ILC in EUROPE – Assorted Issues

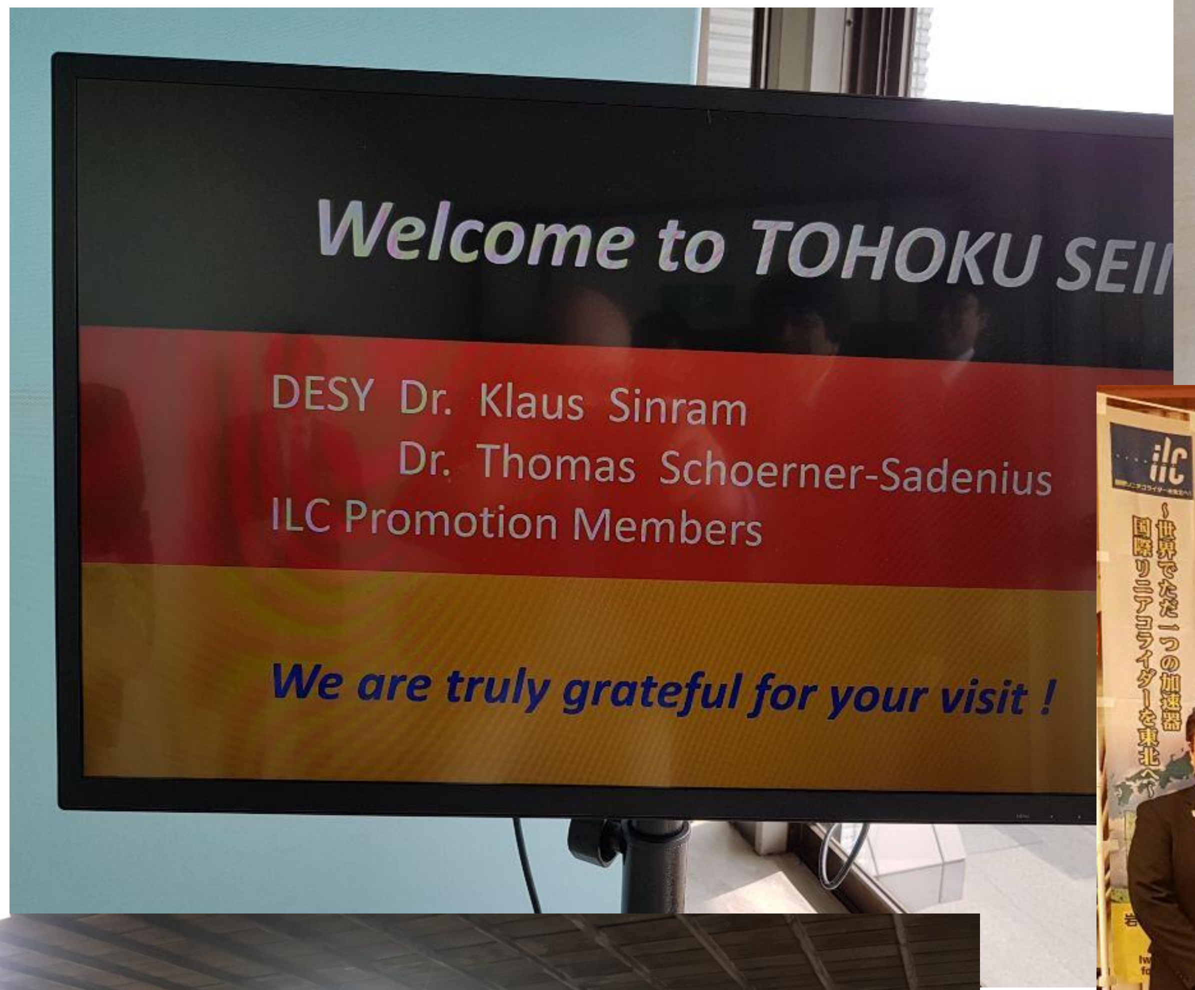
Thomas Schörner-Sadenius (DESY)

MDI / CFS Mini-Workshop
KEK, 16 May 2017

E-JADE is a Marie Sklodowska-Curie Research and Innovation Staff Exchange (RISE) action, funded by the EU under Horizon2020

E-JADE

Last week


Welcome to TOHOKU SEI
DESY Dr. Klaus Sinram
Dr. Thomas Schoerner-Sadenius
ILC Promotion Members
We are truly grateful for your visit !

Contents

- European XFEL
  - Reminder
  - Status of the machine (thanks to Nick Walker)
  - Safety at the European XFEL (see separate presentation)

- ILC in Europe
  - Strategy processes
  - European Action Plan
  - …

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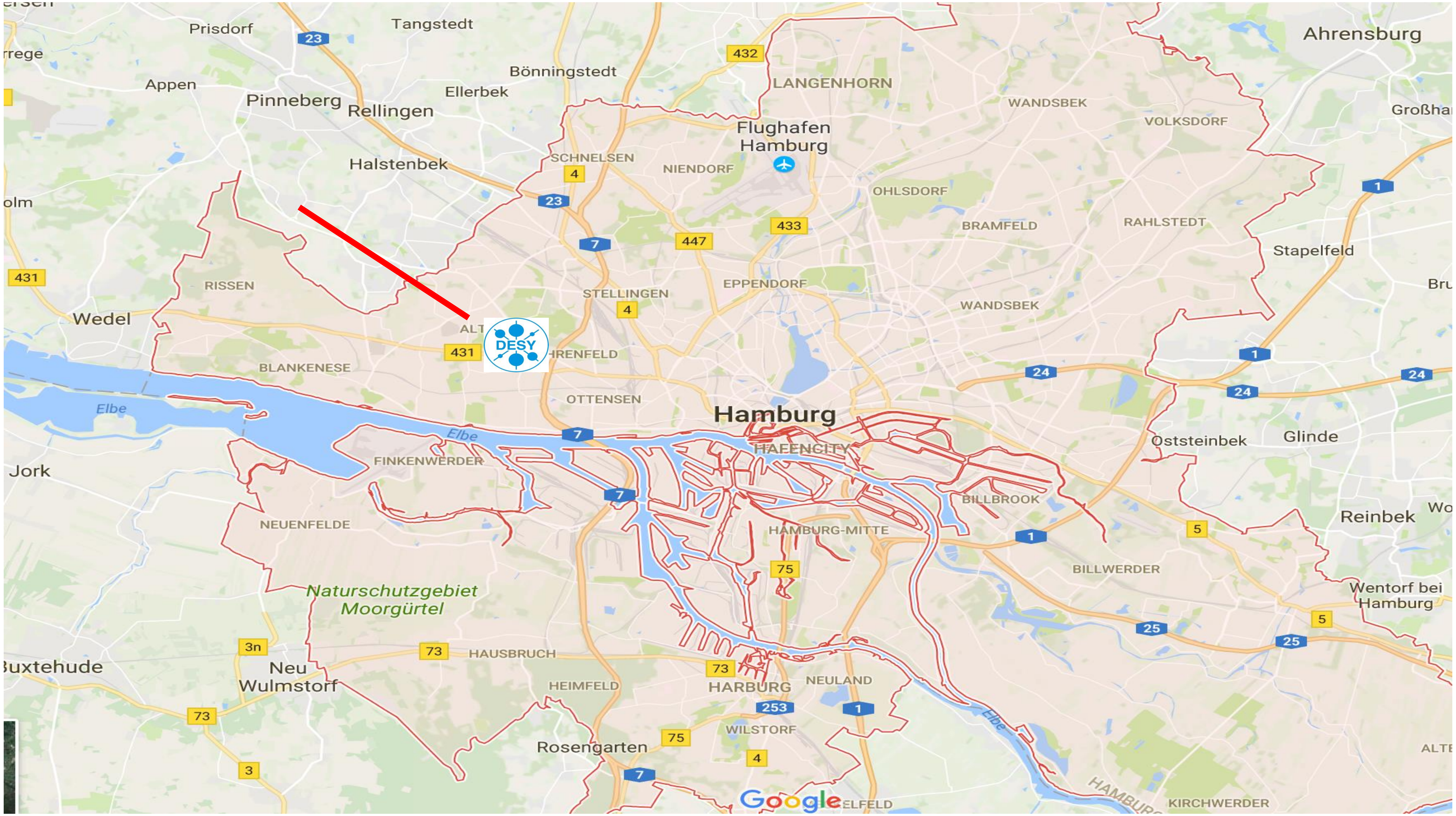
The European XFEL

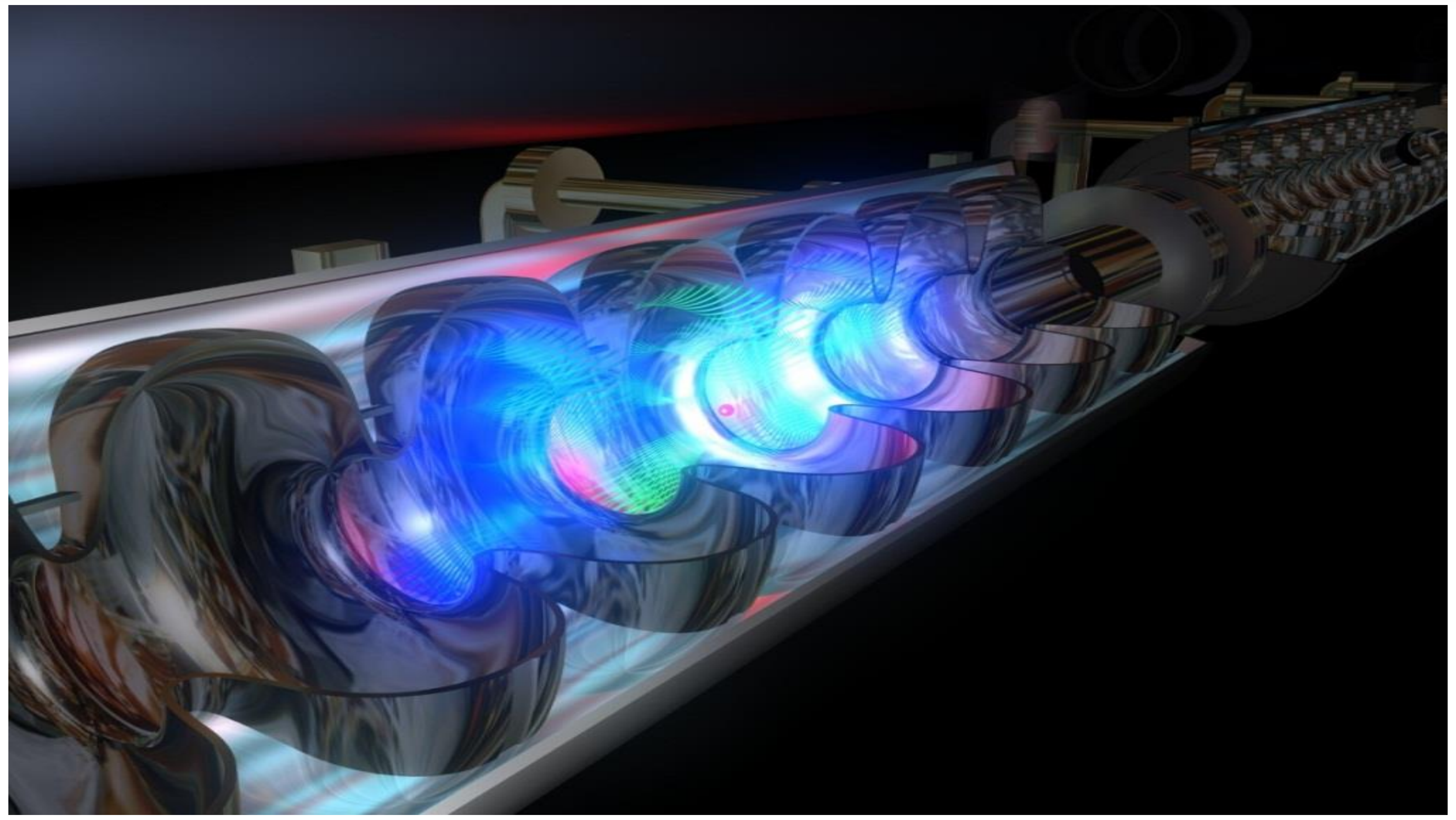


The European XFEL

The European XFEL

Some facts:

- Overall length 3.4 km; superconducting linac (ILC technology) for 2.1 km
- Tunnel between 6 and 38 m underground
- Energy 17.5 GeV
- Cooled with helium to -271ºC.

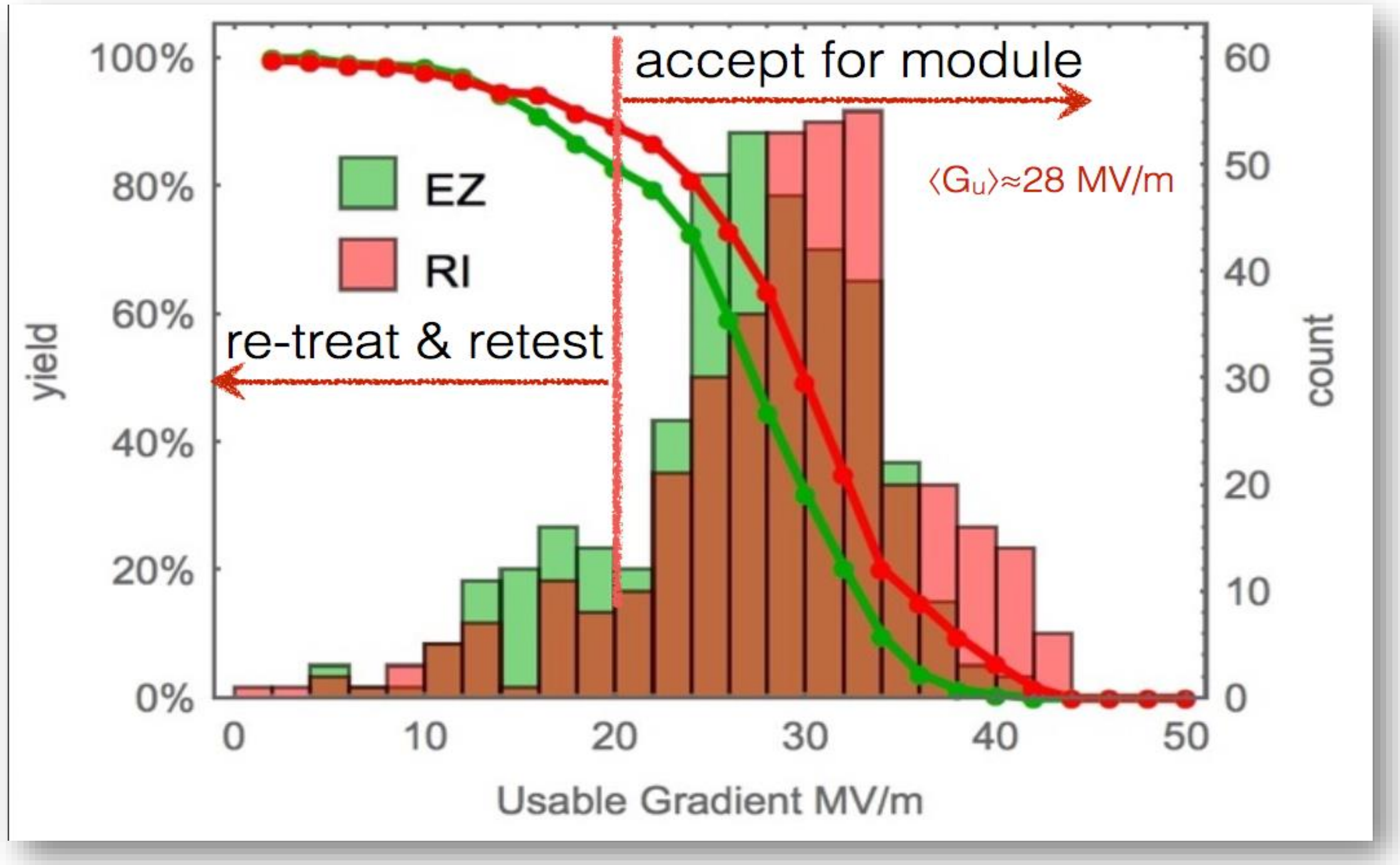


The European XFEL

A prime light source

A 10% prototype of the ILC

- Industrial production of 800 SCRF cavities
- Accelerating gradients close to ILC specs



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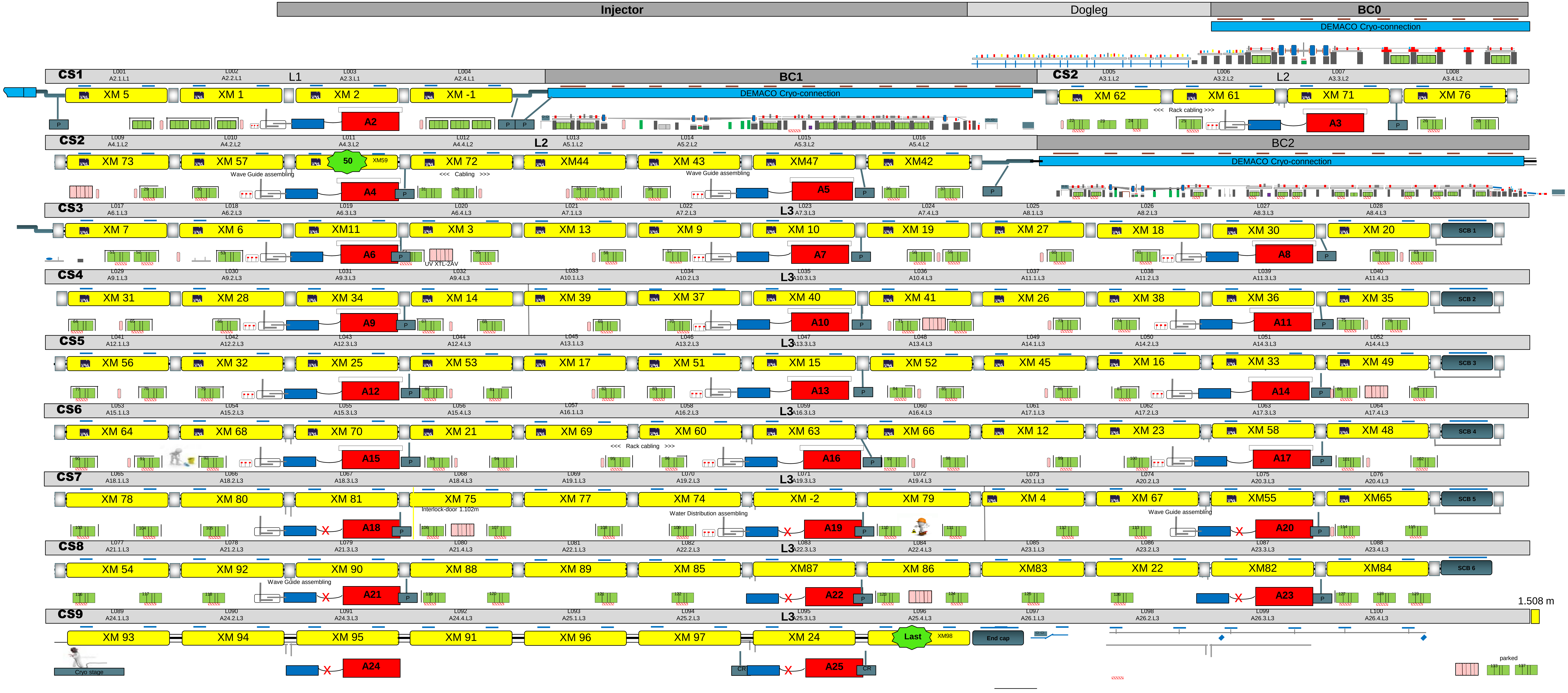
Injector in Operation – First Beam in 12/2015

Dump
Spectrometer　Diagnostic Section　Laser Heater　Transverse Deflecting Structure　3.9 GHz Module　1.3 GHz Module　**Gun**

All Accelerator Modules Installed



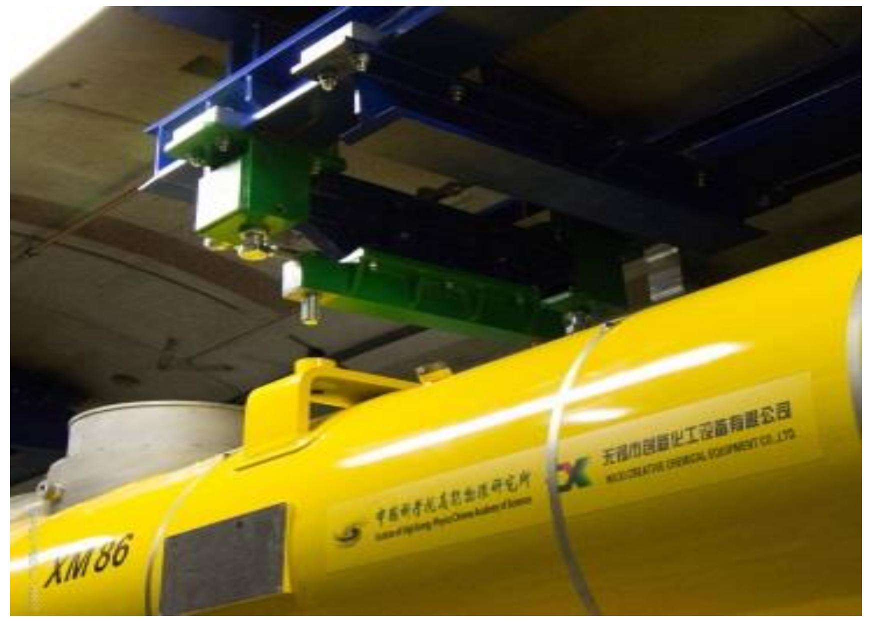
Accelerator Module on its Way to the Tunnel





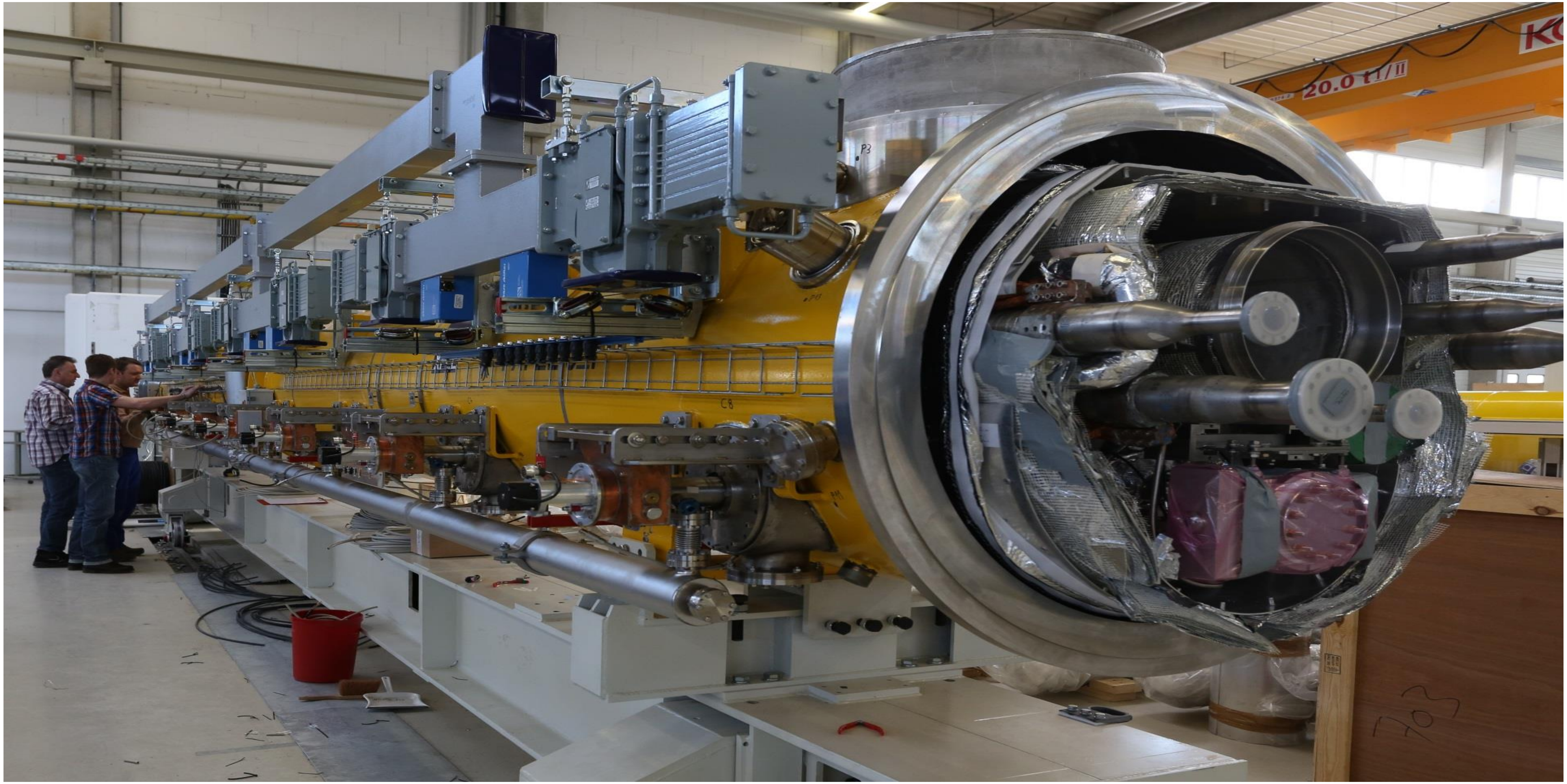




1st module July 1st, 2014 – last module August 1st, 2016

Waveguide Tailoring was done for all Modules

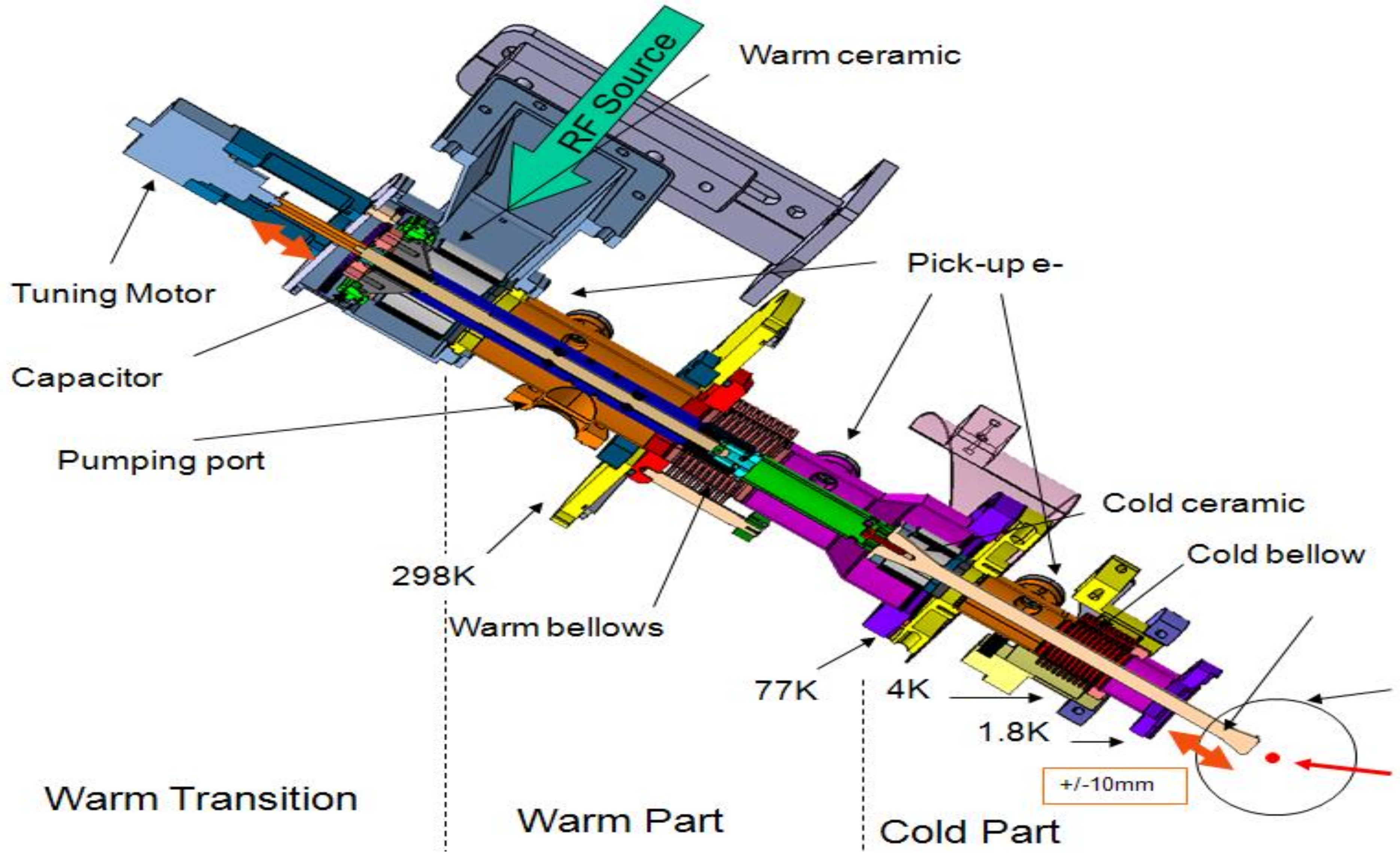


Couplers were the by far the most challenging single items in the supply chain of the modules

- A total of 800 RF power couplers was produced at three different vendors
- The largest fraction was procured by LAL Orsay and produced by Thales / RI
- Approx. 20% were procured from CPI
- RF conditioning of all couplers was done at LAL Orsay at a rate of 10+ couplers/week

Coupler delivery rate did not match the module assembly rate

- Continuing quality and delivery issues needed to be addressed



Tunnel Installation Process

- Optimized global process steps and sequence & daily improvements

Cryo-String

RF

Signal Cables

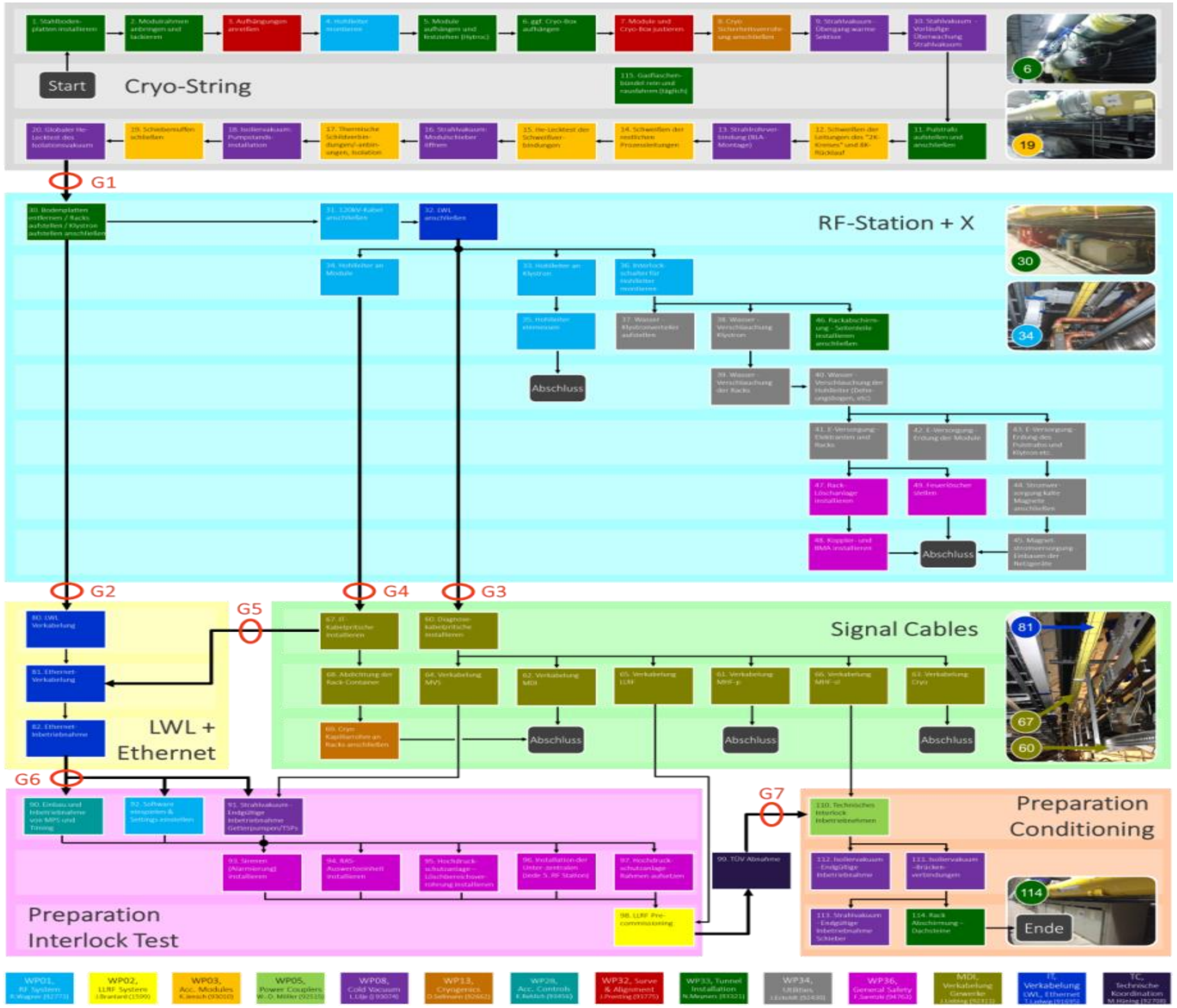
LWL

Ethernet

P.I.

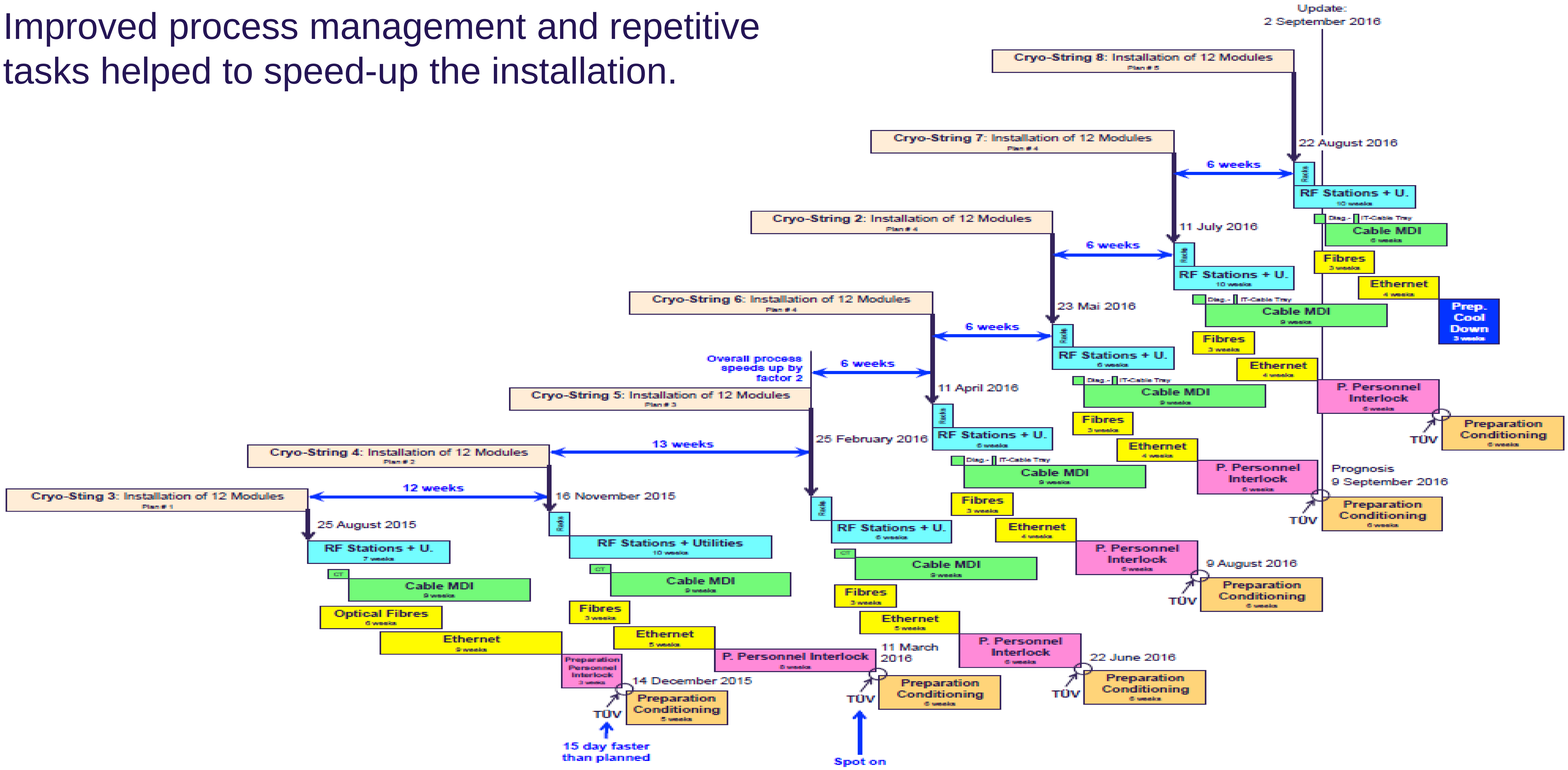
PrepCond

TÜV



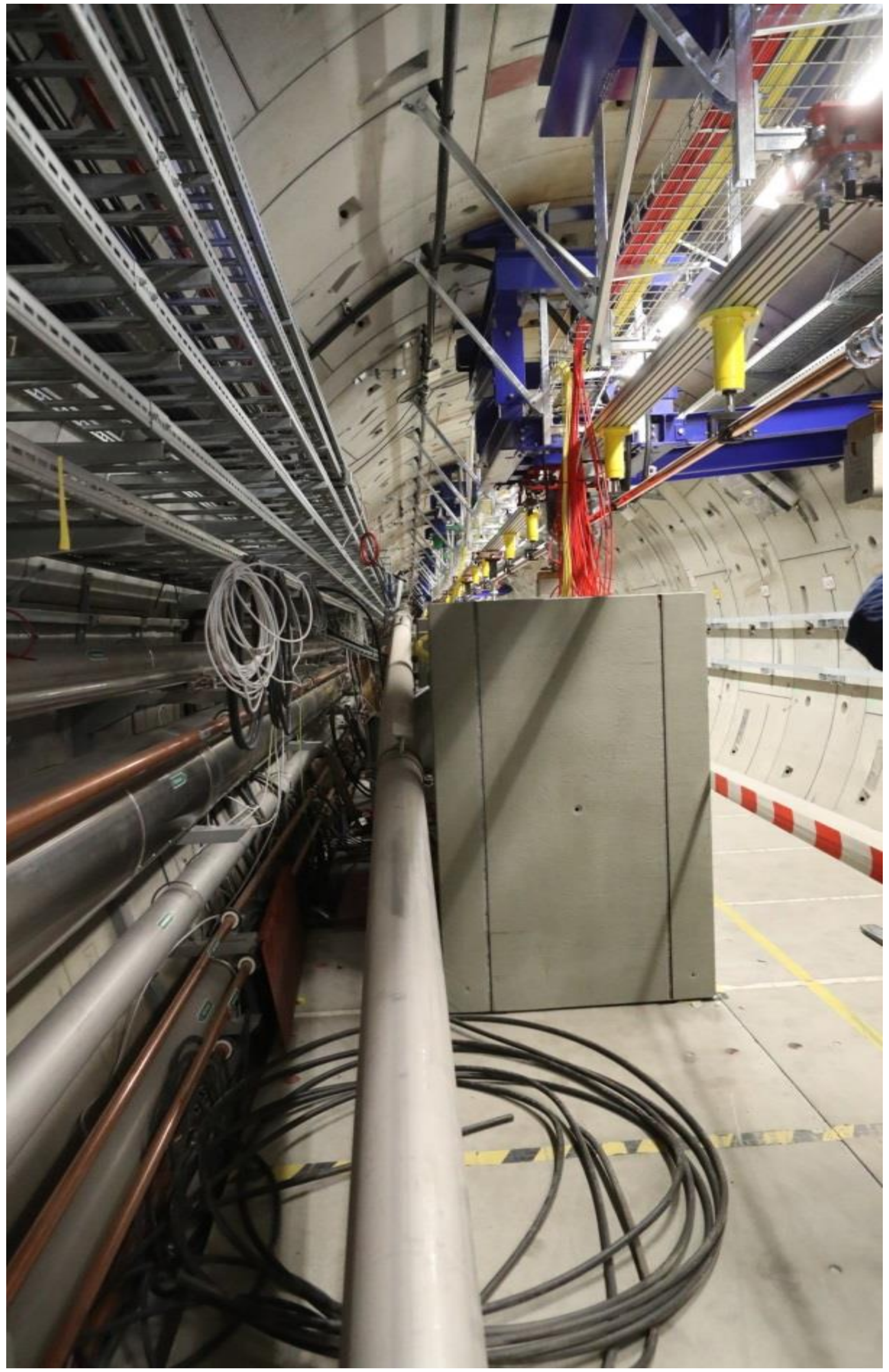
Process Management XTL Installation

- Improved process management and repetitive tasks helped to speed-up the installation.



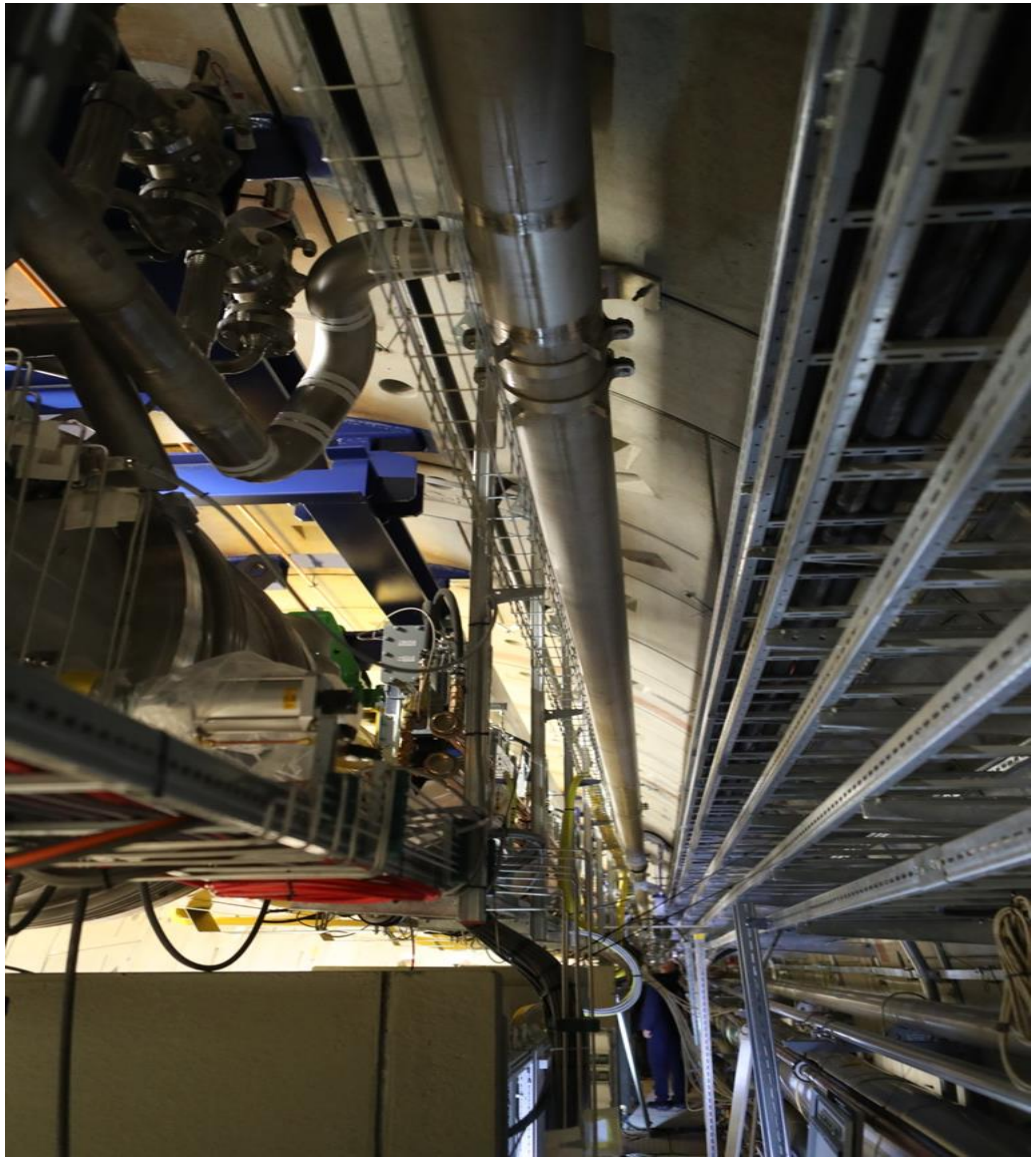
Result of a DN200 Pressure Test Preceding the first Cool Down

- During the pressure test of a Helium exhaust line **severe damage to accelerator infrastructure** happened late night on October 11, 2016.
- **No people were injured** since the tunnel was closed during the test.
- Investigations are still ongoing but a **first rough estimate of the needed repair time** is about three months.
- Both ends of the line have fix points to take the forces in longitudinal direction. The downstream fix point broke, and in consequence the pipe end moved by roughly 1.5 m towards Schenefeld.
- The sliding fixtures along cryostrings CS8 and CS9 also broke and the line fell down.



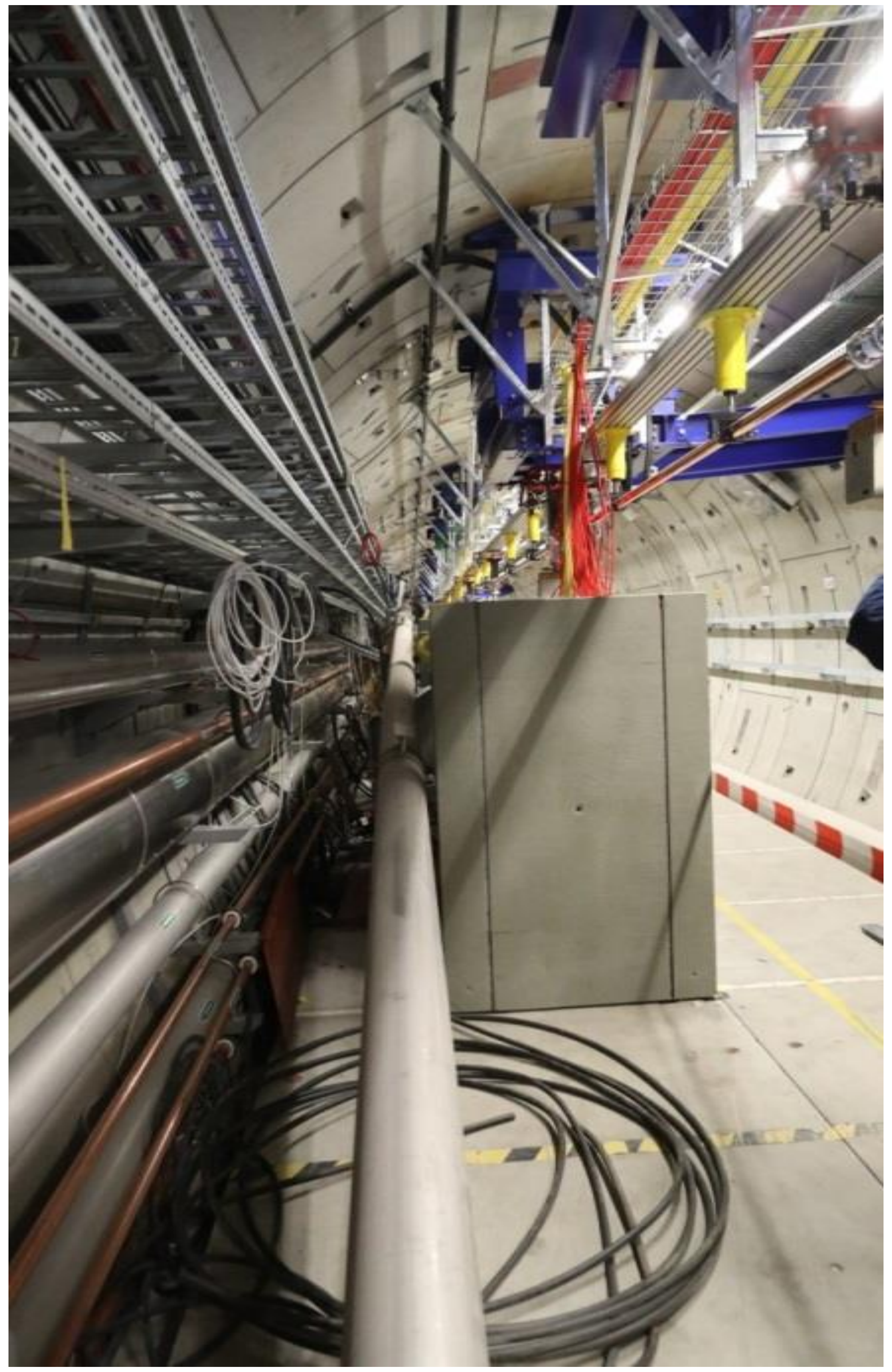
DN200 He Exhaust Line

- DN200 exhaust line goes all along the linac to collect He in case of abnormal operation conditions in the process lines of the accelerator modules. Safety valves with short hoses connect the cryogenic string connection boxes to the exhaust line.
- The exhaust line was designed, constructed and installed by an external company. Installation finished in 2014 with an acceptance test including full pressure check without any apparent problems.
- After completion of connections to all cryogenic boxes a final pressure test was needed to prepare for the upcoming cool-down of the accelerator.



Position of DN200 Pipe right after Pressure Test

- Downstream of CS9, along the replacement line, the pipe fell down to the floor, without major damage to other components.
- Along CS9 and CS8 the line came to a halt on some of the wave guide sections which are 0.5 m below the original position of the pipe.

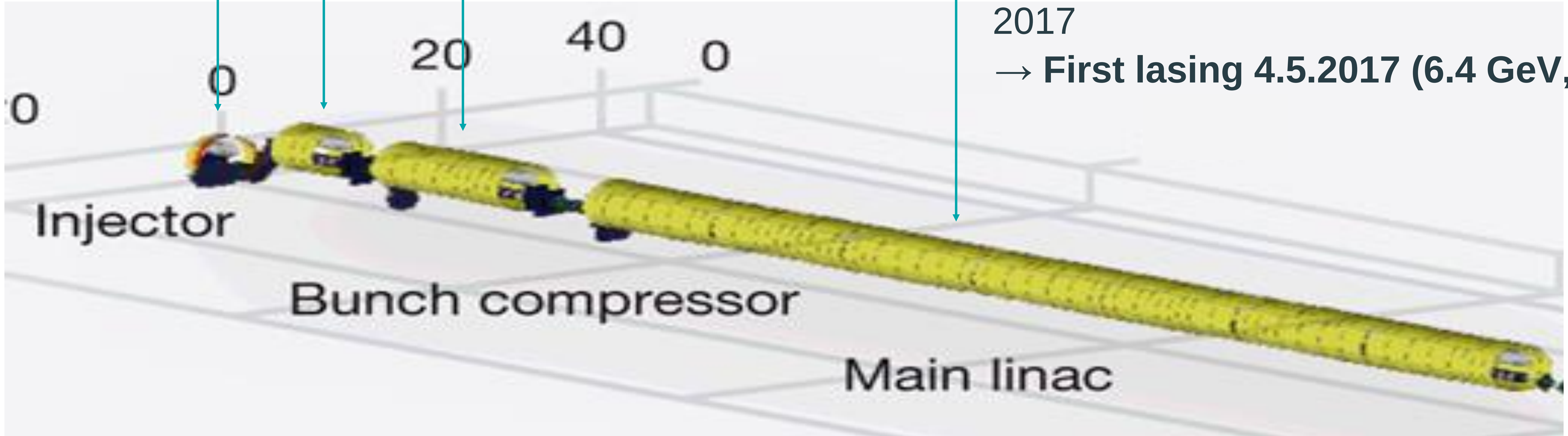


Damage close to Cryogenic End Box

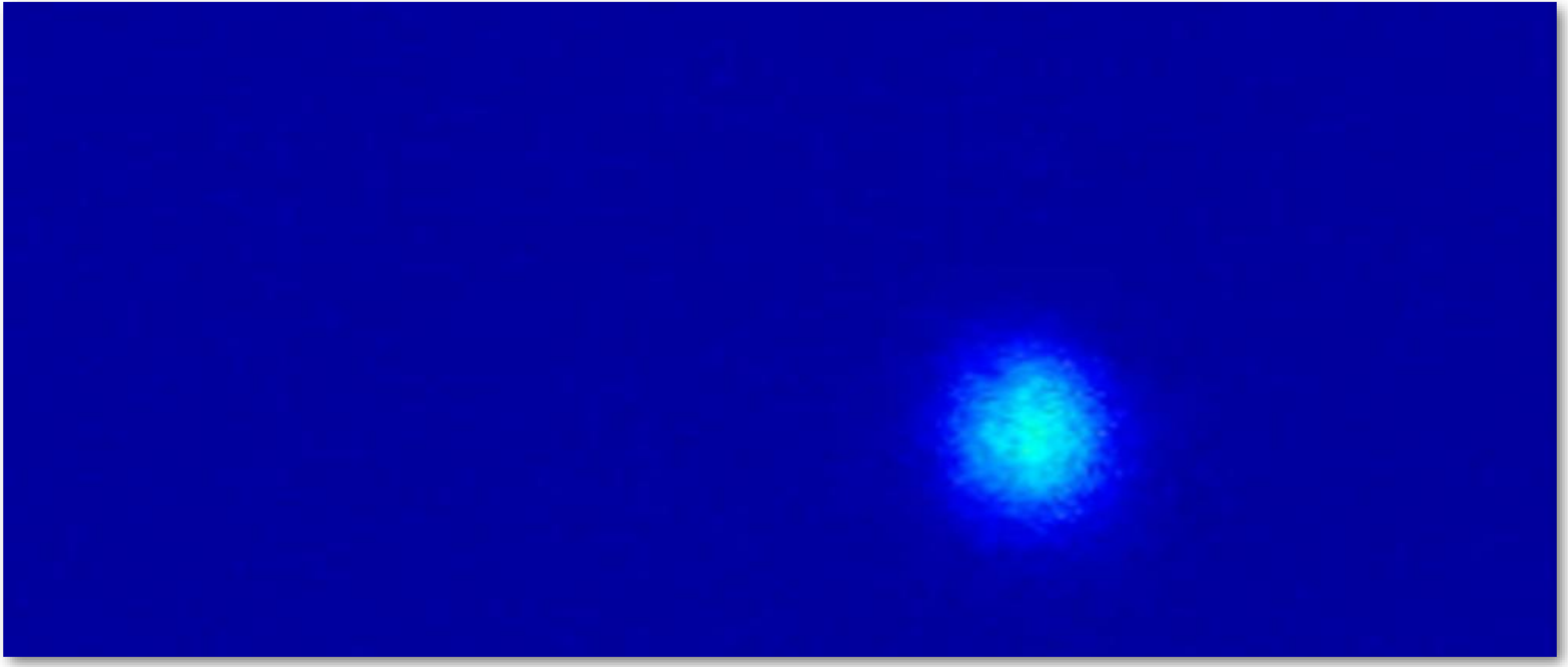
- At the cryo end box and also at the string connection box connecting CS8 to CS9 all connections to the DN200 pipe broke.

XFEL Linac Commissioning (to date)

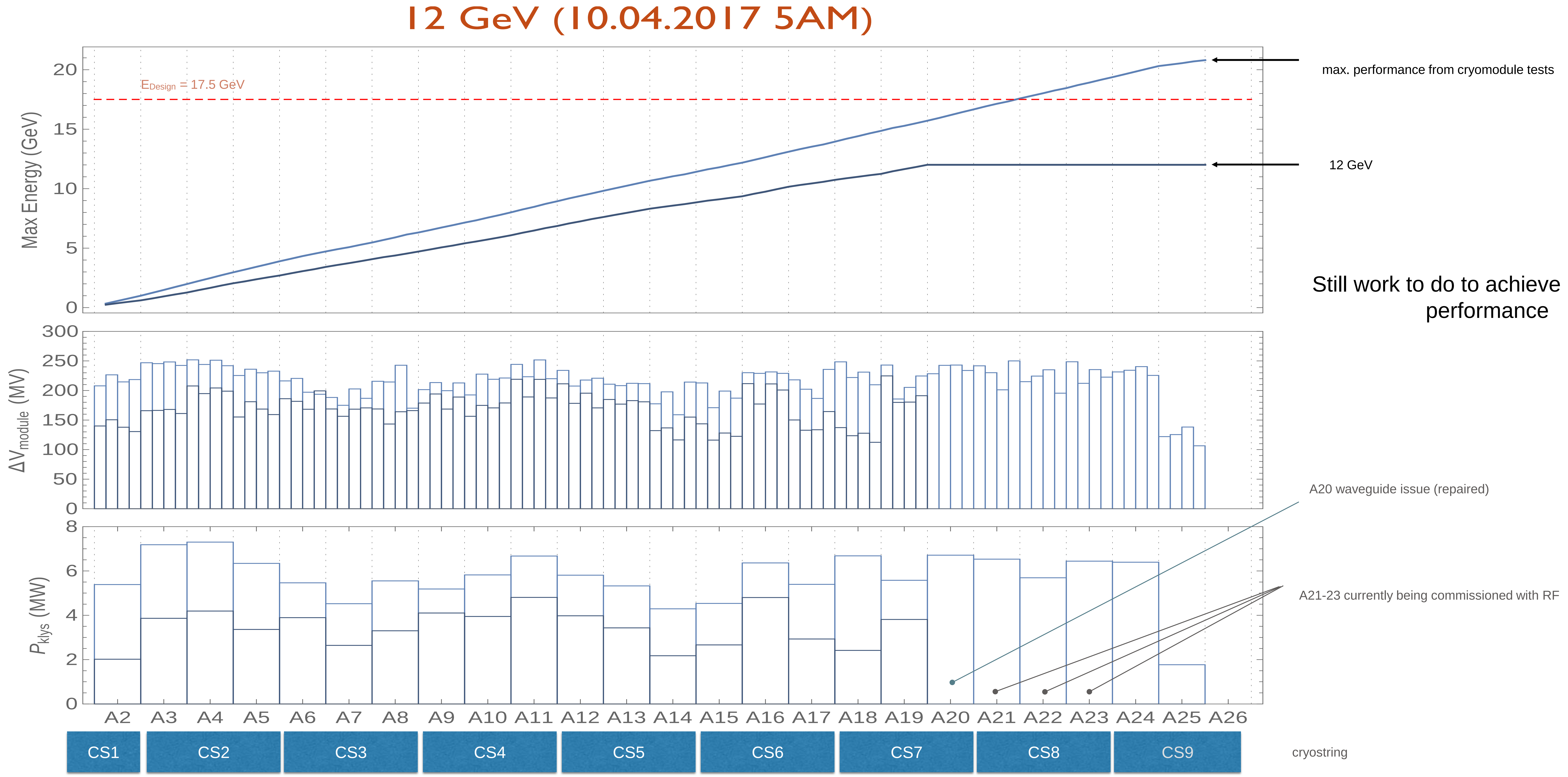
- Injector commissioning (130 MeV) 12.2016 ✓
- L2 and L3 linacs at 2K 6.01.2016 ✓
- L1 (A2) commissioning (600 MeV) 01.02.2016 ✓
- L2 (A2/3/4) commissioning (2.4 GeV) 15.02.2016 ✓
- L3 (A6-25) commissioning ongoing
  → 12 GeV achieved 10 April 2017 ✓
  → **First lasing 4.5.2017 (6.4 GeV, 7.8Å)** ✓



European XFEL: First Laser Light on 3 May 2017



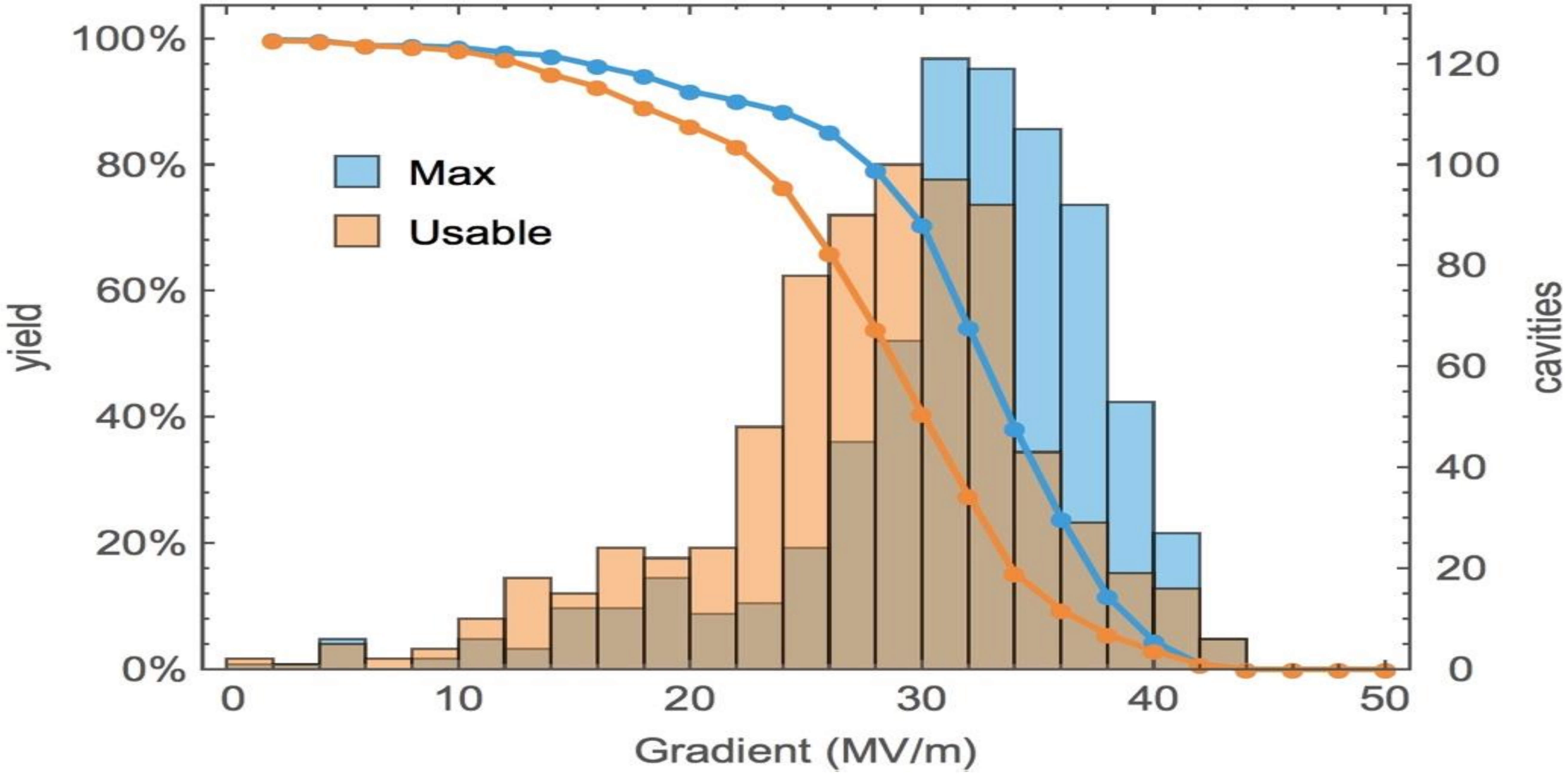
European XFEL: 12 GeV point (max. energy to date)



Still work to do to achieve maximum performance

As Received Usable Gradient in the VT

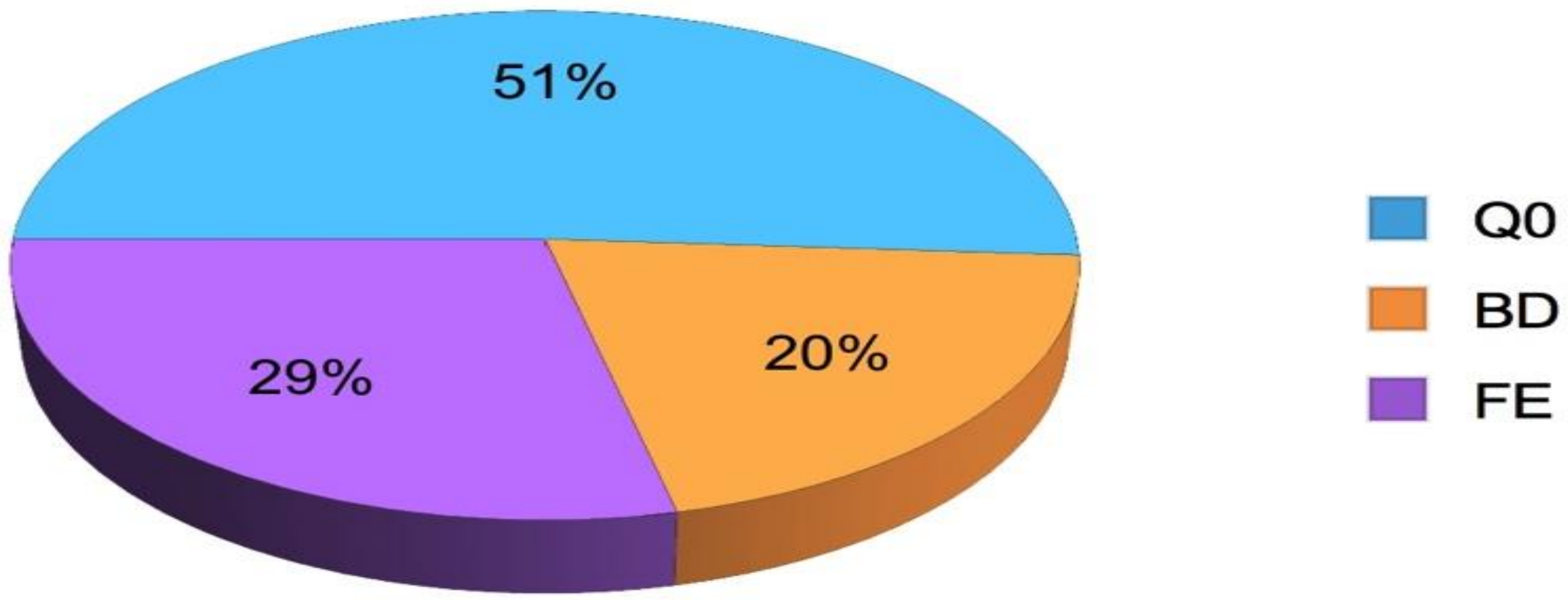
typical individual error: 10%



	Max	Usable
Number of cavities	745	745
⟨G⟩ [MV/m]	31.4	27.7
σ_G [MV/m]	6.8	7.2
$\langle G\rangle_{G\geq 28}$ [MV/m]	34.1	32.8
Yield @20	92%	86%
Yield @28	79%	54%
Yield @35	31%	12%

- Include operations spec
  - $Q_0 \geq 1\times10^{10}$
  - FE threshold (X-ray)

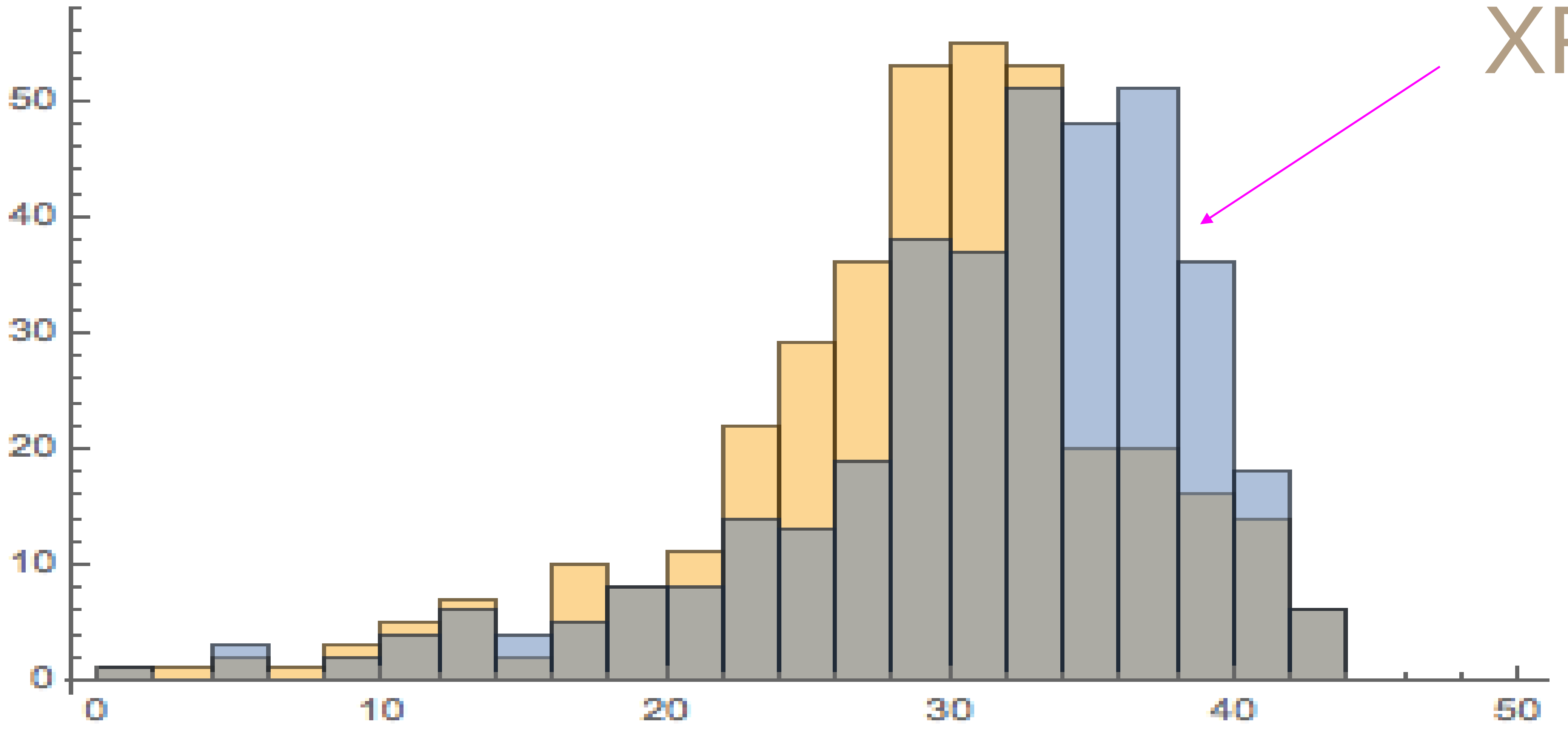
→ Usable Gradient



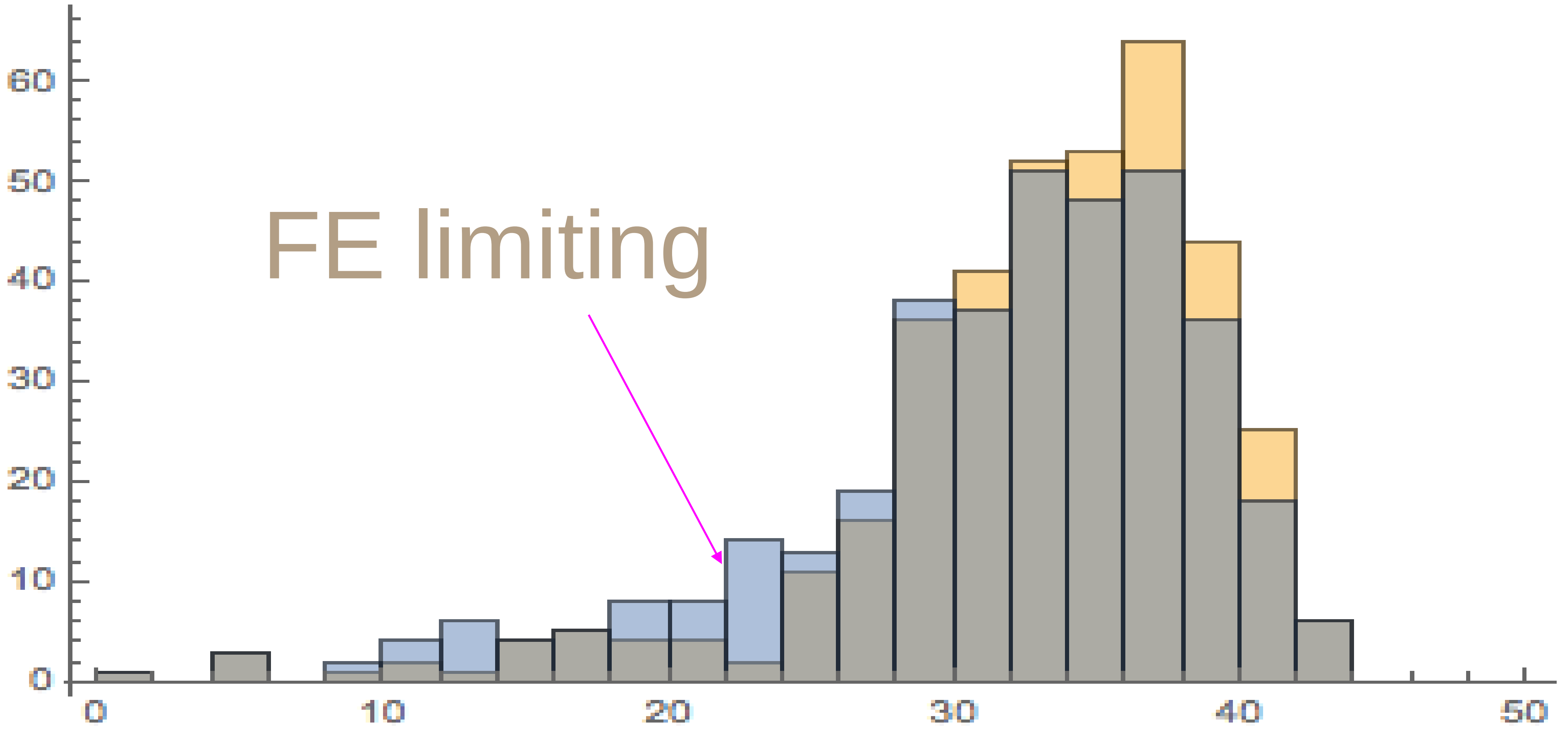
Limiting factor for “as received” cavities.

Usable field – ignore Q_0 criterion? (FE only)

RI cavities only



	Max	Usable	usable No Q
Number of cavities	375	375	372
$\langle G \rangle$ [MV/m]	33.	29.	31.4
σ_G [MV/m]	6.6	7.4	7.5
$\langle G \rangle_{G \geq 28}$ [MV/m]	35.	33.3	34.7
Yield @20	94%	89%	91%
Yield @28	86%	63%	77%
Yield @35	44%	18%	37%



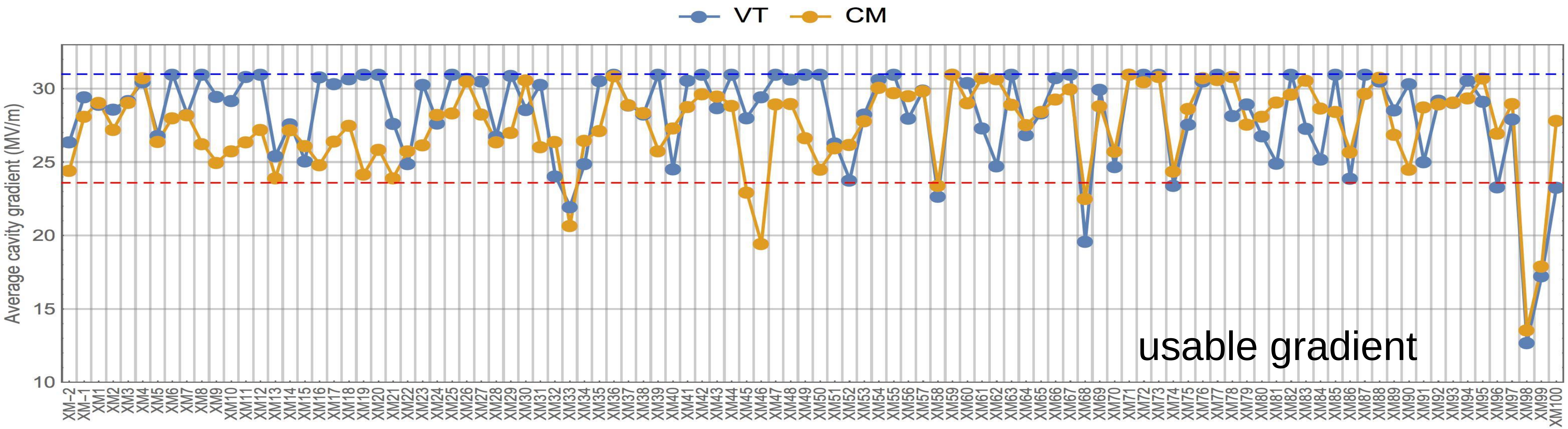
Second pass?

- No direct ‘correct’ comparison possible
  - Cut off for XFEL retreatment ≤20 MV/m
  - ILC is ≤28 MV/m
- Can try to use retreatment MC model based in XFEL results

		ILC TDR (assumed)	XFEL max	XFEL usable
First-pass	Yield >28 MV/m Average >28 MV/m	75% 35 MV/m	85% 35.2 MV/m	63% 33.5 MV/m
First+Second pass	Yield >28 MV/m Average >28 MV/m	90% 35 MV/m	94% 35.0 MV/m	82% 33.4 MV/m
First+Second+third pass	Yield >28 MV/m Average >28 MV/m	- -		91% 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

Cryomodule average gradient performance



	N_{cavs}	Average	RMS
VT	815	28.3 MV/m	3.5
CM	815	27.5 MV/m	4.8

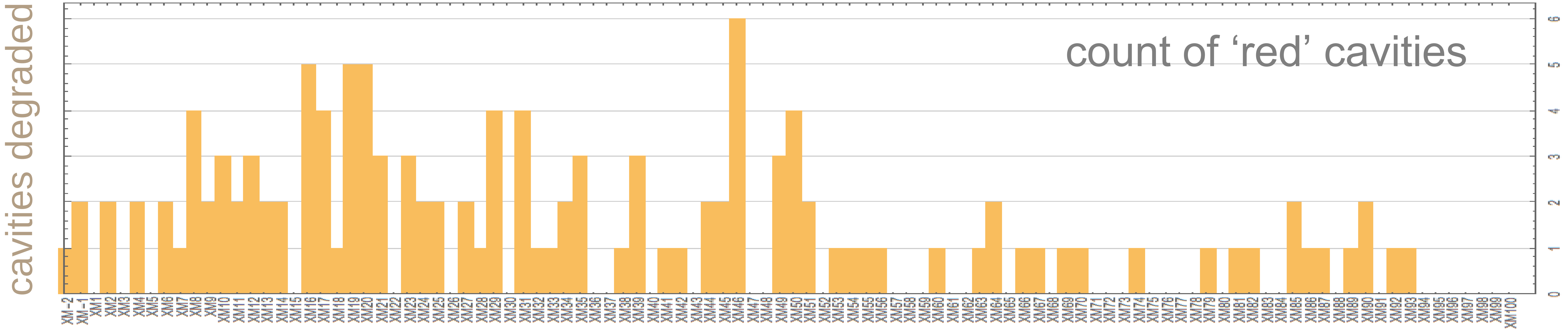
VT capped at 31 MV/m for fair comparison and power considerations

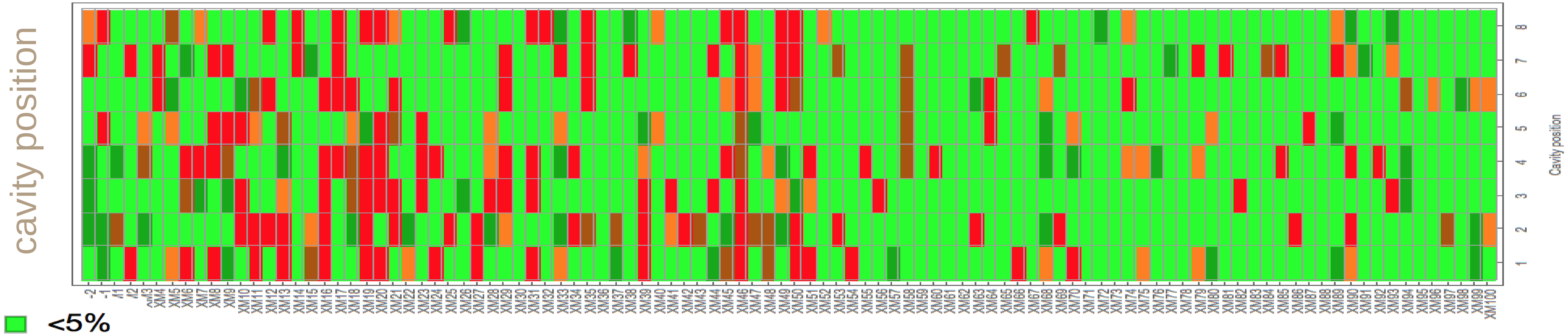
~3% difference measured this way

3% ≤ ΔG ≤ 8%

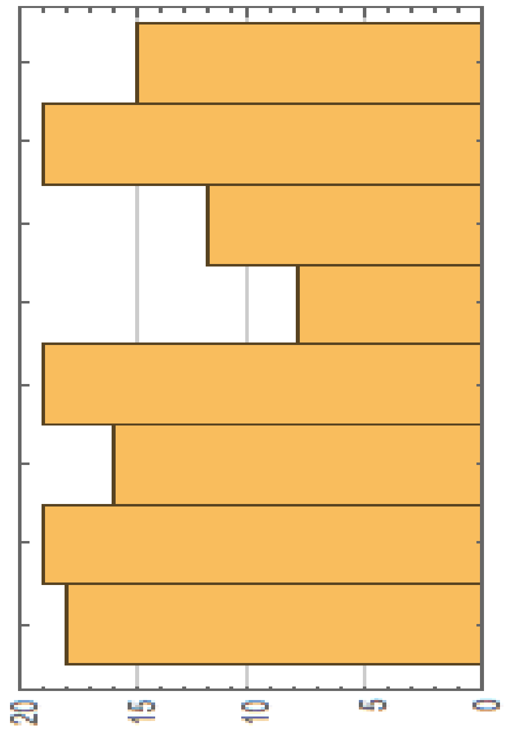
Degradation matrix

Degradation defined as ≥20% (red)





- <5%
- <10%
- <15%
- <20%
- ≥20%



best place to be a happy cavity in a cryomodule

Lessons Learnt?

- TESLA technology has been successfully industrialised and can be mass produced
  - No reasons why this cannot be extrapolated to ILC numbers
- Success requires DILIGENCE (and attention to detail)
  - Close cooperation with cavity vendors
  - Constant feedback, QA and QC
- Standard ‘TESLA’ recipe can *almost* achieve ILC specifications
  - But improvement still needed
  - 30 MV/m average is great, but 7 MV/m RMS spread is too large (why?)
  - Q_0 performance (Nitrogen anybody?)
- String assembly without degradation is not impossible
  - Again, requires diligence!
  - Auditing, QA/QC, feedback, etc.

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The European strategy process

Europe's strategy updated last in May 2013, approved by CERN Council (i.e. the European funding agencies). Central elements:

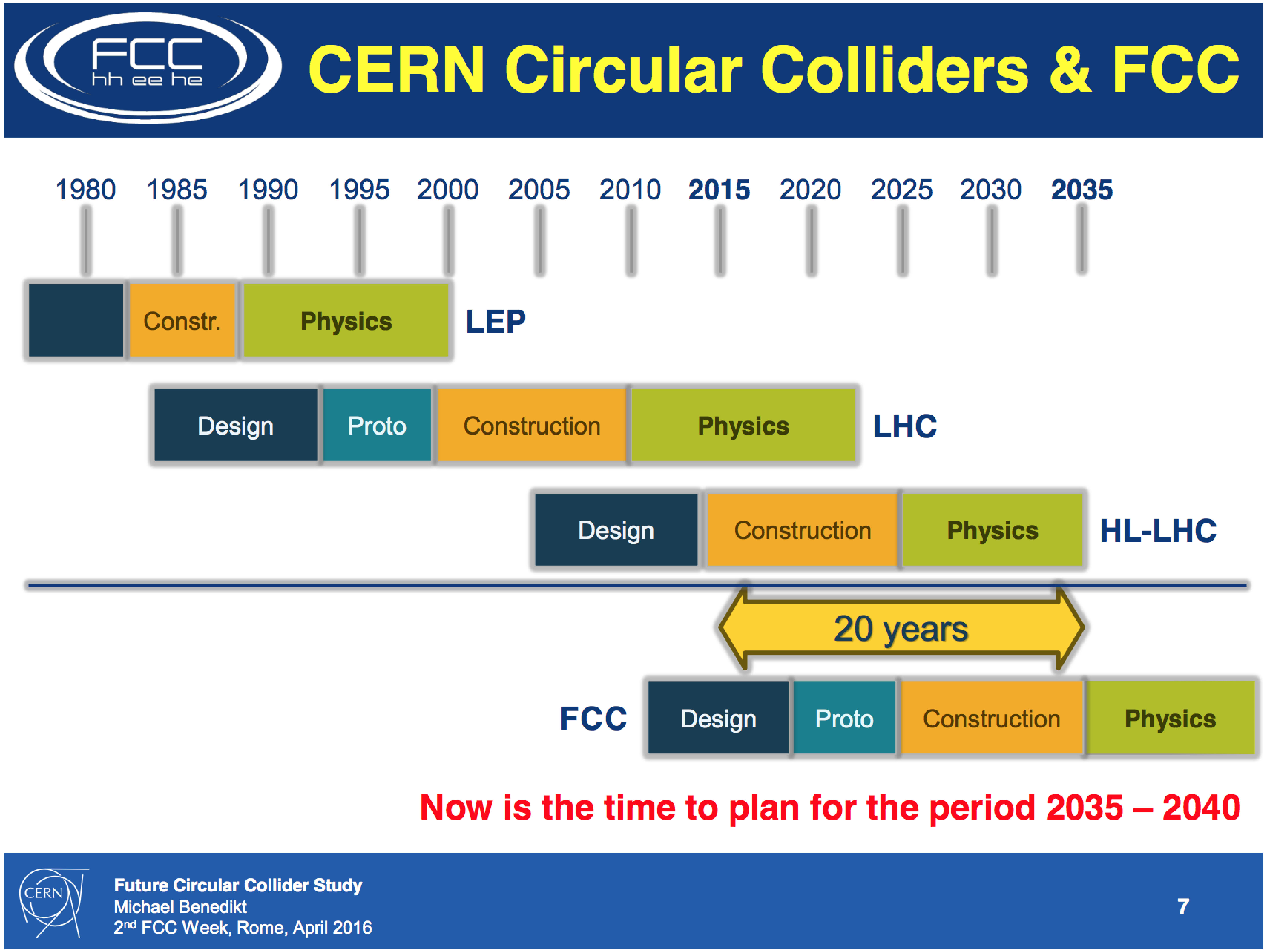
- LHC and HL-LHC
- Accelerator R&D
- Strong support for ILC
- Importance of theory
- Role of national laboratories

> e) There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. *Europe looks forward to a proposal from Japan to discuss a possible participation.*

Next update of strategy expected 2020

- Preparations starting now European countries
- Personal view: Various large contenders for European support:
  - HL-LHC is clearly set
  - CLIC and FCC – there can only be one future project / study?
  - ILC? Interesting development: ILC European Action plan figured in September meeting with European funding agencies.
  - High-energy LHC as very serious option

The European strategy process



Discussion in Germany

Various different elements of strategy development in Germany:

- National roadmap: collection of large-scale research projects (e.g. “LHC upgrades”, “European XFEL” etc.)
- KET (“Committee for Elementary Particle Physics”) drives a HEP strategy process: discussions in and statements from the community.

Last KET workshop:
2/3 May 2016, MPI Munich: e^+e^- physics

- Physics case of future e^+e^- machines
- Presentations from e.g. CLIC, FCC-ee, CPEC, ILC, …
- Trying to define the German community’s opinion concerning the various options
- Surprisingly clear outcome ...
- Outcome will be fed into discussions with ministry;
- but no immediate impact expected.

Outcome of German KET workshop

Conclusions of the

KET Workshop on Future e^+e^- Colliders[a]

Max-Planck-Institut für Physik Munich, May 2-3, 2016

1. The physics case for a future e^+e^- collider, covering energies from M_Z up to the TeV regime, is regarded to be very strong, justifying (and in fact requiring) the timely construction and operation of such a machine.[i]

2. The ILC meets all the requirements discussed at this workshop.[ii] It is currently the only project in a mature technical state. Therefore this project, as proposed by the international community and discussed to be hosted in Japan, should be realised with urgency. As the result of this workshop, this project receives our strongest support.[iii]

3. FCC-ee, as a possible first stage of FCC-hh, and CEPC could well cover the low-energy part of the e^+e^- physics case, and would thus be complementary to the ILC.[iv]

4. CLIC has the potential to reach significantly higher energies than the ILC. CLIC R&D should be continued until a decision on future CERN projects, based on further LHC results and in the context of the 2019/2020 European Strategy, will be made.

[i] Main topics are ultra-high precision tests of the electroweak Standard Model and of Quantum-Chromodynamics (QCD), precision Higgs Physics (mass, width, couplings, self coupling) and precision top-quark physics, which are all well defined and not based on speculation. Apart from these "guaranteed" advancements of our knowledge, precision tests also carry a huge potential towards physics Beyond the Standard Model (BSM), especially through the effects of radiative corrections with sensitivities beyond the TeV region. At high energies these projects are sensitive to the direct observation of physics BSM, complementary to and extending the reach of searches performed at the LHC.

[ii] The basic requirements and features of e^+e^- circular and linear collider projects have been extensively discussed at this workshop, and are summarized, in a simplistic scheme, in the following table:

Topic	CEPC	FCC-ee	ILC	CLIC
Higgs Mass, couplings	+	+	+	+
Higgs self-coupling	-	-	+	+
Top physics	-	+	+	+
ew- precision parameters	+	+	+	-
BSM (direct searches)	-	-	+	+
Flexibility to new high mass signal	-	-	-	+
Maturity of project	-	-	+	-
Start by/before 2035	+	-	+	-

[iii] Technological maturity is reached in general, proven by successful industrial mass production and implementation in the European XFEL, which can be considered as a large scale technological prototype of the ILC. The design provides the possibility of beam polarisation, which is an essential ingredient for precision physics results. The project is under political consideration in Japan. There exist superior detector designs and respective R&D.

[iv] Circular colliders are especially advantageous for efficient measurements with highest statistics at the "low-energy" (M_Z and below) side of the targeted energy spectrum. This "Tera-Z" operation allows to reduce the uncertainties of electroweak parameters substantially, which are an important ingredient for theoretical predictions at high energies. The efficiency of the linear collider projects at M_Z and below is limited and requires substantial effort. This opens the possibility of efficient task- and cost-sharing between circular and linear colliders, if regional considerations and possibilities lead to the realization of more than one project.

Outcome of German KET workshop

C. Zeitnitz

My Pros and Cons Matrix

Topic	CEPC	FCC-ee	ILC	CLIC
Higgs Mass, couplings	+	+	+	+
Higgs self-coupling	-	+-	+	+
Top physics	-	+	+	+
ew- precision parameters	+	+	+-?	?
BSM	-	+-	+-	+
Flexibility to new high mass signal	-	-	+-	+
Maturity of project (not age!)	-	-	+	-
Detectors	-	-	+	+
Start 2035	-	-	+	-

03.05.2016 Christian Zeitnitz – KET e+e- Workshop 26

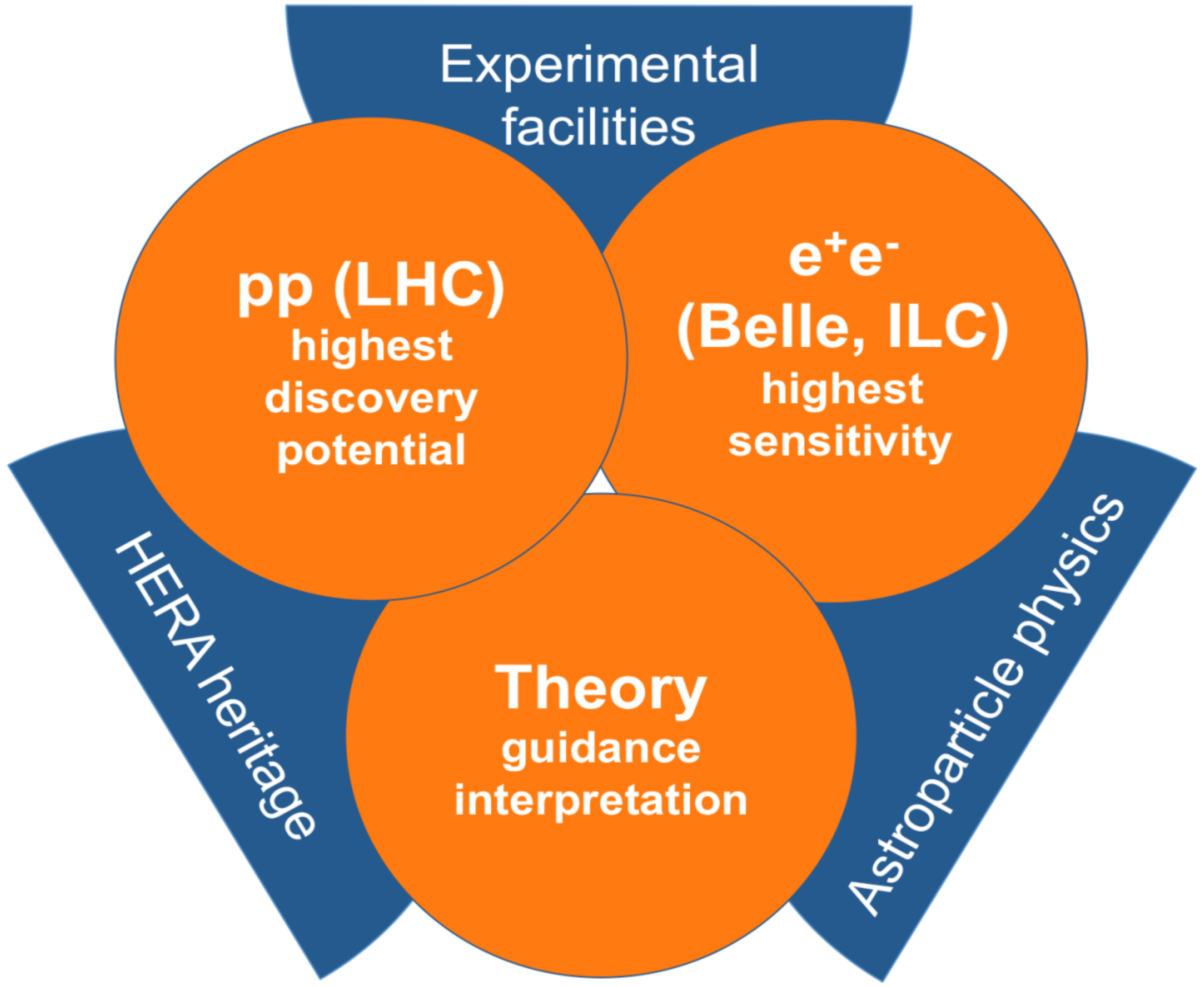
Other options

On the other hand …

Situation in Germany

DESY / Helmholtz:

- e^+e^- physics at ILC and Belle on of the pillars of our current strategy.
- May aspects of physics & detector; some machine development (SRF)
- Update of strategy soon (<1 year, clash with European timeline)
- Will probably rather speak of “future projects”



Universities:

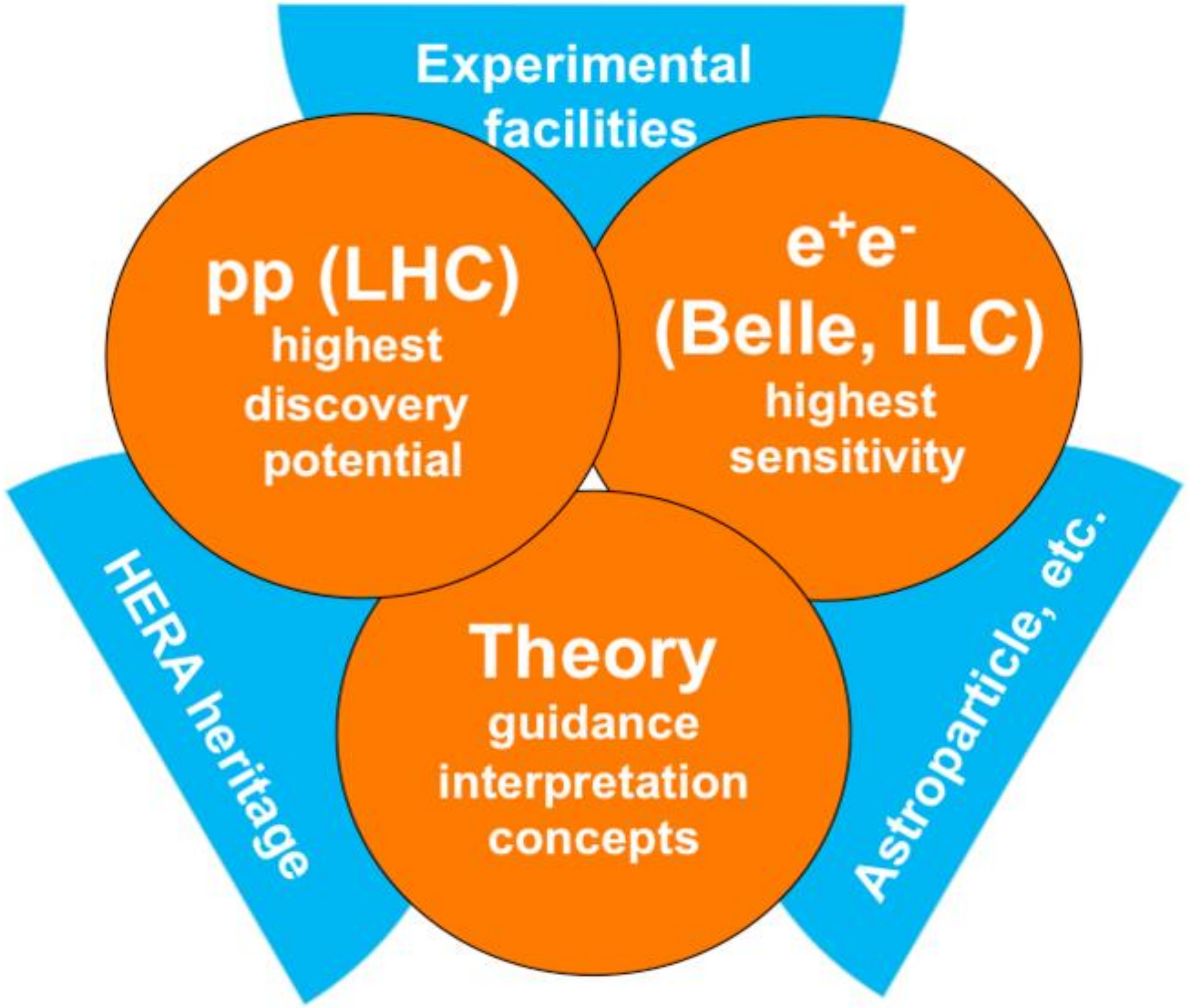
- Some federal funding secured, e.g. for physics / theory and positron polarisation; but future not clear

Outlook:

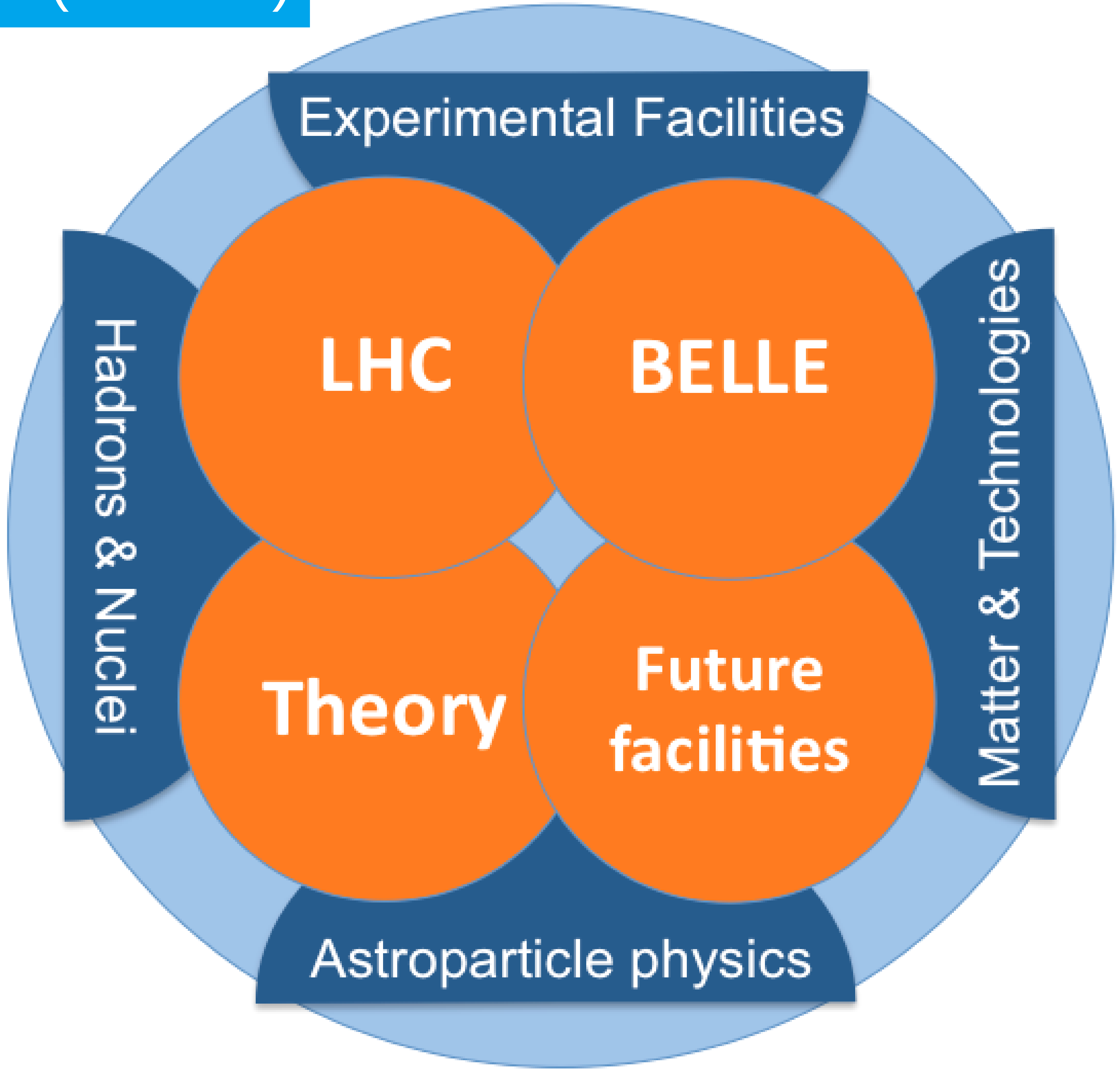
- Currently orientation / strategy building on DESY and national level
- It gets harder to justify ILC as “the” future project without clear positive signs from Japan.
- This statement is true for all countries.

DESY STRATEGY BEYOND PoF III

POF 3 (2015-19)



POF 4 idea (2020++)



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Towards a European Action Plan

Originally requested by Okada-san from the KEK ILC Planning Office

- A report outlining Europe's possible contribution during the four-year preparatory phase
- Similar to KEK document
- Discussed by Okada-san and E. Elsen
- Suggestion to prepare this within E-JADE context, with Steinar Stapnes as coordinator
- Originally intended timescale: two month, 4+4 European and Japanese colleagues

Comparison to KEK document

- KEK document deals with only one country (in fact only one lab)
- Europe is much more complicated: many countries, labs, funding agencies
- Scope therefore shifted to potential EU in-kind contributions (cost if EU IKC, EU core competencies, who might do what …) along ILC WBS

Table 2. Technical issues to be settled during the ILC accelerator preparation phase

	Pre-preparation Phase	Main Preparation Phase			
	Present	P1	P2	P3	P4
ADI	Establish main parameters	Verify parameters w/ simulations			
SRF	Accelerate beam with SRF cavity string and cryomodule	Demonstrate mass-production technology and stability Demonstrate Hub-lab functioning and global sharing			
Nanobeam	Achieve the ILC beam-size goal	Demonstrate the nanobeam size and stabilize the beam position			
Positron source	Demonstrate technological feasibility	Demonstrate both the undulator and e-driven e+ sources			
CFS	Pre-survey and basic design	Geology survey, engineering design, specification, and drawings			
Common technical support	Support engineering and safety	Common engineering supports (network, radiation safety, etc.)			
Administration	Project planning and promotion Preparation for the ILC pre-lab	General affairs, finance, international relations, public relations Establishing the ILC pre-lab and managing the ILC preparation			

Table 3. Human resources required during the ILC accelerator preparation (FTE) [1)]

	Pre-P.[2)]	Main Preparation[3)]				Construction[4)]		Notes
	(present)	P1	P2	P3	P4	C1	C2	
Acc: JP	42	54	74	98	122	172	530	JP: needs to mature SRF mass-prod. technology[5)]
: abroad	≥ 20	28	41	65	89			EU/US: already has experience[6)]
CFS: JP	3	11	11	13	17	52	53	JP: is primarily responsible, w/ outsourcing
: abroad	1	3	5	5	5			abroad: professional contribution
Comm: JP	2	7	10	13	14	109	109	JP: is primarily responsible
: abroad	1	3	4	6	7			abroad: professional contribution[7)]
Admin: JP	5	8	10	14	18	77	230	JP: is primarily responsible
: abroad	3	4	6	8	10			abroad: professional and regional contribution[8)]
Sum	≥ 77	118	161	222	282	410	922	

Additional comments
1) During the preparation phase, the contribution from abroad is to gradually increase to 20–40% (of total number) and to prepare for further contribution in the construction phase after reaching an international agreement for the ILC construction and work-sharing.
2) Pre-preparation Phase: Current status (based on general advanced accelerator R&D budget)

Towards a European Action Plan

Europe
Philip Bambade (LAL Orsay)
Benno List (DESY)
Philip Burrows (Oxford)
Angeles Faus-Golfe (Valencia)
Brian Foster (DESY)
Olivier Napoly* (CEA)
Thomas Schörner-Sadenius (DESY)
Marcel Stanitzki* (DESY)
Steinar Stapnes* (CERN - coordination)
Nick Walker* (DESY)
Hans Weise (DESY)

KEK
Tomio Kobayashi*
Shinichiro Michizono*
Yasuhiro Okada*
Akira Yamamoto*

* Originally proposed joint-WG membership by Okada

Who can speak for "Europe"?

Purpose of document not entirely clear:

- KEK says it will be useful for them? Will they show it to MEXT?
- Might also be useful for European discussion (starting 2019) – input to CERN Council?
- How to make it carry some weight?

Towards a European Action Plan

May 11, 2017

ILC European Action Plan

Towards a European Contribution to the International Linear Collider

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E-JADE

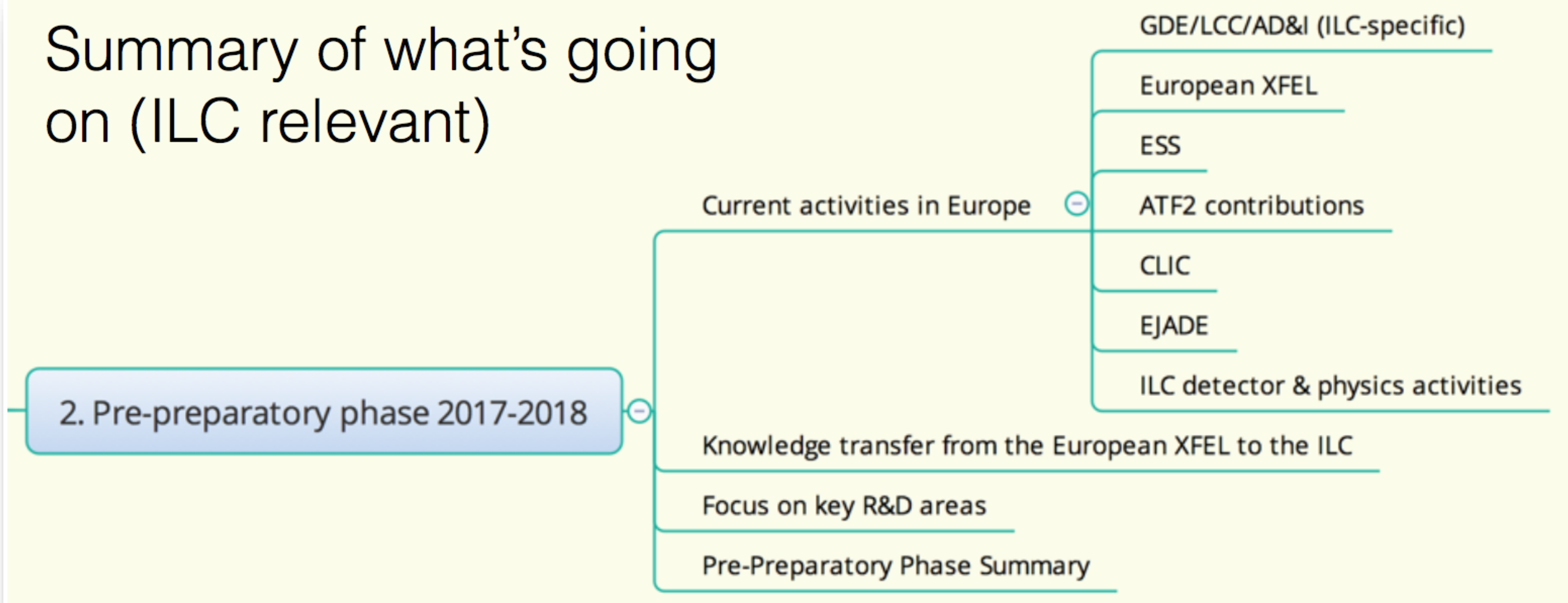
Revision:66 May 11, 2017 by stanitz

Figure 6: The currently on-going ILC-related activities in Europe.

Going through three phases of ILC

- Pre-preparatory phase
- Preparatory phase
- Construction phase

… and asking what Europe is (currently) or might be doing. “Currently” is the easiest part:



XFEL synergy always as biggest European contribution

Towards a European Action Plan

Preparatory Phase (4 years)

- Four-year phase before construction - R&D and industrial preperation for European IKC
- Will look at European capabilities for deliverables across the ILC
- Estimate 3% (200 MEuro) in overall prep. phase budget, with 40 M$ European budget Emphasis that we now consider a build up phase towards construction later (beyond 2022) for each item.
- Assume we are talking about final prototypes, pre-series with (preferable) European industry, plus

Components	European part	Fraction (%)	Rationale
SC cryo-modules (34% of project)	Assume 1/3 Europe	11.4	European expertise and industry (EXFEL and ESS)
Cryogenics system (8.6% of project)	Assume 1/2 Europe	4.3	European expertise and industry (LHC and EXFEL)
1.3 GHz RF (9.5% of project)	Assume 1/3 Europe	3.1	European expertise and industry (EXFEL and ESS)
Components for ES, PS, DR, RTML, ML, BDS	Too early to detail but need match of capabilities and contribution size	4.2	Magnets and power, instrumentation, controls & computing, etc
Sum		23	

Table 5: A Model for a European Contribution to the ILC

Construction phase even more complicated.

Possible forms of EU involvement complicated:

- AKA “what is the role of CERN”?
- Trying to demonstrate the ILC contribution is within CERN mandate (ILC as NGO in GDE “Project Implementation Plan”)
- For preparatory phase assume MoU-based “collaborations” with annual budget of ~10MCHF/year + 20 FTE (more from non-CERN collaborators?)

Towards a European Action Plan

	Accelerator Design and Integration										SCRF						
	BDS	DR	Electron Source	Positron Source	RTML	ML Integration	Simulations	CFS	Controls	Total AD&I	Cavities	Cavity Processing	Cavity Production	Cryogenics			
CERN	3	3		2		4	5	4		21				1			
France	21			16	5				25	67	74						
CEA/Saclay	9									9	11						
CNRS					5					5	10						
IPN-Orsay											8						
LAL-Orsay	12			16					19	46	45						
LAPP-Annecy									7	7							
Germany	4	3	1	22	1	7	5	5	41	88		89	7	7			
DESY	1	3	1	22	1	5	5	5	37	79		89	7	7			
FhG									2	2							
GSI									1	1							
Mannheim									1	1							
Rostock						2				2							
TU Darmstadt	3									3							
Italy		19							2	21	45			2			
INFN		19							2	21	45			2			
Poland									20	20							
IPJ									6	6							6
TUL									10	10							10
WUT-ISE									4	4							4
Russia			36	21				14		71	10				51		
Budker				21						21							
JINR			36					14		50	10				51		
Spain	16					4				20					2		
CIEMAT										0					2		
IFIC	16					4				20							
Sweden	2				2					3							
UU	2				2					3							
Switzerland									3	3							
PSI									3	3							
UK	80	9		11						100							
ABCD-UK	4									4							
Birmingham	1									1							
Dundee	1									1							
Lancaster	3									3							
Liverpool		5		1						6							
Manchester	3									3							
Oxford	31									31							
RHUL	13									13							
STFC	22	4		11						36							
UCL	3									3							
Total	126	34	37	71	7	15	10	23	90	413	129	89	7	10	72	7	

Figure 2: Estimated total FTE (person years) contribution to the ILC GDE (

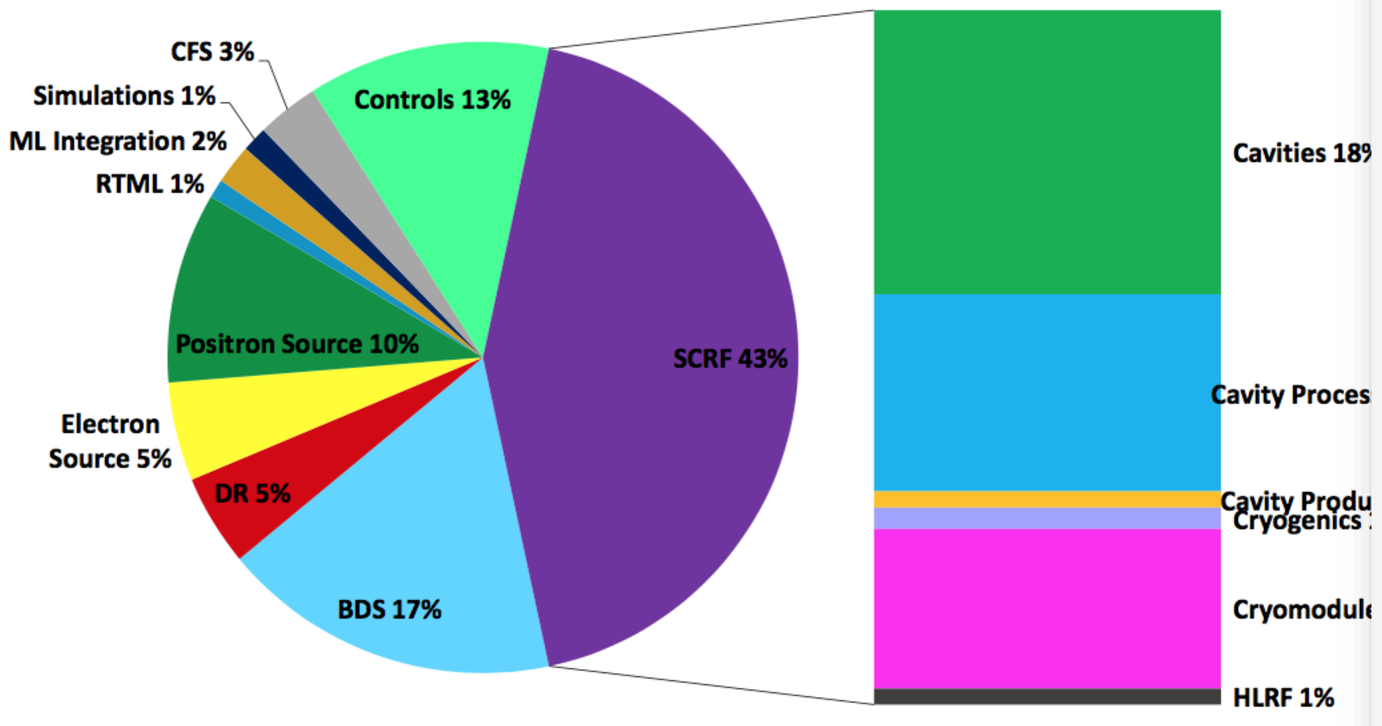


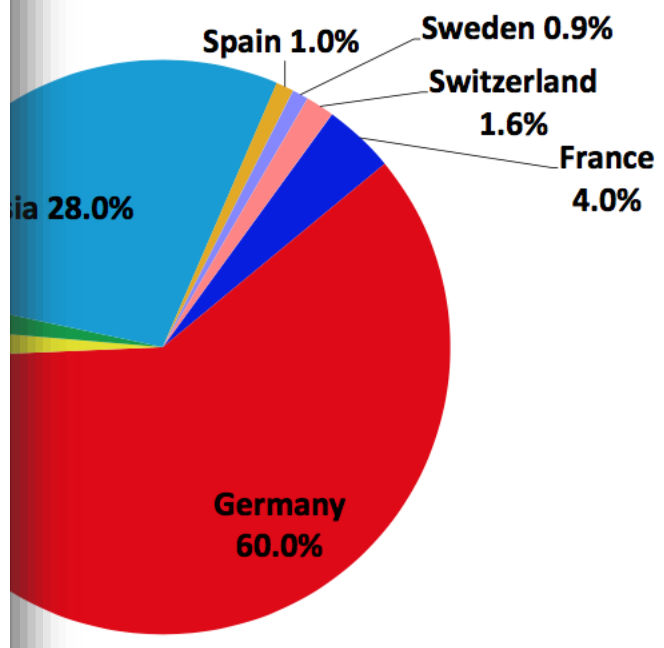
Figure 3: The distribution of the effort to the ILC GDE (2007

WPG-1 LINAC	Germany DESY	France CEA Saclay	France LAL	Italy INFN Milan	Poland IFJ PAN	Poland WUT	Poland NCBJ	Russia BINP Nov	Spain CIEMAT
WP-03 Cryomodules	■	■		■					
WP-04 SRF cavities	■			■					
WP-05 Power Couplers	■		■						
WP-06 HOM couplers							■		
WP-07 Frequency Tuners	■								
WP-08 Cold Vacuum	■							■	
WP-09 Cavity string assembly	■	■							
WP-11 SC magnets	■				■				■
WPG-5 Infrastructure									
WP-10 AMTF	■				■	■		■	
WP-13 Cryogenics	■								
WPG-6 Sites & Buildings									
WP-45 AMTF hall	■								

Table 2: Responsibility matrix for cryomodule production and testing for the European XFEL. (Note only cryomodule-relevant work packages are shown. Note also that including projects such as ESS will bring additional European institutes into play for SCRF; see Section 2.2.3)

Country	Tracking	Calorimetry	MDI	System Integration
CERN	■	■	■	■
DESY	■	■	■	■
Czech Republic	■	■		
France	■	■		■
Germany	■	■		
Israel		■		
Netherlands	■			
Norway		■	■	
Poland		■		
Serbia		■		
Spain	■	■		■
UK	■	■	■	

Table 4: An overview of the present activities in the area of ILC-related detector R&D and integration in Europe.



es contributing to the XFEL total

Country	Fraction (%)
Germany	60.0
Russia	28.0
France	4.0
Italy	2.0
Poland	2.0
Switzerland	1.6
Spain	1.0
Sweden	0.9

Table 1: Fractions per Country to the XFEL total project costs (**Ed:** *NUMBERS TO BE UPDATED)*

Conclusions

- European XFEL
  - Impressions
  - Status
  - Lessons learnt

- ILC in Europe (Germany)
  - Activities become harder to justify

- European Action Plan
  - To be finalised until end of May (Steinar Stapnes, Marcel Stanitzki)
  - Impact and usefulness not yet entirely clear.