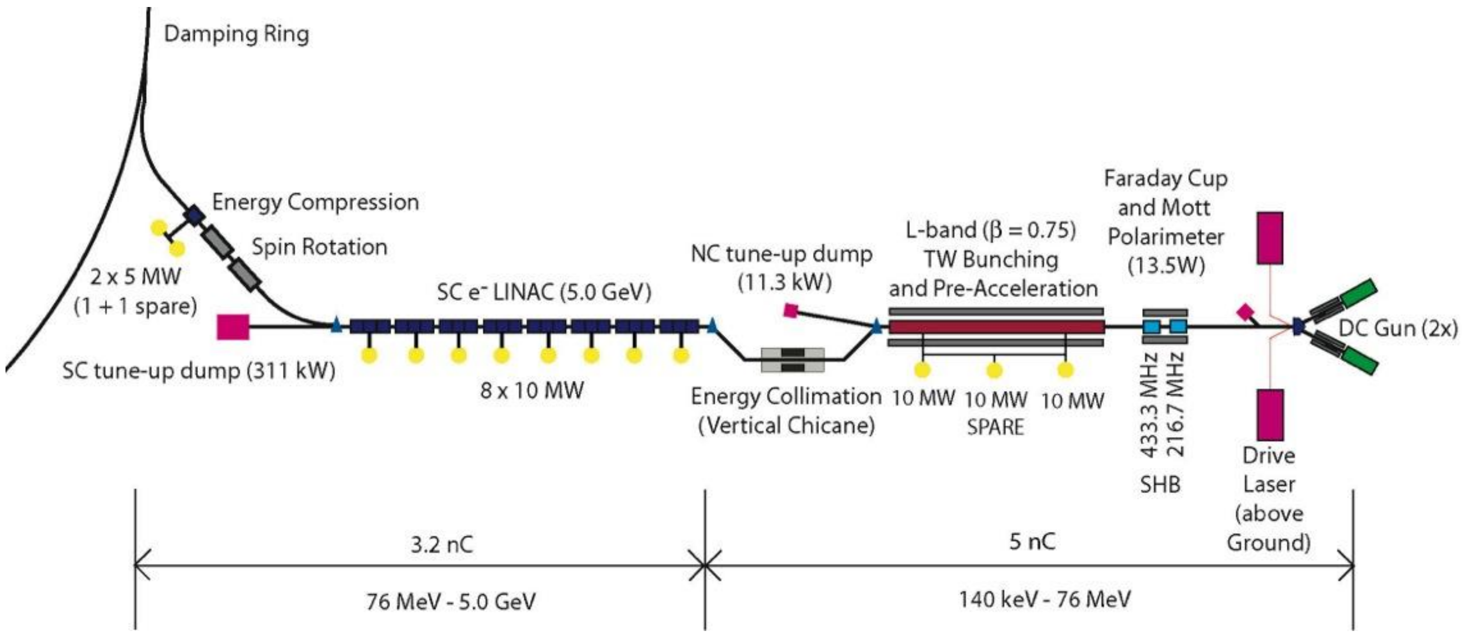
Gamma-Gamma General Status

- γ-γ technology is still premature
  - need > 5 years of R&D
- Cannot start with γ-γ at the lowest energy if early start is planned
  - need 100% confidence at the time of project approval
- From technology view point it is reasonable to start with e^+e^- at ZH and, if needed, convert to γ-γ later
  - importance of γ-γ must be evaluated before the construction of e+e- (possible constraints in IR, e.g., the crossing angle)

(Yokoya LCWS12)

Polarised Electron Source

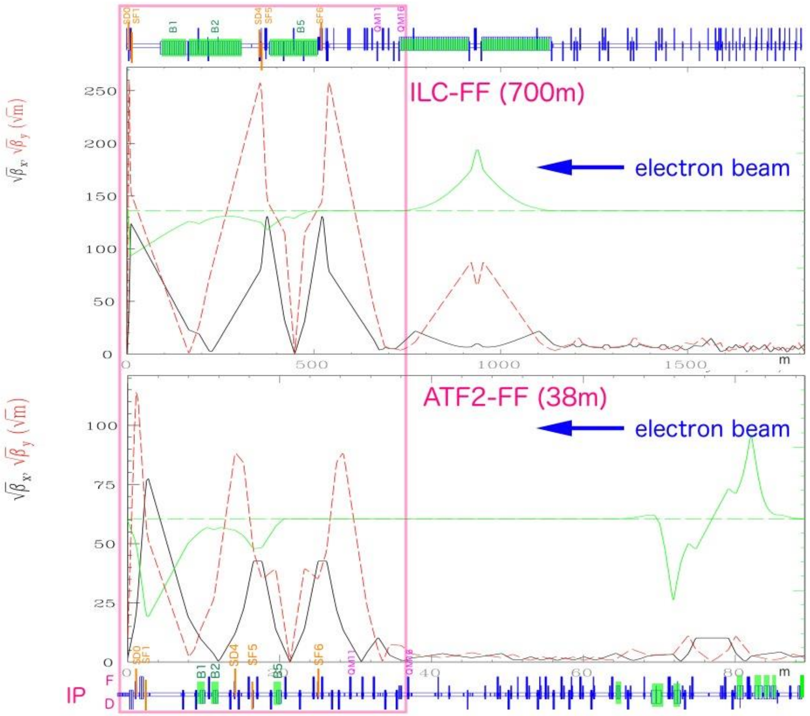
- Laser-driven photo cathode (GaAs)
- DC gun
- Integrated into common tunnel with positron BDS

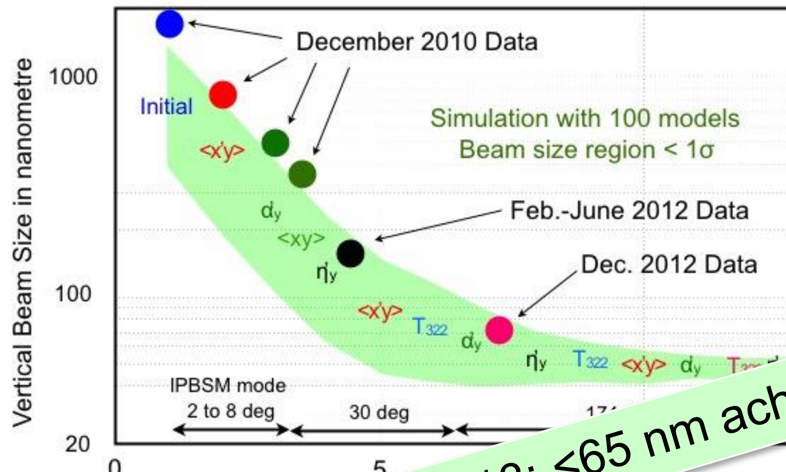


Final Focus R&D – ATF2

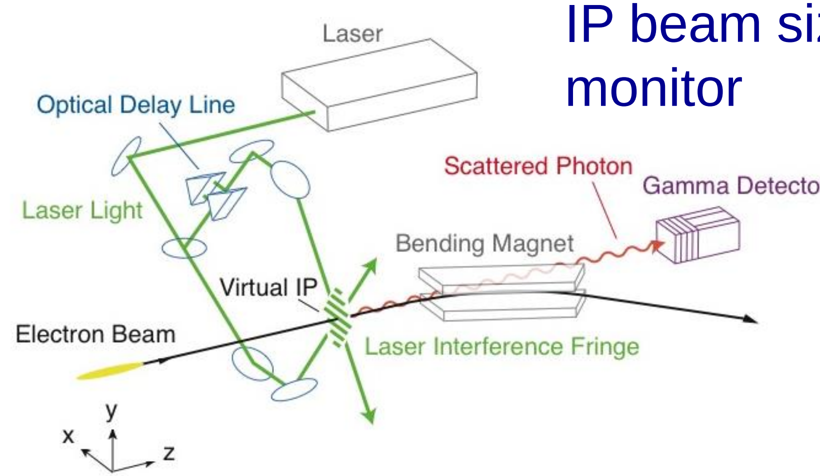
Test bed for ILC final focus optics

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





March 2013: <65 nm achieved



IP beam size monitor