TTC Meeting 参加とDESY見学の報告 (2014/3/24-27 @DESY）

坂中 章悟
加速器研究施設

2014/04/08 第82回ERL検討回

v1

TESLA Technical Collaboration (TTC) Meeting at DESY

TESLA Technical Collaboration (TTC) Meeting at DESY

Working group session

TTC Meeting

ウェッブページ:
https://indico.desy.de/conferenceDisplay.py?ovw=True&confId=9637

- The mission of the TESLA Technology Collaboration is to advance SRF technology R&D and related accelerator studies across the broad diversity of scientific applications, and to keep open and provide a bridge for communication and sharing of ideas, developments, and testing across associated projects. To this end the Collaboration supports and encourages free and open exchange of scientific and technical knowledge, expertise, engineering designs, and equipment.
- The TTC organizes regular collaboration meetings where new developments are reported, recent findings are discussed and technical issues are concluded. The next meeting will be hosted by DESY 24-27 March 2014.
- Program Committee:
  Olivier Napoly, CEA Camille Ginsburg, FNAL Hans Weise, DESY Eiji Kako, KEK Wolf-Dietrich Möller, DESY

- 今回のKEKからの参加者: 梅森、阪井、坂中、山本(明)、加古、山本(康)、加藤(茂)、土屋(清)、増沢

Plenary Talks

- Introduction and update since last collaboration meeting, Olivier Napoly
- CEBAF Upgrade Experience, Mike Dury
- First Beam Recirculation and Energy Recovery in Compact ERL at KEK, Shogo Sakanaka
- ESS SRF, Christine Darve
- European XFEL Accelerator Module Aseembly, Stephane Berry
- FLASH operational experience, Siegfried Schreiber

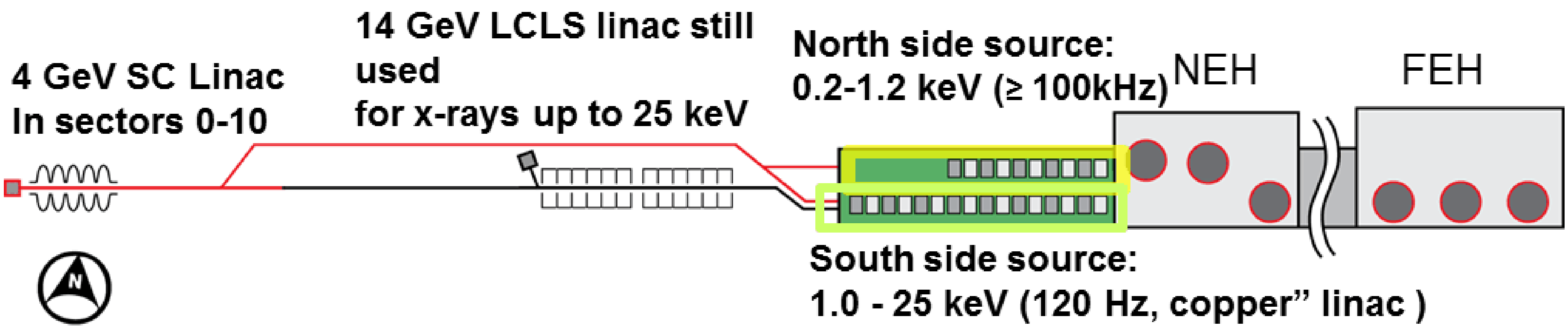
Closing Plenary

- LCLS-II overview - SRF related, Marc Ross
- TTC High Q0 working group - report, Charles Reece

発表スライドは indico ページを参照:
https://indico.desy.de/conferenceDisplay.py?ovw=True&confId=9637

A New LCLS-II Project:

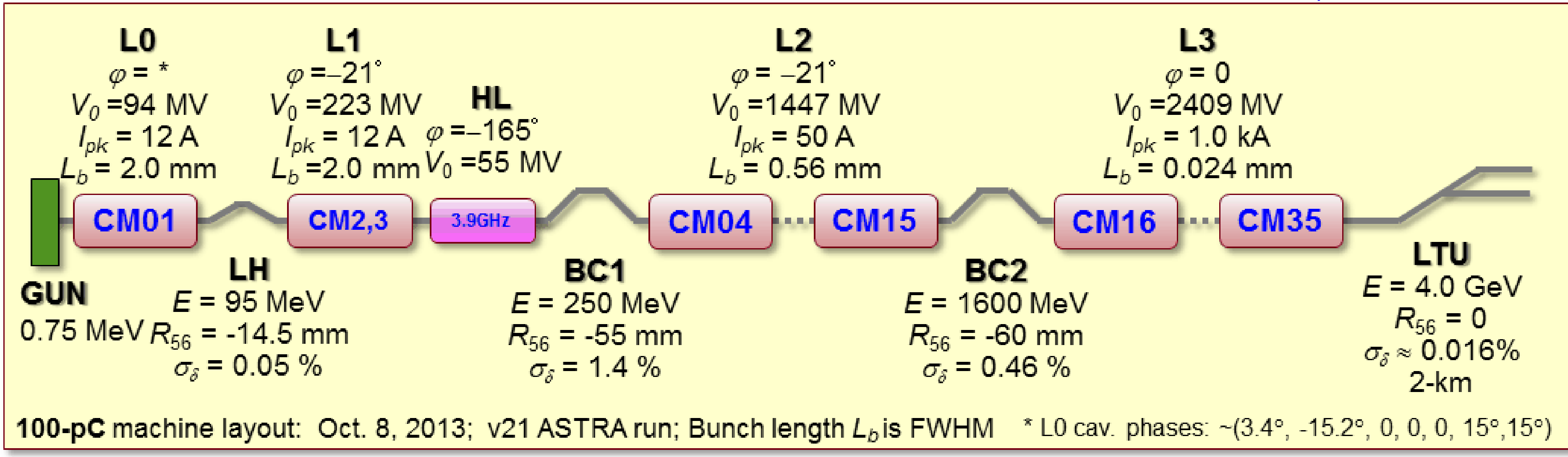
Accelerator	**Superconducting linac**: 4 GeV
Undulators in existing LCLS-I Tunnel	New variable gap (north) New variable gap (south), replaces existing fixed-gap und.



Commissioning planned for late 2019

LCLS-II - Linac and Compressor Layout for 4 GeV

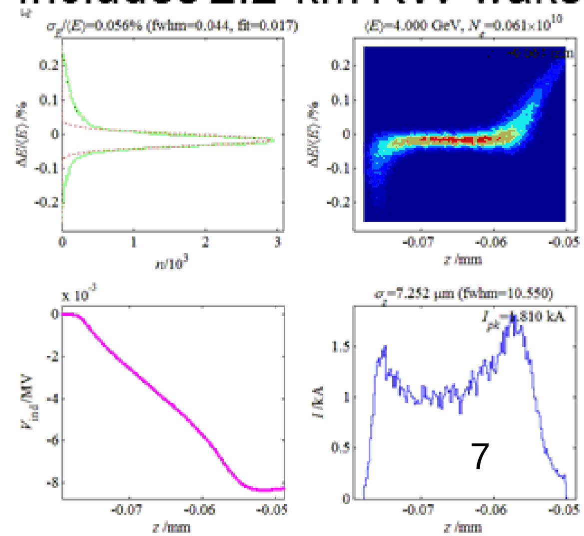
LCLS-II Overview - SRF related, Marc Ross



P. Emma, L. Wang, C. Papadopoulos

Linac Sec.	V (MV)	φ (deg)	Acc. Grad. (MV/m)	No. Cryo Mod's	No. Avail. Cav's	Spare Cav's
L0	94	*	13.2	1	8	1
L1	220	–21	14.3	2	16	1
HL	–55	–165	14.5	3	12	1
L2	1447	–21	15.5	12	96	6
L3	2409	0	15.4	20	160	10

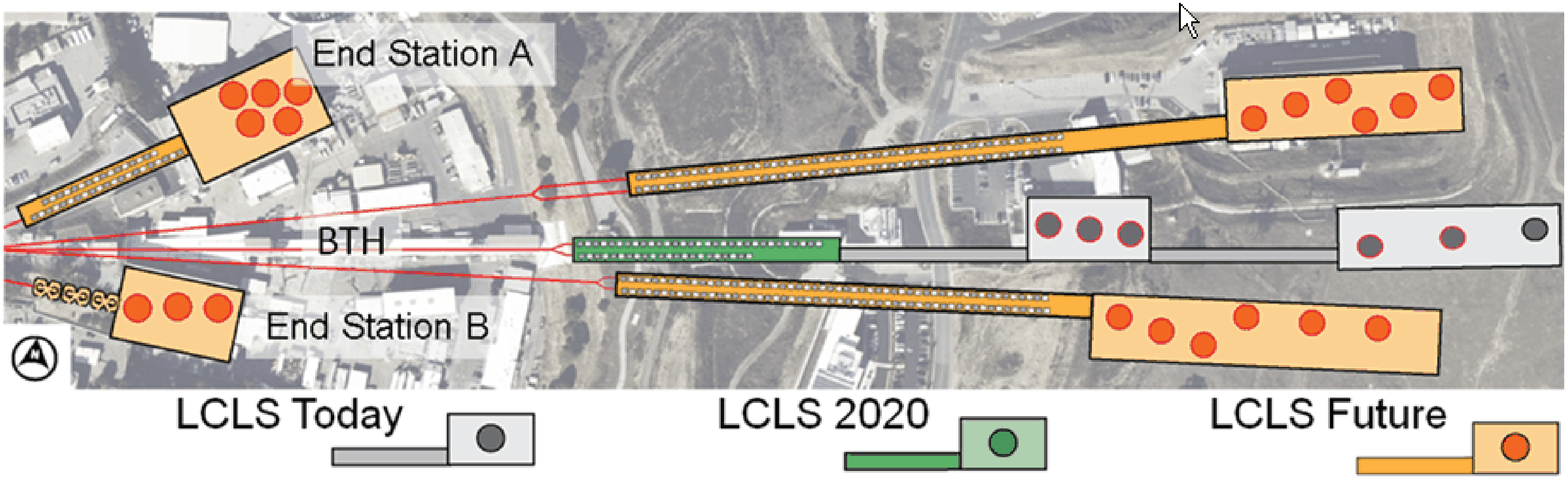
Includes 2.2-km RW-wake



Future Facility Expansion

SLAC has extensive infrastructure that will allow expansion

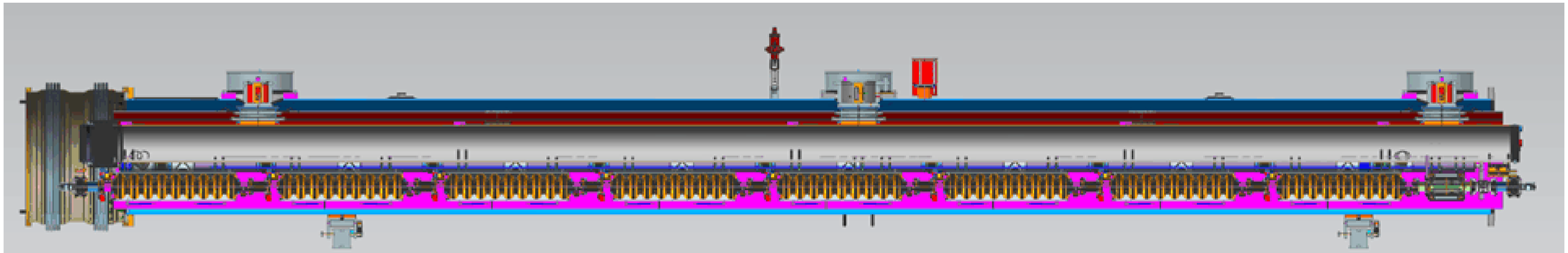
- New tunnels are possible north and south of existing LCLS tunnel (complete design for LCLS-II$_{\text{Phase I}}$) and could be optimized for long, high pulse energy, hard X-ray FEL's
- Original research halls: ESA and ESB suitable for shorter, soft X-ray FEL's



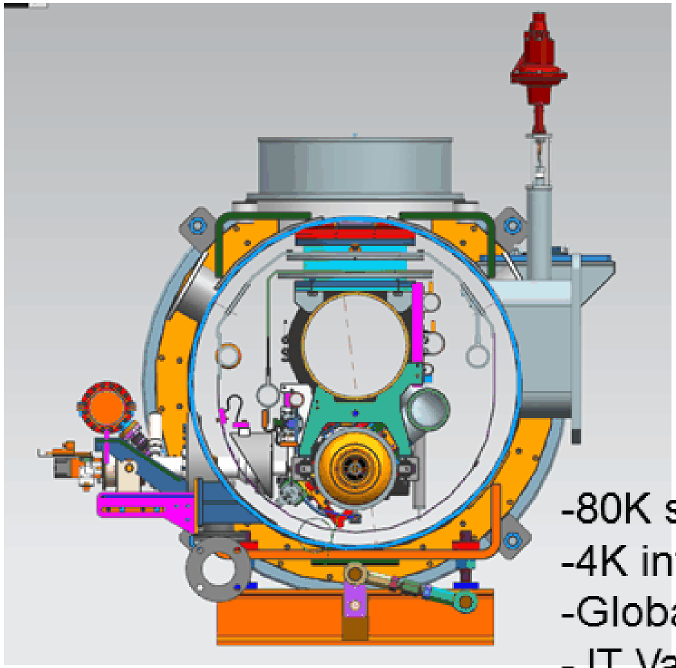
Cavity Specifications (1)

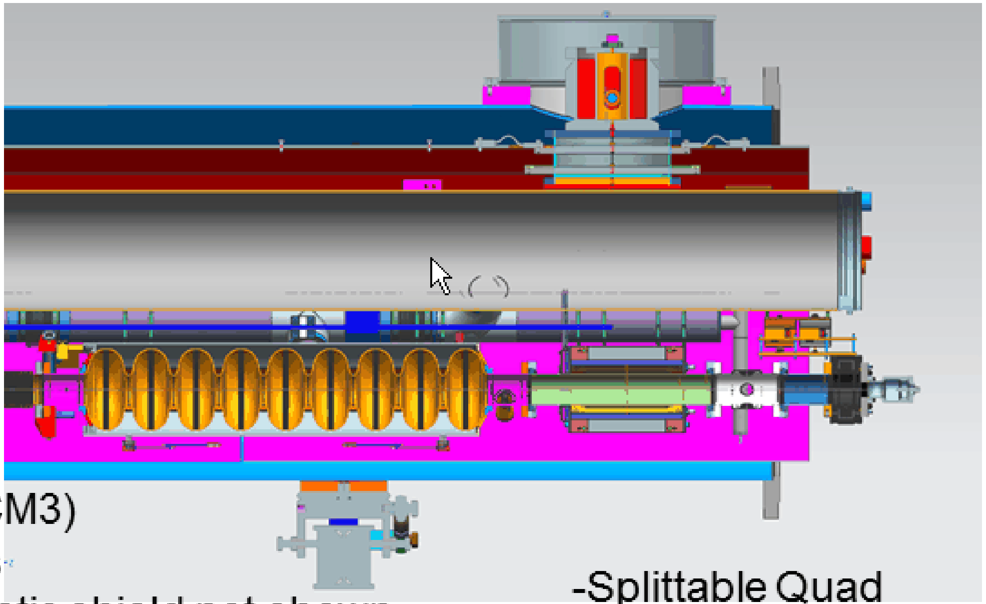
RF frequency	1300	MHz
Operating temperature	2	K
Average operating gradient	~16	MV/m
Average Q_0	2.7×10^{10}	-
Cavity length (L)	1.038	M
R/Q (r/Q)	1036 (998)	Ω (Ω/m)
Geometry constant (G)	270	Ω
HOM damped Q value (monopole and dipole)	$\leq 10^{7}$	-
Number of cavities per CM	8	-
Cavity alignment requirements (RMS)	0.5	mm
RF beam power per cavity (@300 μA load)	5	kW
RF power needed per cavity	6.3	kW
Cavity dynamic load	10	W

LCLS-II Preproduction Cryomodule



8 cavities (End Tuner) + 1 Splittable Quad (V. Kashikhin), 6 Current Leads ~50A





-80K shield (CM3)
-4K intercepts
-Global magnetic shield not shown
-JT Valve

-Splittable Quad
-BPM
-Gate Valve

Project Collaboration

Fermilab

- 50% of cryomodules: 1.3 GHz
- Cryomodules: 3.9 GHz
- Cryomodule engineering/design
- Helium distribution
- Processing for high Q (FNAL-invented gas doping)

Jefferson Lab

- 50% of cryomodules: 1.3 GHz
- Cryoplant selection/design
- Processing for high Q (gas doping)

Berkeley Lab

- Undulators
- e^- gun & associated injector systems

Argonne National Laboratory

- Undulator Vacuum Chamber
- Also supports FNAL w/ SCRF cleaning facility
- Undulator R&D: vertical polarization

Cornell University

- R&D planning, prototype support
- processing for high-Q (high Q gas doping)
- e^- gun option

Working Groups

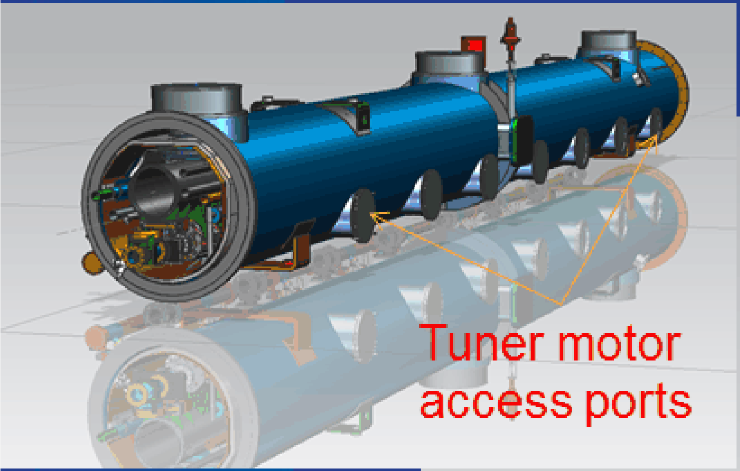
- WG1: Elliptical cavity production
- WG2: Cavity material
- WG3: Cavity treatment
- WG4: RF power coupler
- WG5: Accelerator modules
- WG6: Low beta
- WG7: Magnets & feedthroughs & BPMs
- WG8: Module testing

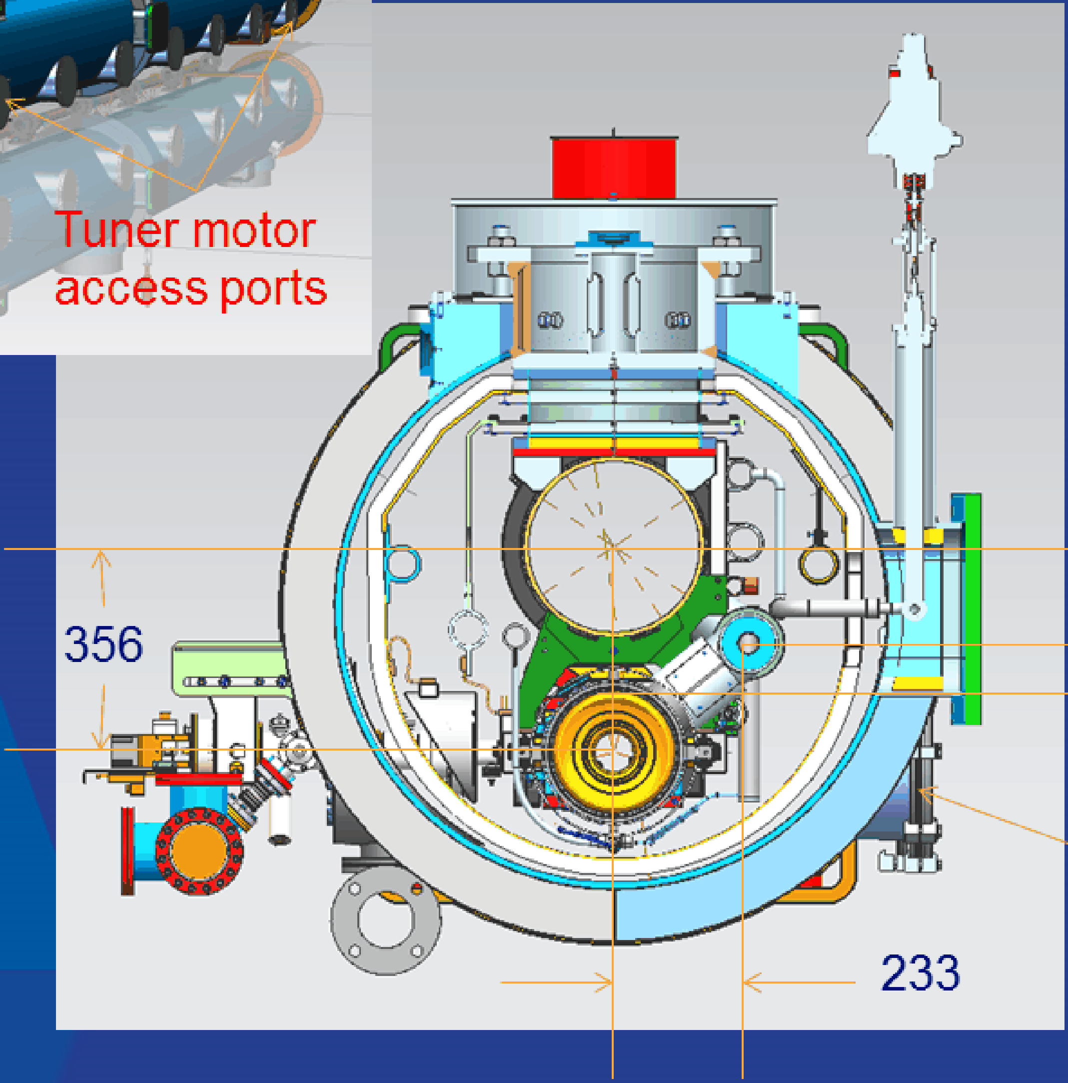
WG5: Accelerator Modules

- 前半は CW対応モジュールに関する議論をした

- Modification for CW operation for LCLS-II, Tom Peterson and Yuriy Orlov (FNAL)
  - LCLS-II のため、ILC型クライオモジュールをCW用に変更するための考察
  - 液体ヘリウムのフローレートなどを考慮。しっかりとした考察を行っているように見えた
- French light source Lunex, Massamba Diop
  - Couprie さんらの発案。第1段階は常伝導リニアック 400 MeV、S-bandリニアックベースの光源。第2段階で超伝導ベースのリニアックにする。まだ構想段階の模様
- Commissioning international ERL cryomodule, Alan Wjeelhouse
  - LC1: 10.8 MV/m, LC2: 12.5 MV/m   static load: 6.2 W/cryomodule
  - Microphonic issue: 326 Hz p-p → 原因を究明するが、使えず、一旦撤去した
- HZB experience with CW operation at the HoBiCaT, Axel neumann
- Cornell CW cryomodule, Georg Hoffstaetter
  - 入射器 4 MeV, 75 mA CW を達成
  - 主空洞: 10K サーマルサイクルの後で、$Q_0=1\times10^{11}$ at 1.6 K (16 MV/m)を達成

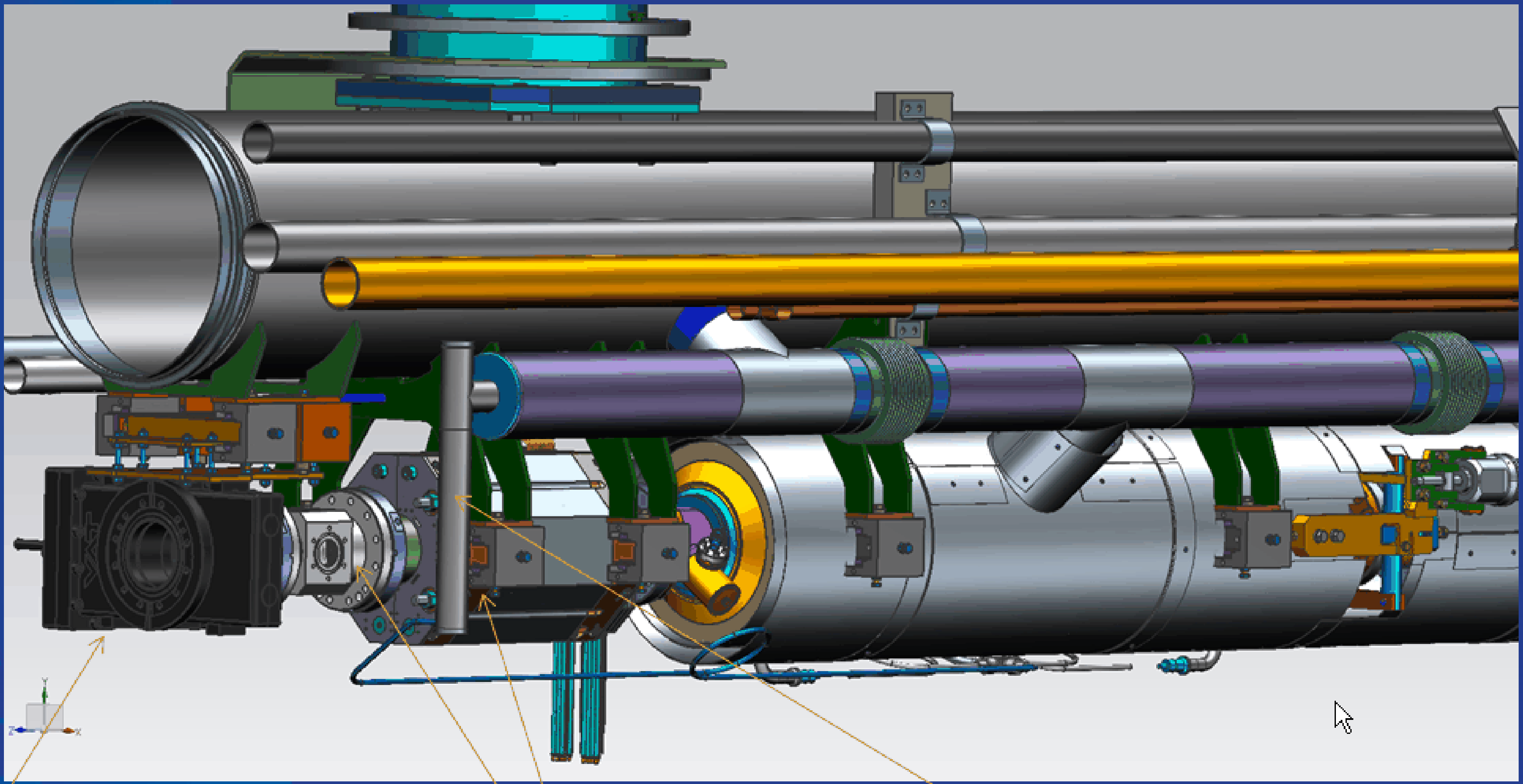
LCLS-II cryomodule





He Internal Pressure:
4 bar-cold
2 bar-warm

LCLS-II- Cold Mass Downstream End.



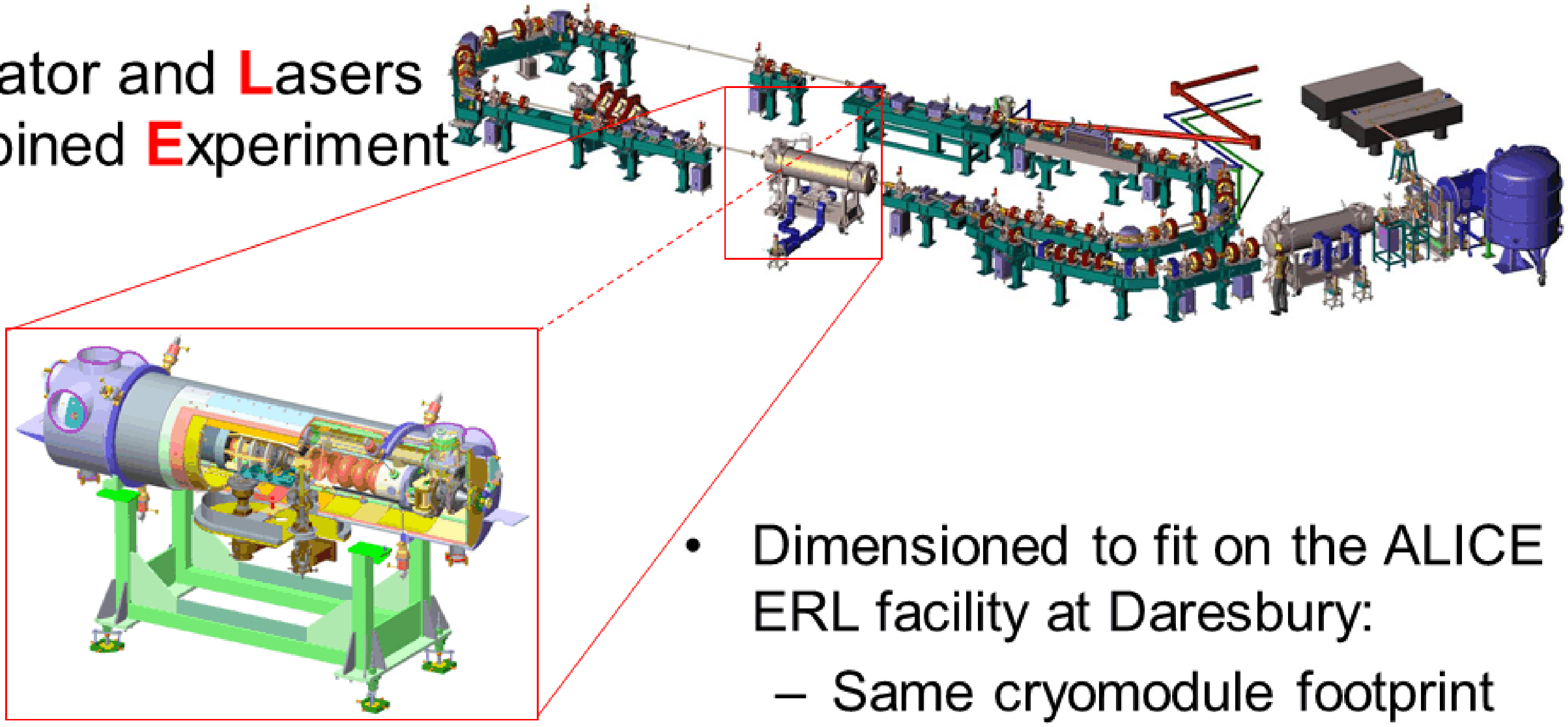
Downstream Gate Valve

Splittable quad
BPM

Downstream He level

New CM Integration on ALICE

Accelerator and **L**asers in **C**ombined **E**xperiment

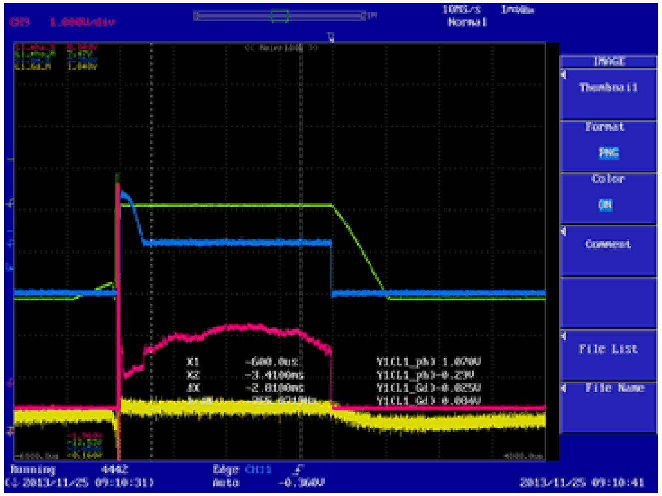


- Dimensioned to fit on the ALICE ERL facility at Daresbury:
  - Same cryomodule footprint
  - Same cryo/RF interconnects
  - 'Plug Compatible' with existing cryomodule

Cavity Conditioning

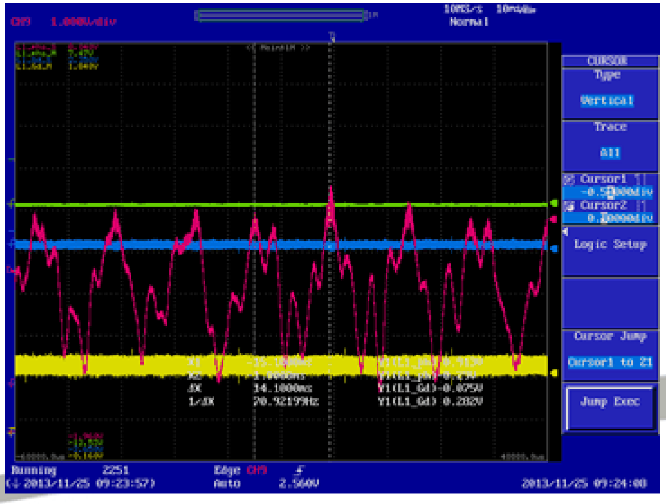
Pink – Phase set
Green – Phase measure
Blue – Gradient set
Yellow – Gradient measure

- Q_{ext} set to original Linac settings:
  - LC1 – 6.4 x 10^6 (BW ~ 100 Hz)
  - LC2 – 8.3 x 10^6 (BW ~ 80 Hz)
- Initial conditioning done with Self Excited Loop:
- Gradients Reached:
  - LC1 – 10.8MV/m
  - LC2 – 12.5MV/m
- Target Specification 16 MV/m

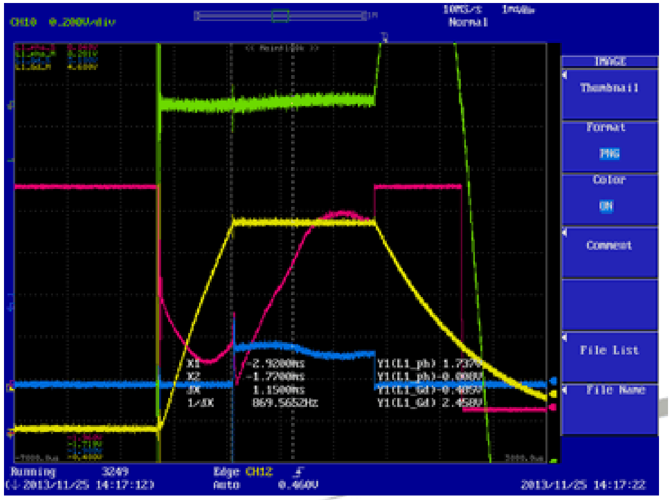


LC1
Gradient ~0.8MV/m
Phase set 40^0

- Microphonic issues discovered with analogue LLRF
  - Phase set limit of 60^o reached at low gradients
  - 71Hz oscillation seen on the phase set under CW conditions



LC1 (CW)
Gradient ~0.8MV/m
71Hz oscillation



LC2
Gradient 7MV/m
Phase set 60^0

No FE radiation observed!

Science & Technology Facilities Council

Initial Measurements (DLLRF4)

- Comparison of forward power phase to probe phase
- Peak to peak phase variation ~60Hz

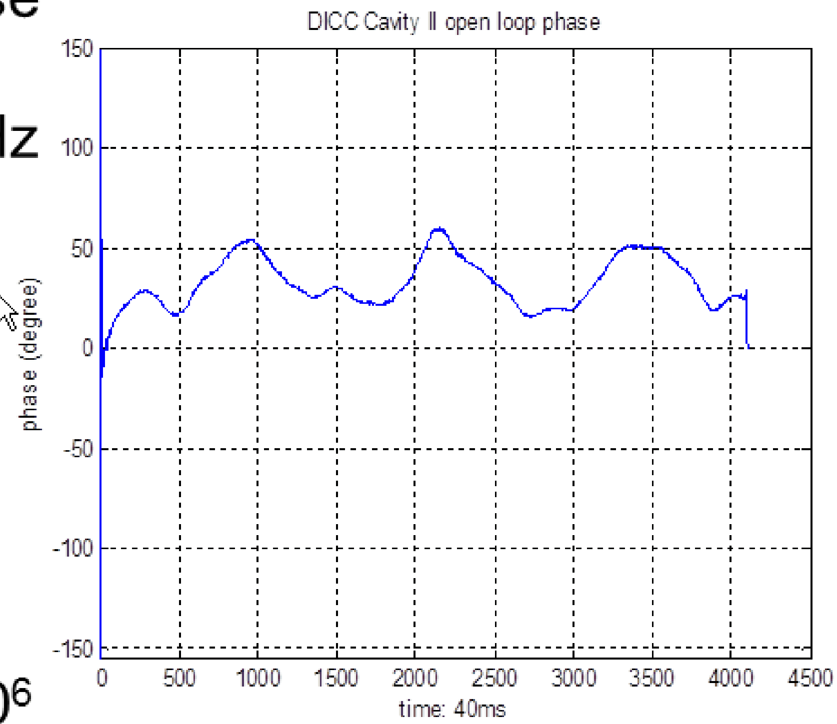
⇨ Deviation from flat = 30°

$$\Delta f = \frac{\tan(\theta) * f_0}{2 * Q_E}$$

⇨ Max detuning of 163Hz

⇨ Pk-Pk detuning 326Hz

- Operational Q_{ext} needs to be 6 x 10^6 giving a 3dB bandwidth of 216Hz
- **Cannot** run the cavities under these conditions
  - Insufficient RF power overhead



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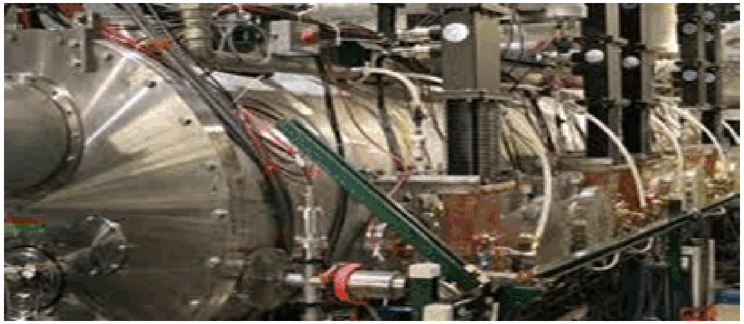
CM Results from Cornell

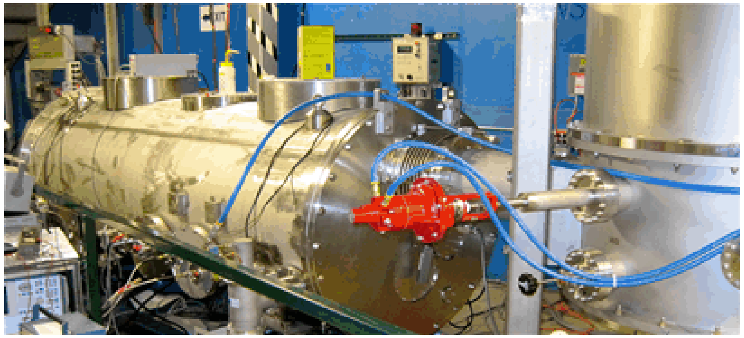
CLASSE

World Record CW beam current & brightness from a photoinjector



4 MeV, 75 mA CW beam accelerated by SRF cavities

World Record Q_0 of an SRF cavity in a cryomodule

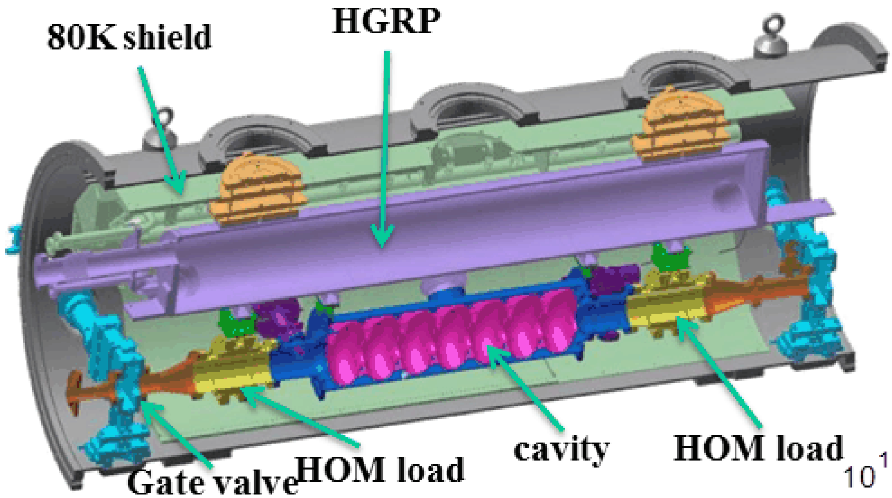


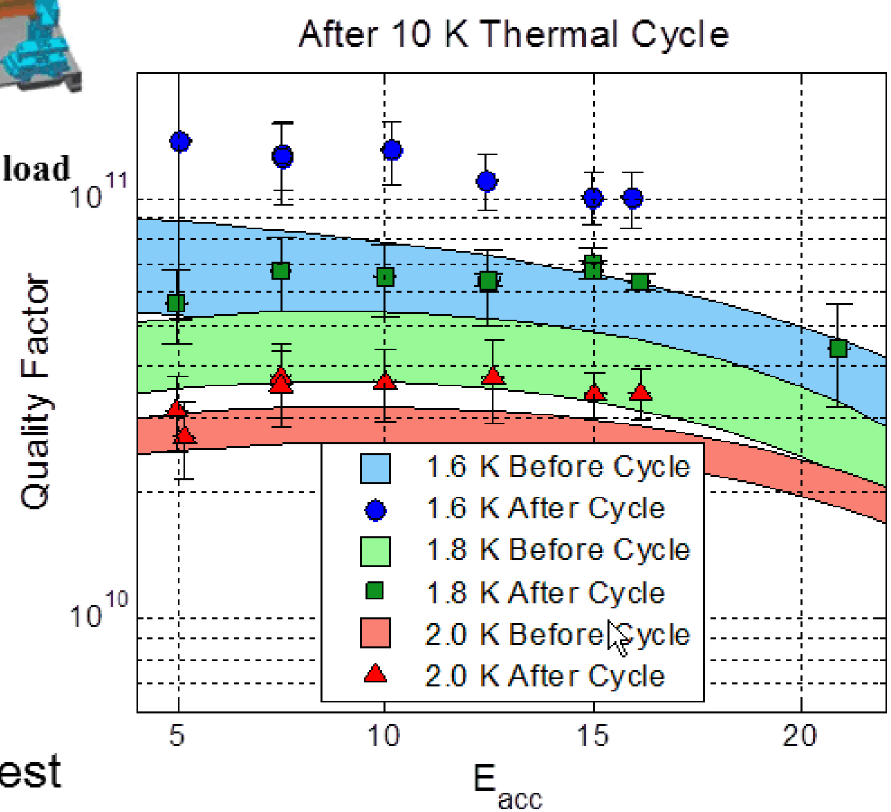
$Q_0 = 1 \cdot 10^{11}$ at 1.6K, 16 MV/m in a cryomodule

Now a main ERL cryomodule is under construction

Cornell University

Summary of HTC results





Horizontal Test Cryostat:
(@16MV/m, 1.8K):

Q0 = 3.5E10 without coupler

Q0 = 2.E10 with couplers

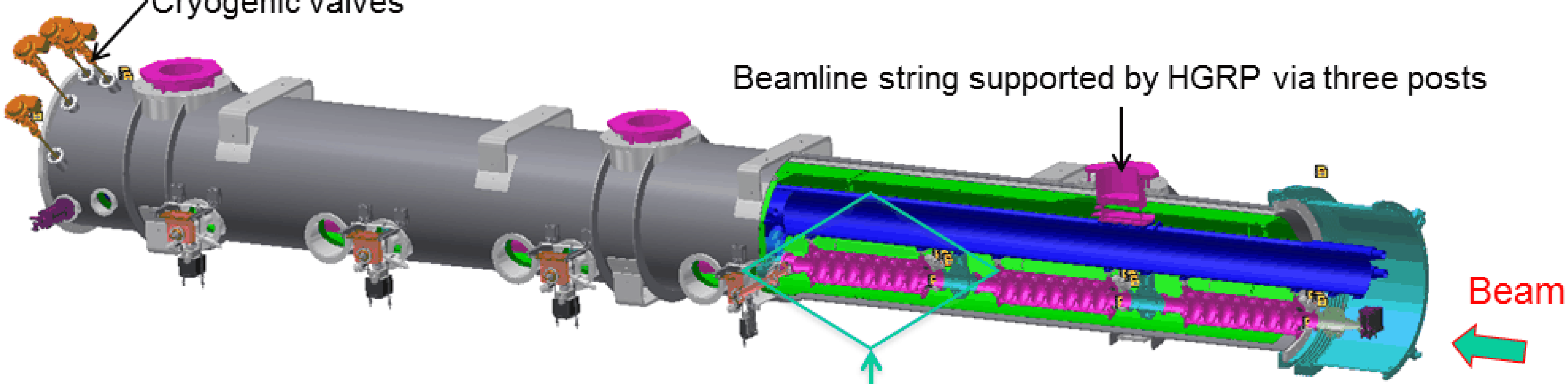
Q0 = 6E10 with coupler and HOM absorbers

The HTC provides the only horizontal test in an ERL-like environment

Cornell University

Main ERL Cryomodule: Design and Construction

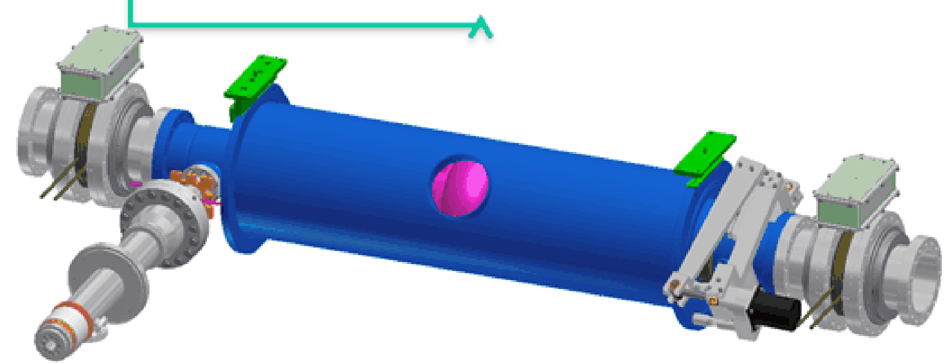
CLASSE



Full Cryomodule

- Modified ILC cryomodule design
- Study reproducibility of low-loss cavities
- Test cavity statistics
- Demonstrate High Q and CW operation
- Prepare industrialization of ERL linacs

Completion end of 2014



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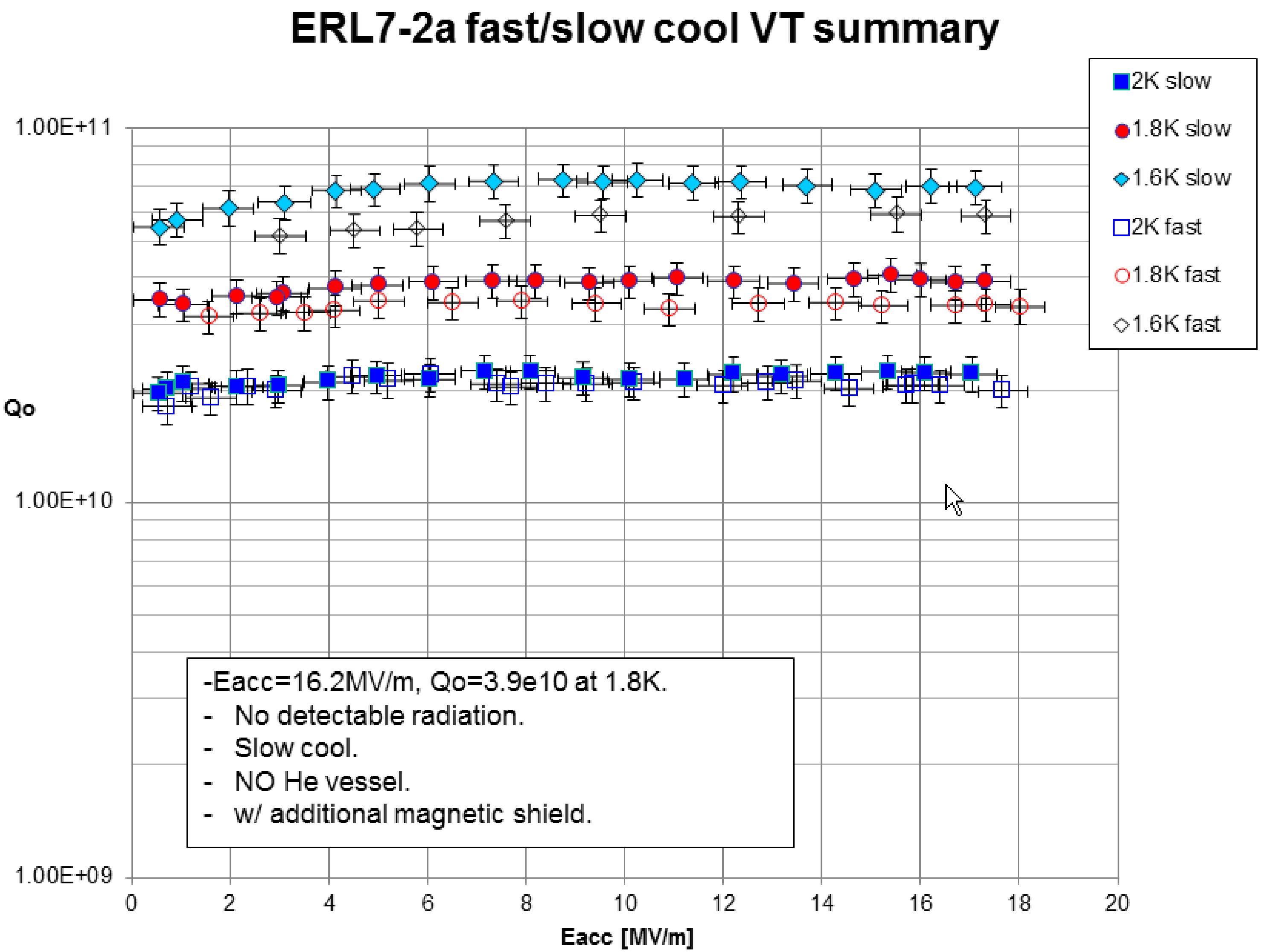
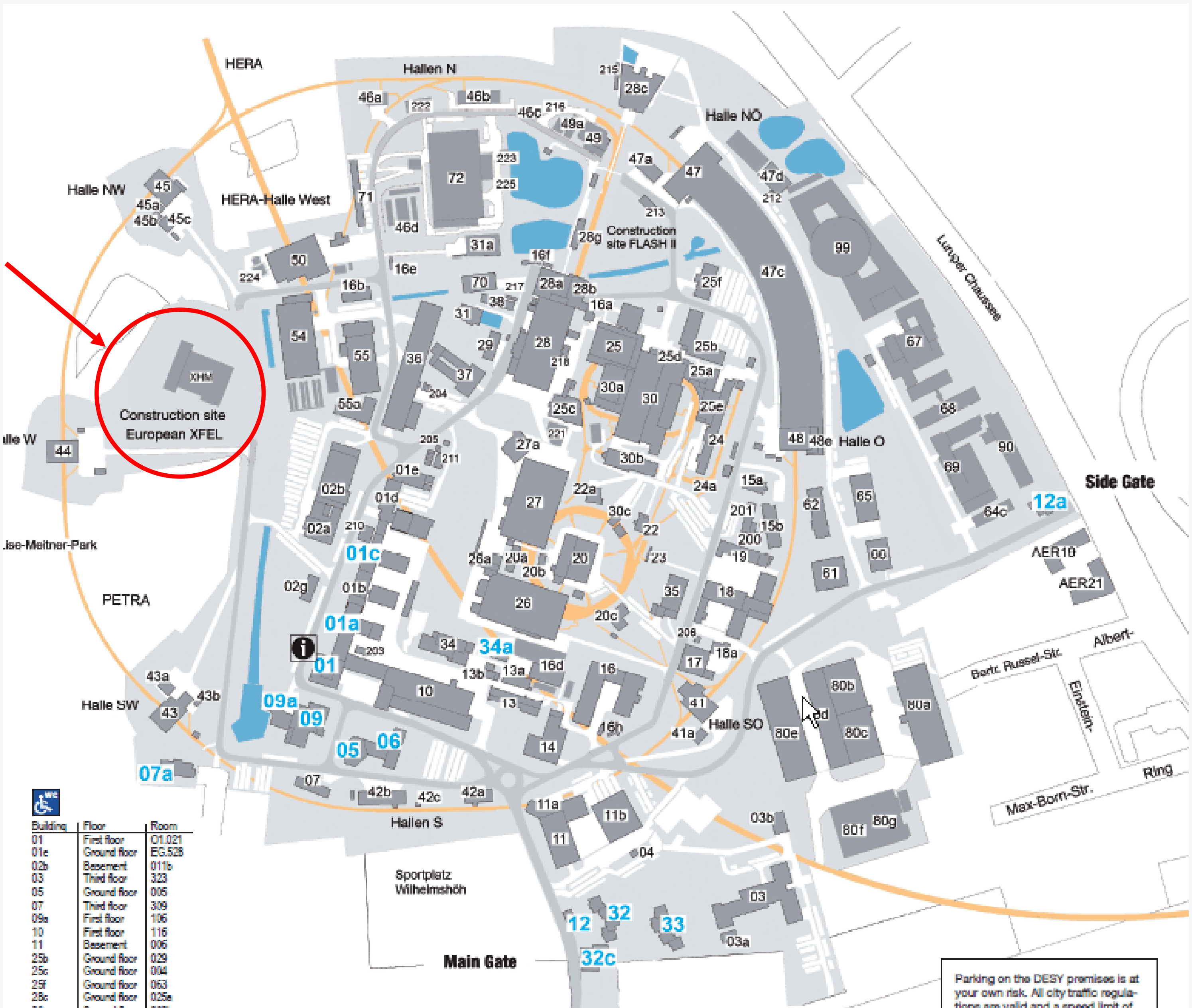
Latest vertical test
B-shielding, no return current

CLASSE



DESYのサイト見学

European XFEL Construction Site



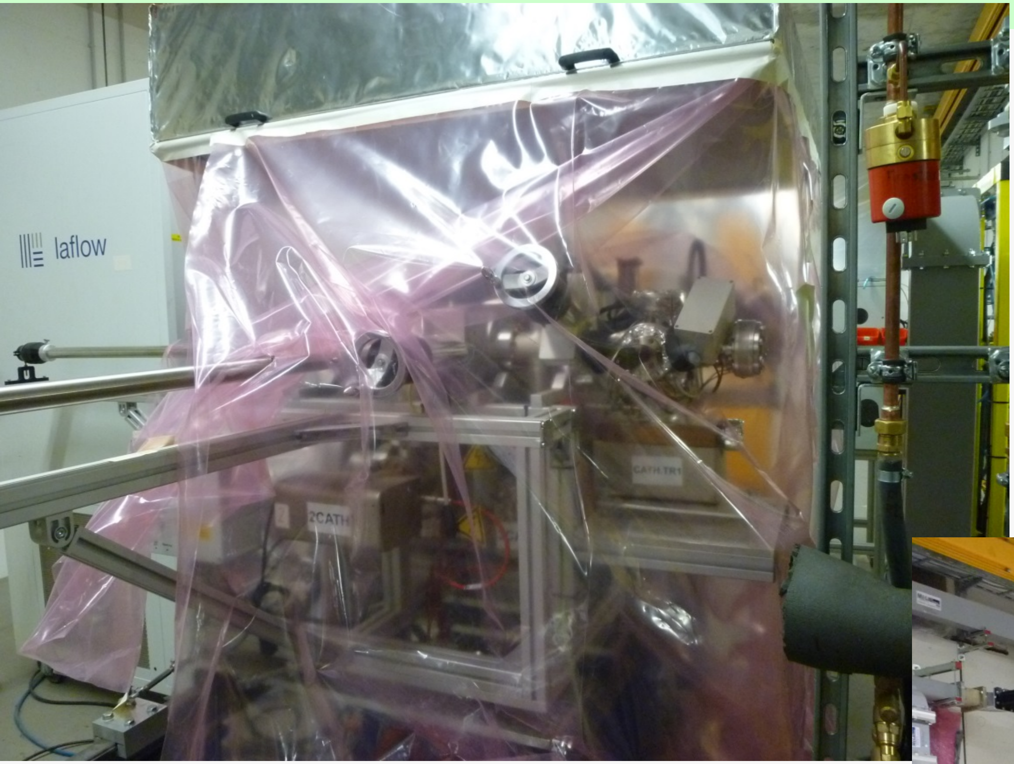
XFEL Tunnel - 搬入用シャフト (深さ35 m)

XFEL Tunnel

Personal Transponder

XFEL Tunnel - B5F 入射部用RF源

XFEL Tunnel - RF電子銃



XFEL Tunnel - 入射部

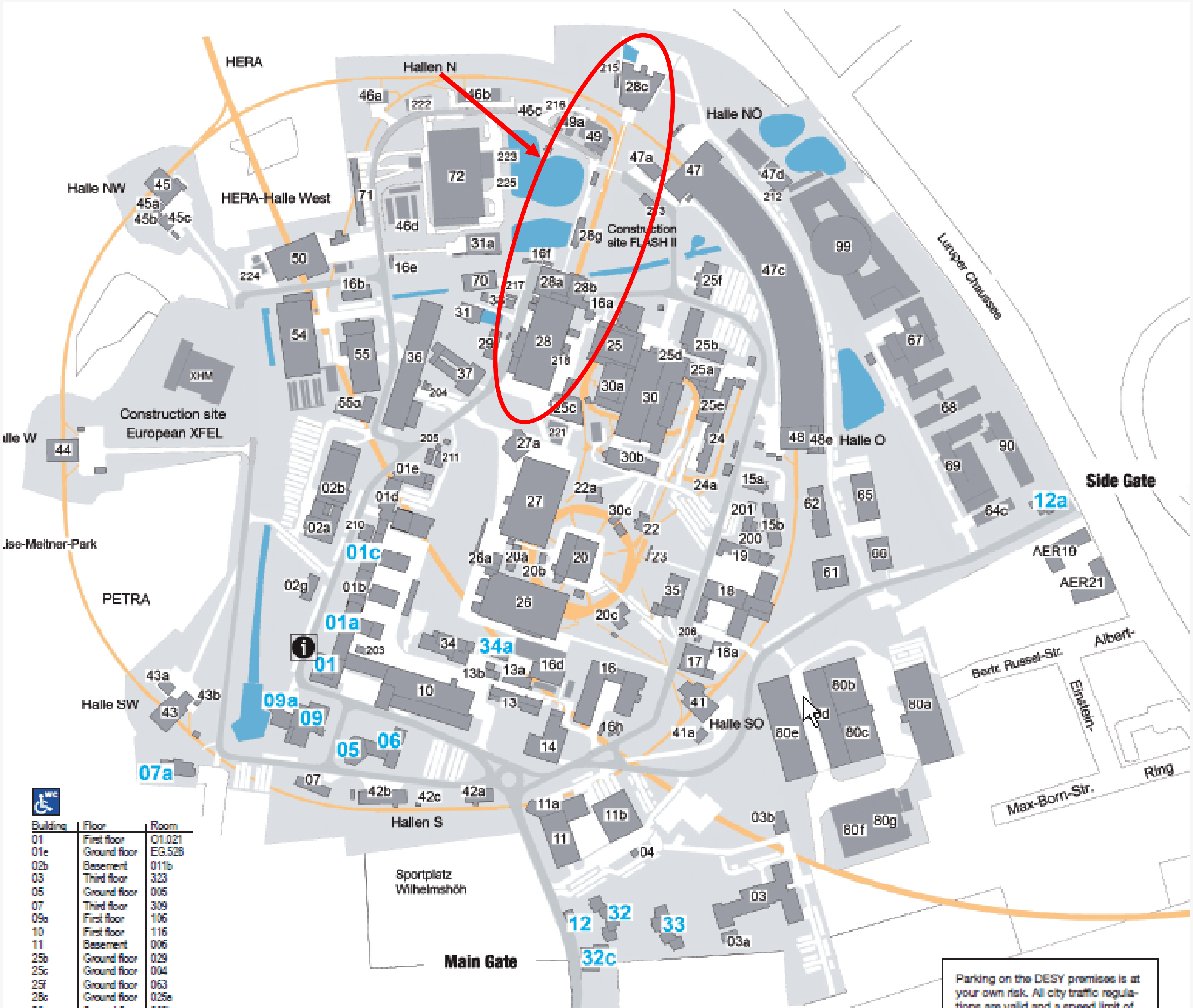
搬入口を下から見る

XFEL Tunnel - Schaft

XFEL Tunnel - 2km, laser-straight

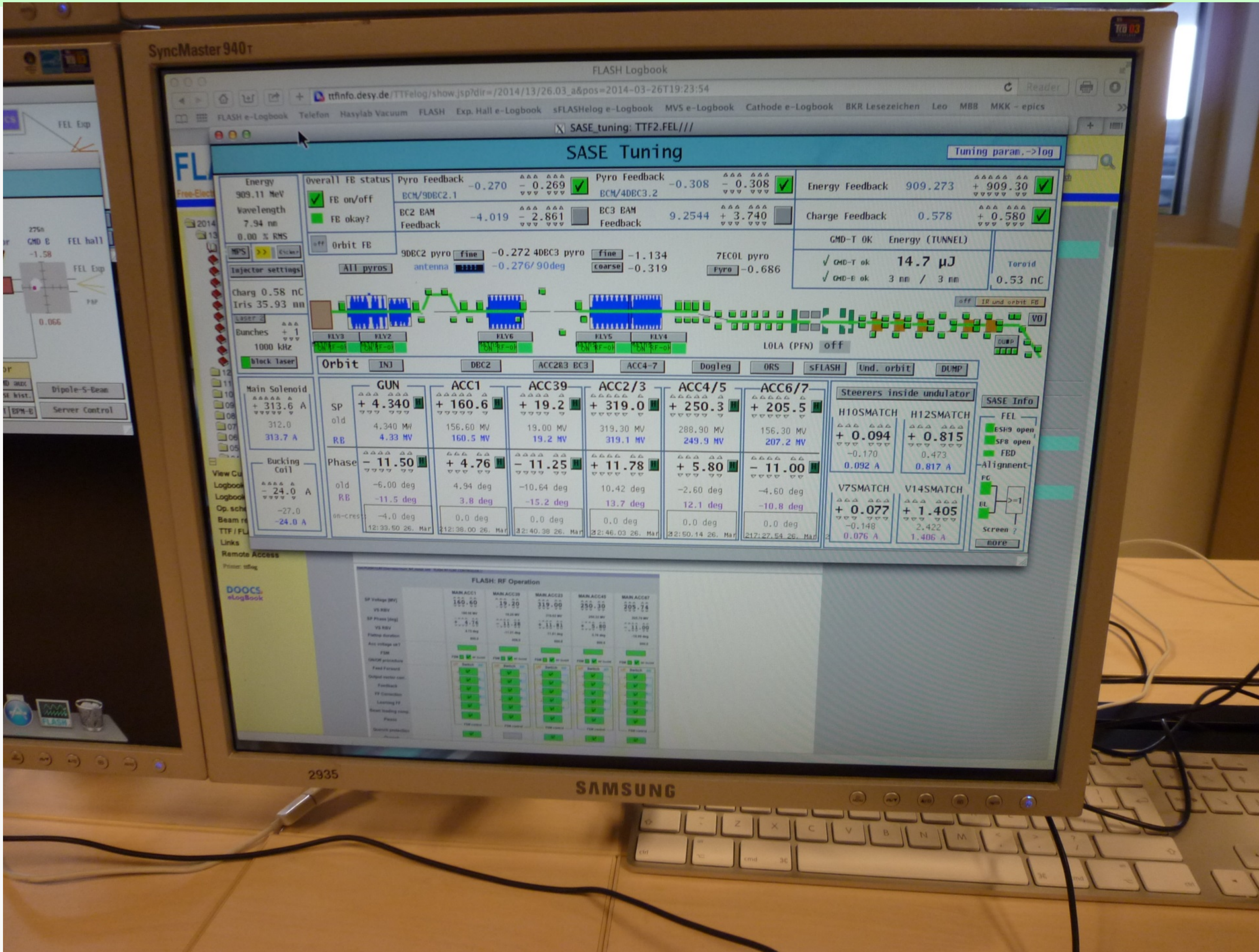
XFEL Tunnel

FLASH and FLASH-II

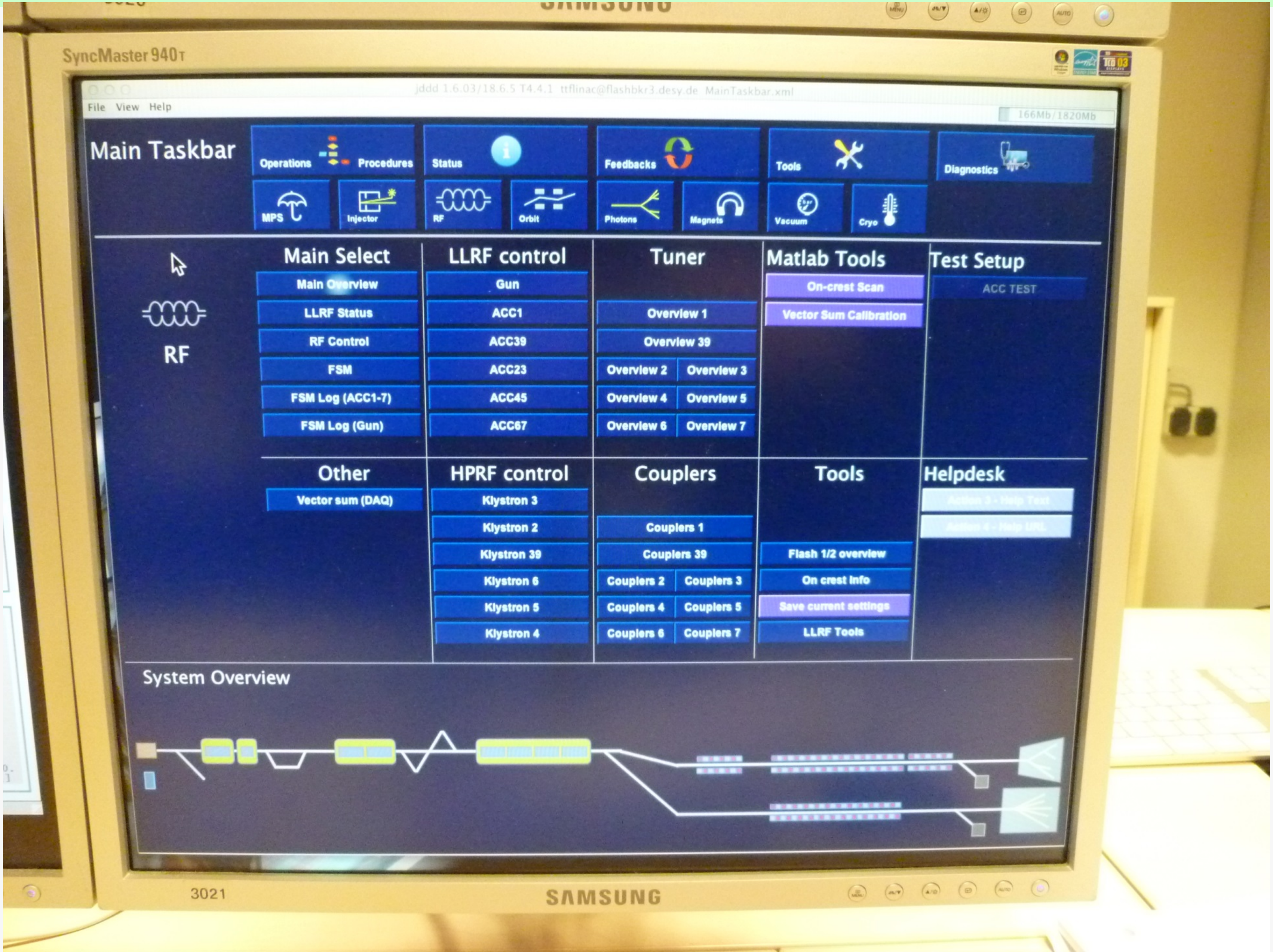


FLASH Control Room

FLASH 制御画面の一部（運転中）



ランチャー画面



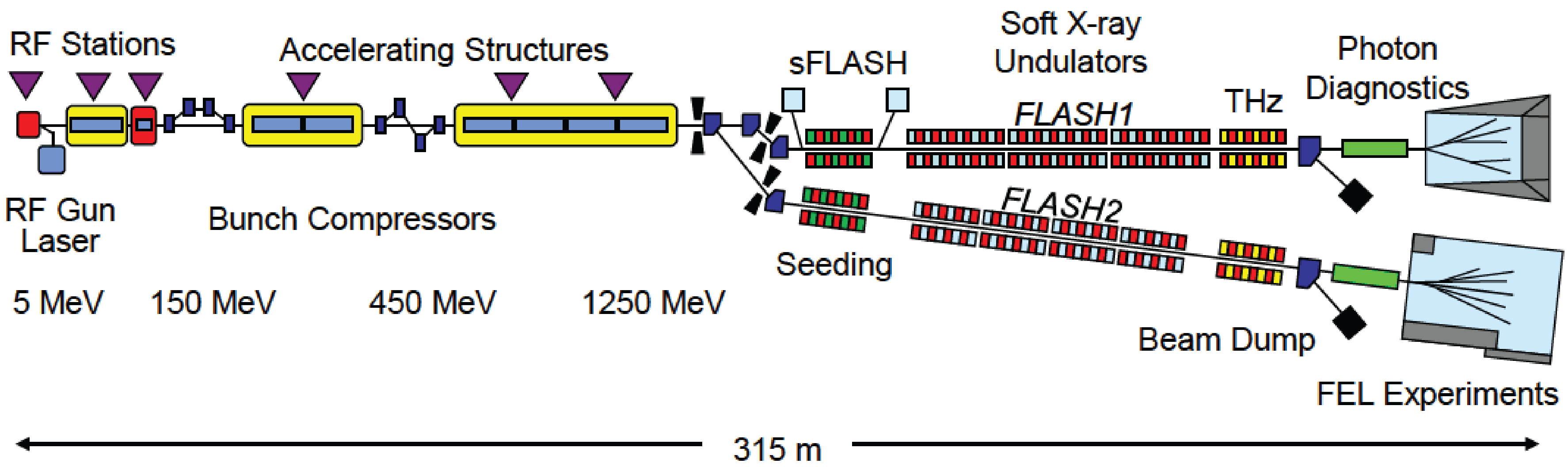
SyncMaster 940T
File View Help
Main Taskbar
Operations
Procedures
Status
Feedbacks
Tools
Diagnostics
MPS
Injector
RF
Orbit
Photons
Magnets
Vacuum
Cryo
RF
Main Select
Main Overview
LLRF Status
RF Control
FSM
FSM Log (ACC1-7)
FSM Log (Gun)
LLRF control
Gun
ACC1
ACC39
ACC23
ACC45
ACC67
Tuner
Overview 1
Overview 39
Overview 2
Overview 3
Overview 4
Overview 5
Overview 6
Overview 7
Matlab Tools
On-crest Scan
Vector Sum Calibration
Test Setup
ACC TEST
Other
Vector sum (DAQ)
HPRF control
Klystron 3
Klystron 2
Klystron 39
Klystron 6
Klystron 5
Klystron 4
Couplers
Couplers 1
Couplers 39
Couplers 2
Couplers 3
Couplers 4
Couplers 5
Couplers 6
Couplers 7
Tools
Flash 1/2 overview
On crest Info
Save current settings
LLRF Tools
Helpdesk
System Overview
3021
SAMSUNG

FLASH実験ホール

FLASH-II

H. Honkavaara, B. Faatz, J. Feldhaus, S. Schreiber, R. Treusch, M. Vogt

Proceedings of FEL2013, New York, NY, USA WEPSO26



FLASH-II

- λ_{ph} = 4-60 nm
- second undulator line, second experimental hall
- Kicker/septum で同じビームパルスの前・後半を振り分ける

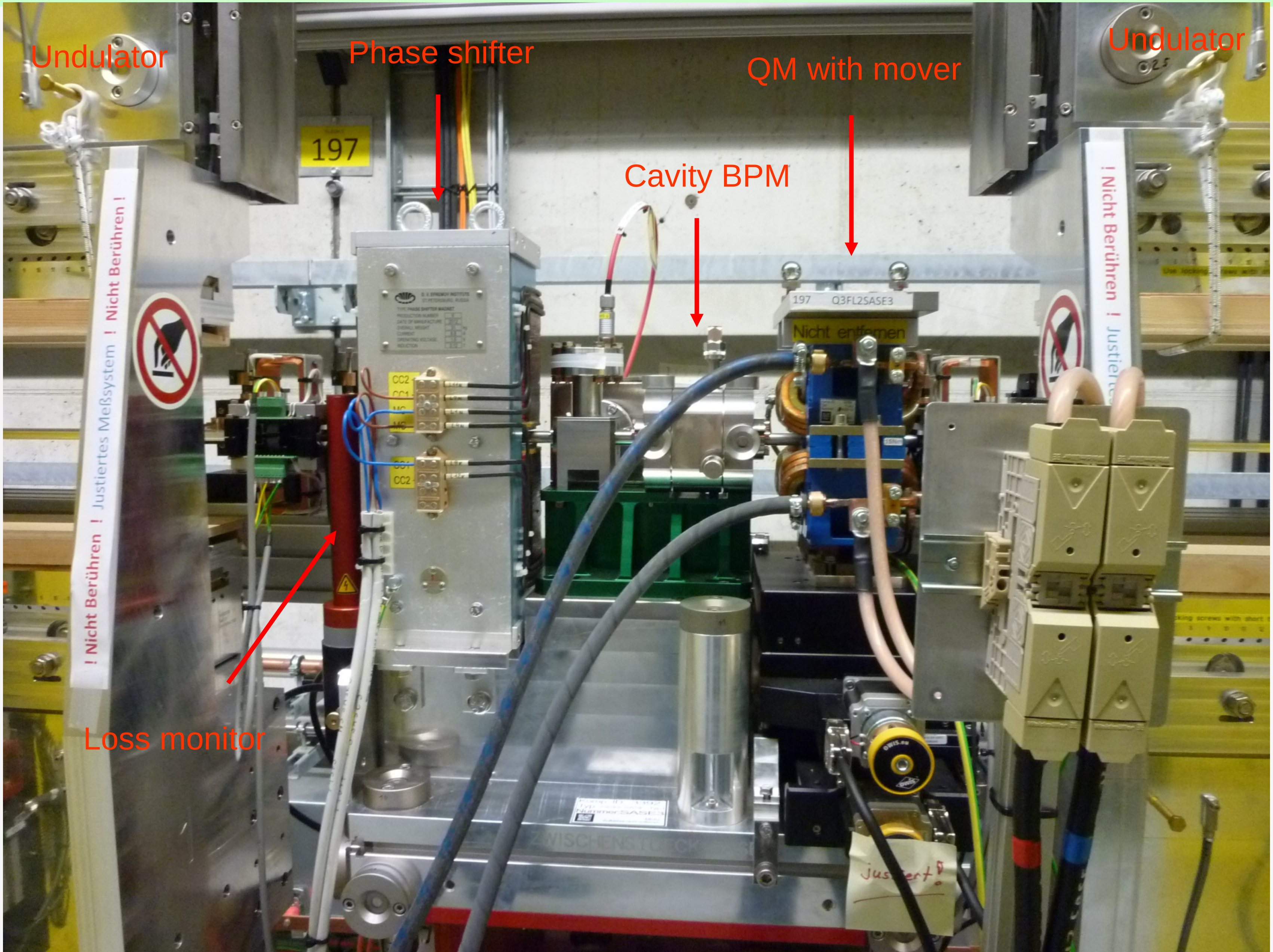
FLASH/FLASH-II

- E=1.25 GeV
- frep = 10 Hz
- 7 modules x 8 cavities (9-cell)
- 3.9 GHz cavitieis x 4
- 500 bunches/train x 10 Hz

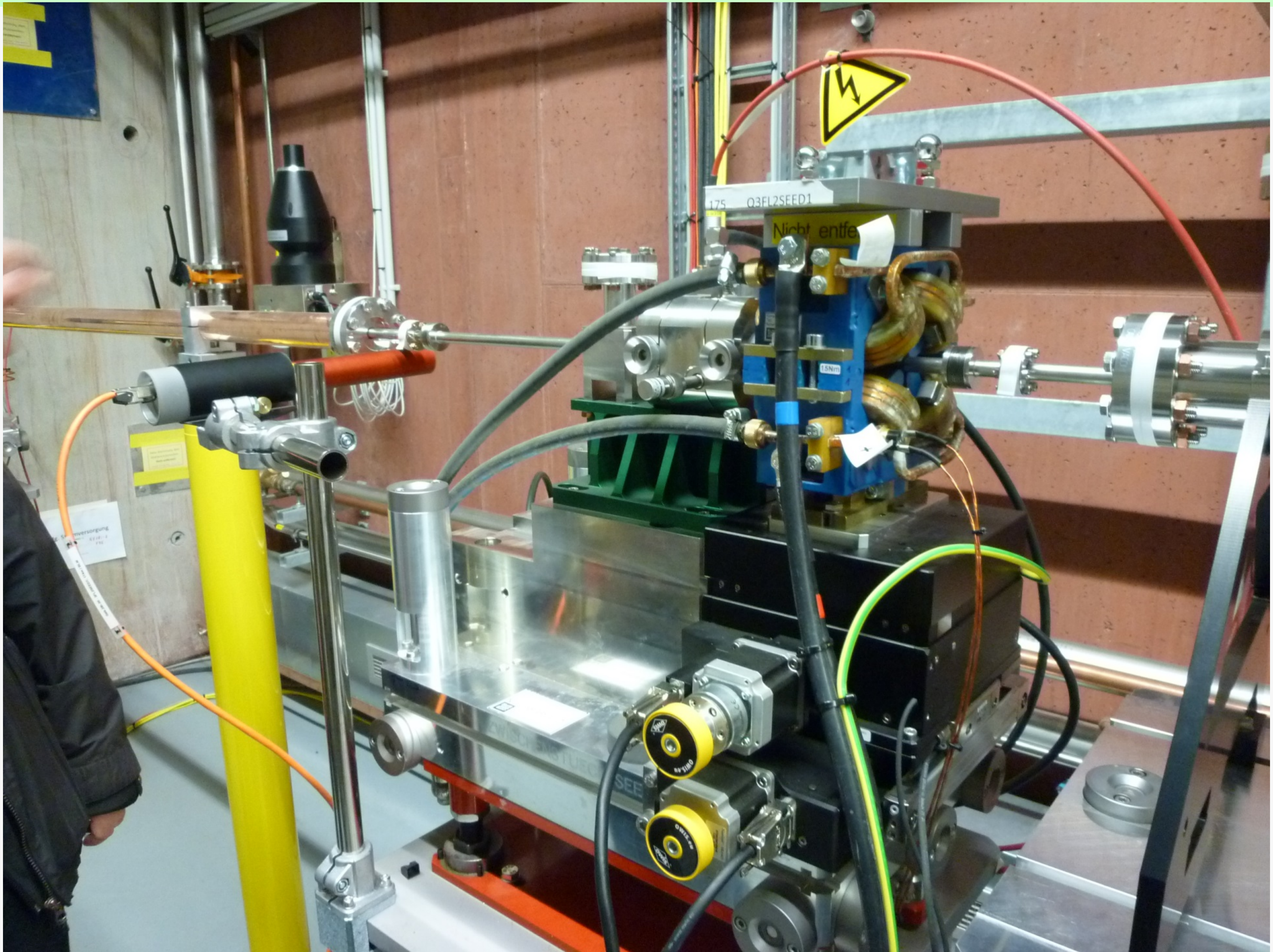
FLASH-II実験ホール（建設がほぼ完了）

FLASH-IIアンジュレータ（インストールほぼ完了）

FLASH-IIアンジュレータ間



FLASH-II ビーム輸送路（アンジュレータより上流）

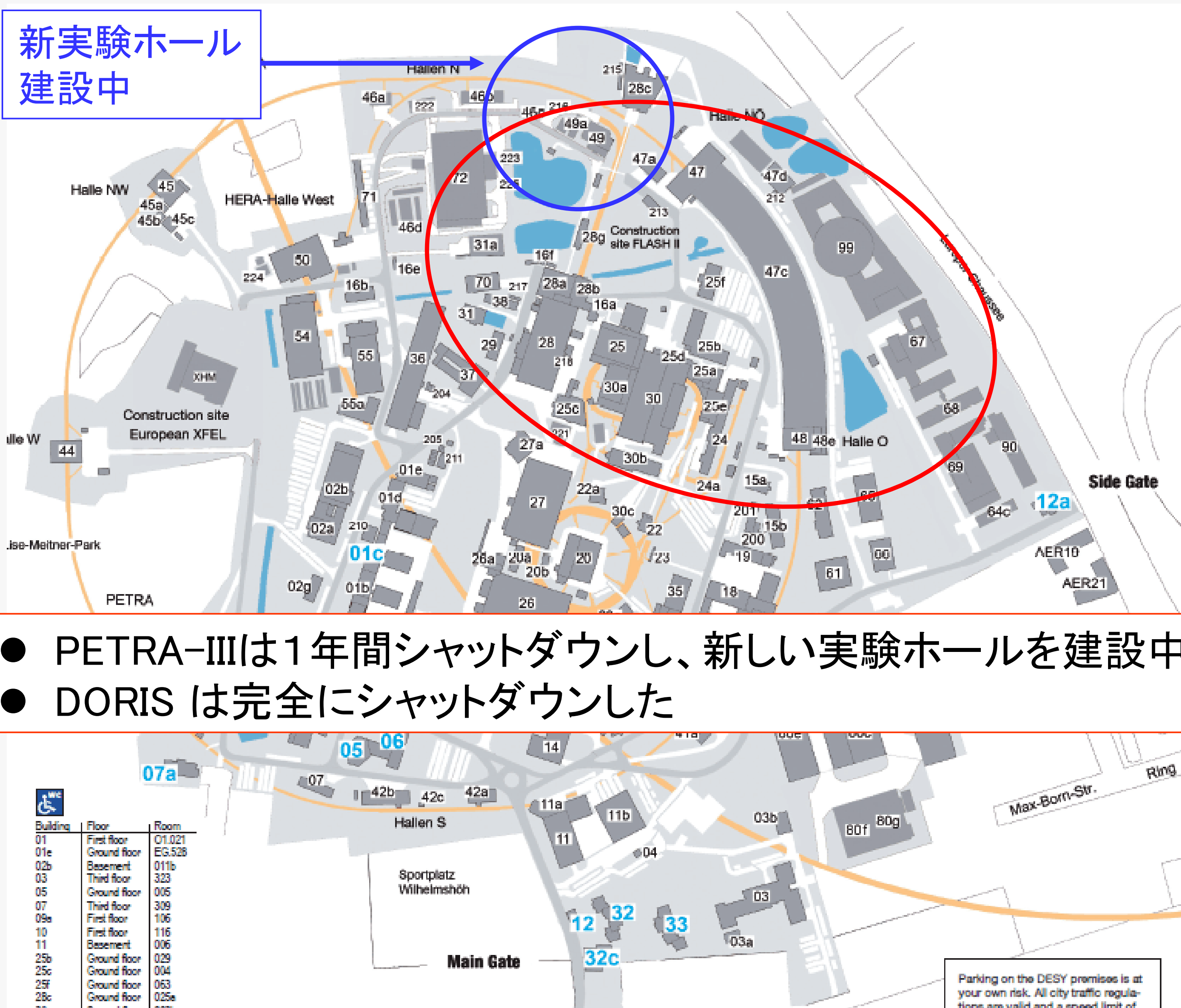


Local Clean Room

FLASH-II Experimental Hall (almost completed)

PETRA-III

新実験ホール
建設中

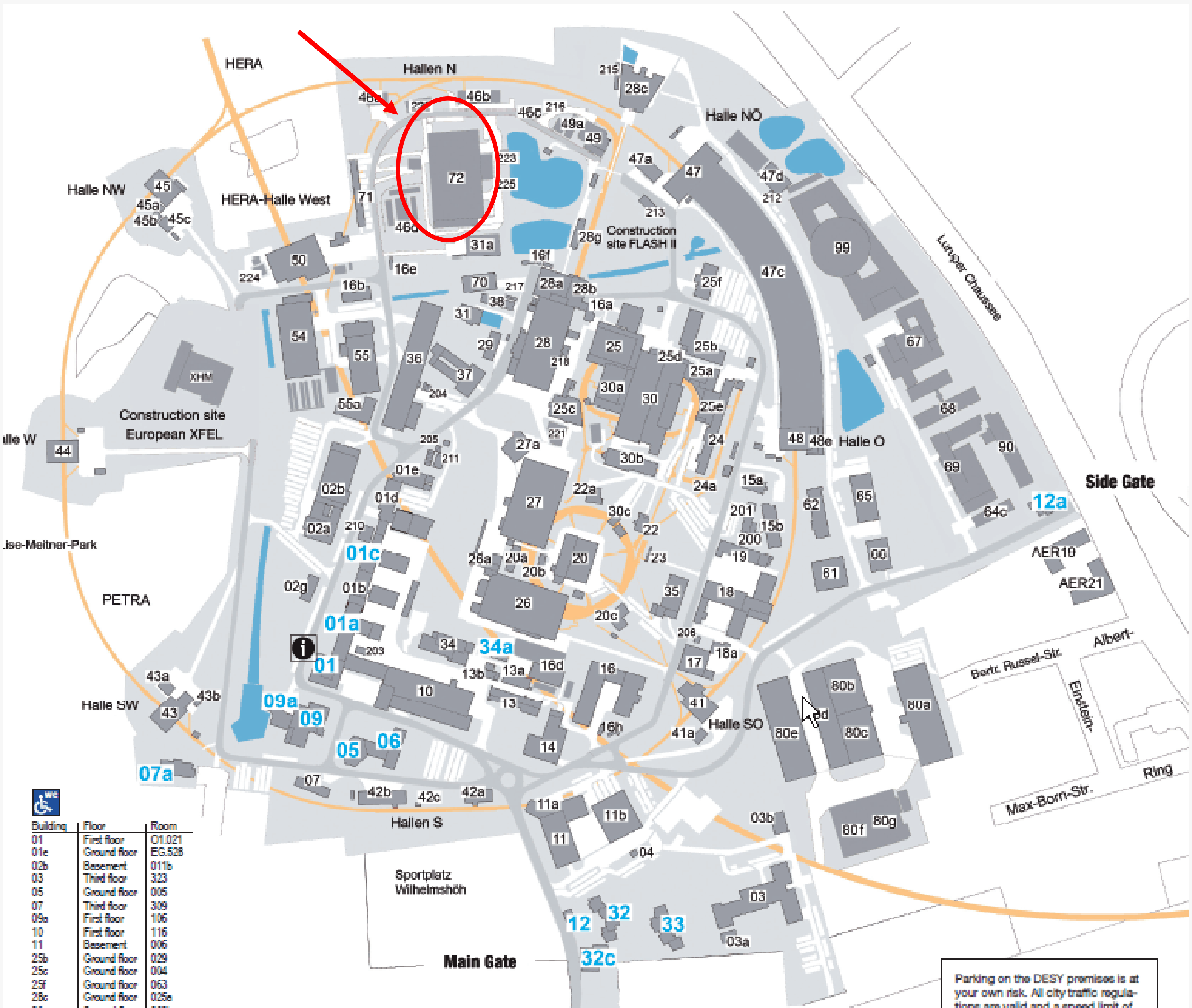


- PETRA−IIIは１年間シャットダウンし、新しい実験ホールを建設中
- DORIS は完全にシャットダウンした

PETRA-III 実験ホール

PETRA-III 新実験ホール建設中

Accelerator Module Test Facility (AMTF)



Accelerator Module Test Facility (AMTF)

AMTF: 縦測定の準備

同時に4本ぐらいの加速管がテストできる

ローカルなクリーンブース内で、真空の接続作業中

AMTF: 縦測定の準備（続）

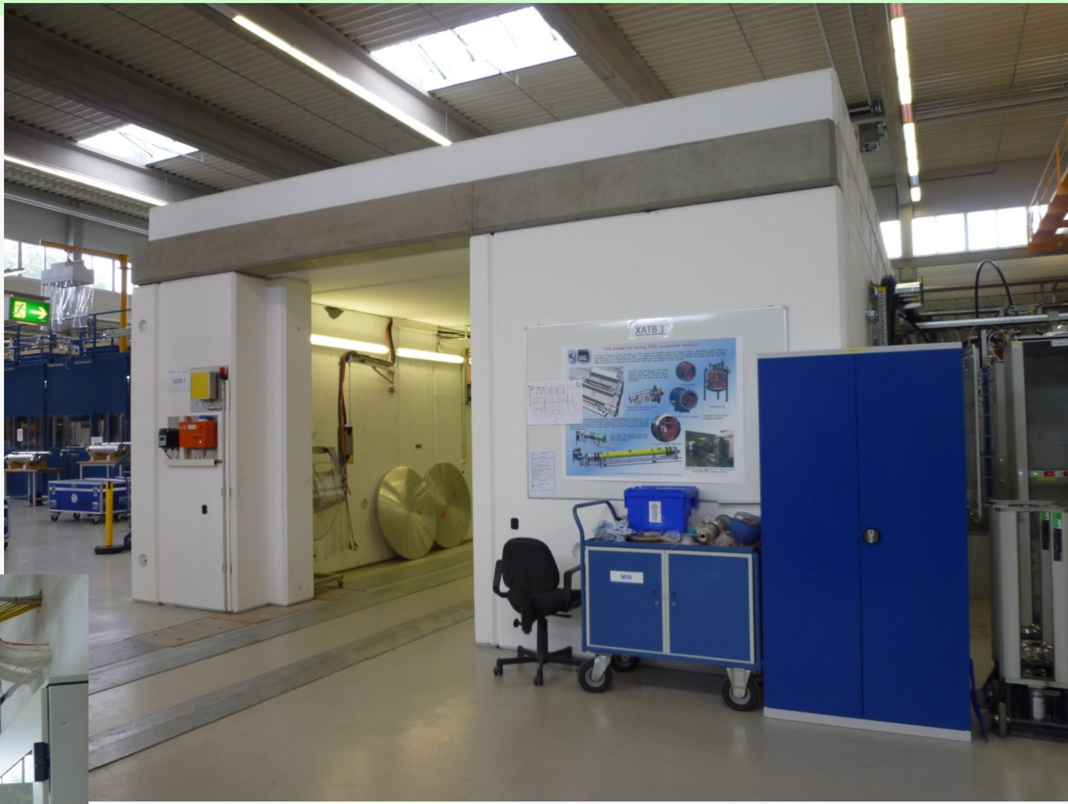
AMTF: 縦測定の準備（天井部）

AMTF: 縦測定用設備

Helium Distribution System （コールドボックス）

減圧ポンプシステム（隣の部屋）

モジュールの横測定設備



モジュールの横測定設備(内部)

モジュールの横測定用RF源

試験準備中のクライオモジュール（E. ZANON製）

まとめ (TTC meeting)

- European XFEL用のクライオモジュールの製造、試験が精力的に進められていることから、製造や試験の工程を担当する会社や研究所の人から、製造工程や品質管理の詳細な情報や recipe が発表され、議論がなされた。Euro-XFELは量産化のノウハウが非常に進んでいる。

- JLab の CBAF upgrade についても、量産および初期コミッショニング（1ターンのみ）に関する発表があった。

- 将来計画として大きなものは、European Spallation Source (ESS) と LCLS-II がある。

- LCLS-II計画が始まった（？）こともあり、CW運転対応のクライオモジュールの設計がホットな議論の一つであった。

まとめ (DESY関係）

- European XFEL は、会社（E. ZANON, RI； 空洞製造）、Saclay（モジュール組み立て）、DESY（モジュールテスト）で量産・試験する体制ができ、着々と進行している。
- Euro-XFEL 用空洞とクライオモジュールの量産用縦測定、横測定を行える大規模な設備 AMTF (Accelerator Module Test Facility) が立ち上がり、着々と試験を進めている。
- 波長4.2-44 nmのFEL光を発生するFLASHでは、FLSAH-II （アンジュレータと実験室）の建設がほぼ完了に近づいている。繰り返し10 Hzのマクロパルスの前半・後半をキッカーで分けて、同時に利用する計画である。
- PETRA-IIIは1年間の長期シャットダウン中。この間に、新たに実験ホールを建設中。DORISが終了したので、ビームラインの数が必要なため。