STATUS OF THE HIE-ISOLDE PROJECT

Presentation by Matthew Fraser on behalf of the HIE-ISOLDE Project Team.

12th International Conference on Heavy Ion Accelerator Technology
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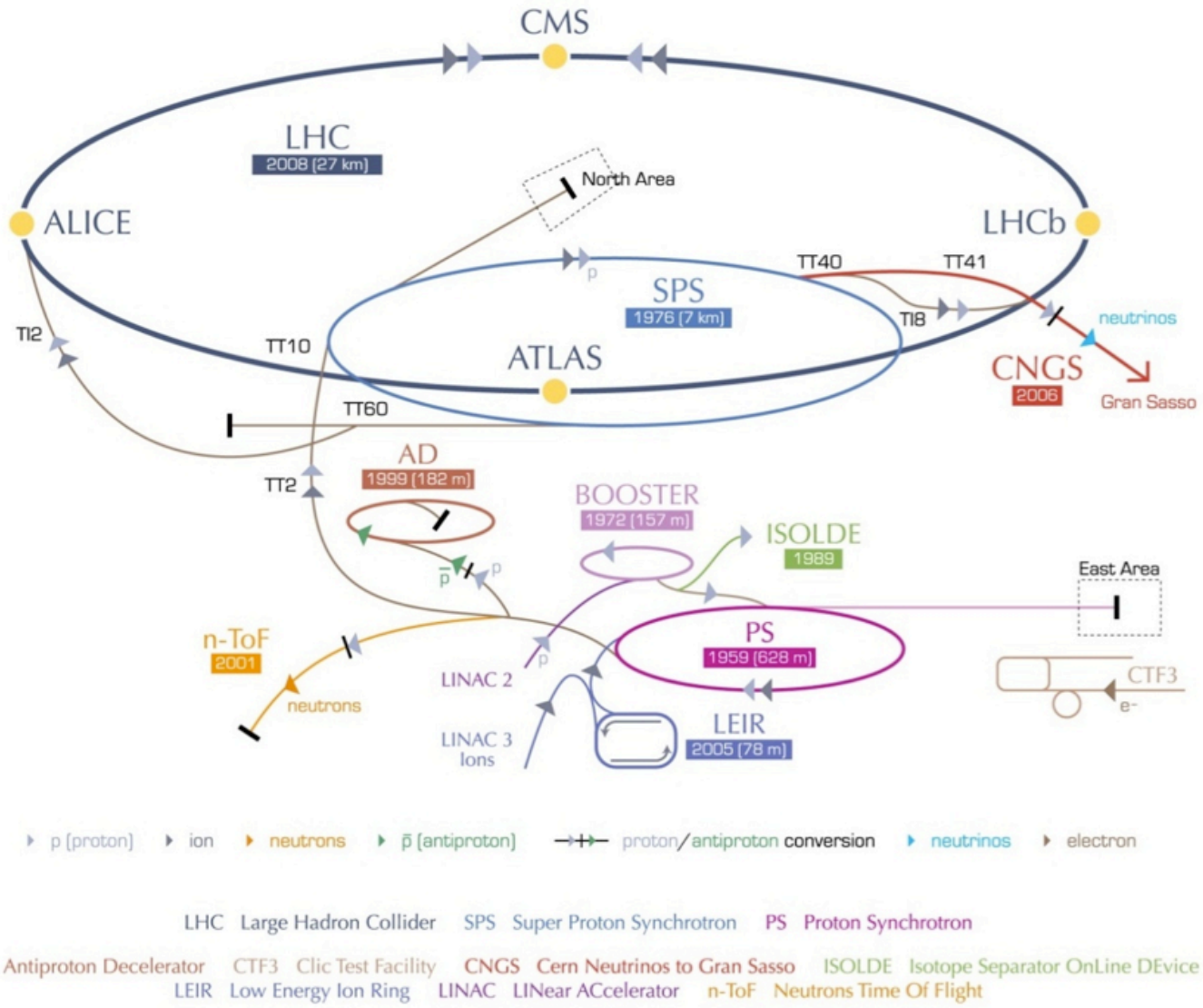
mfraser@cern.ch (CERN, BE-RF-BR)

Contribution number WEC02

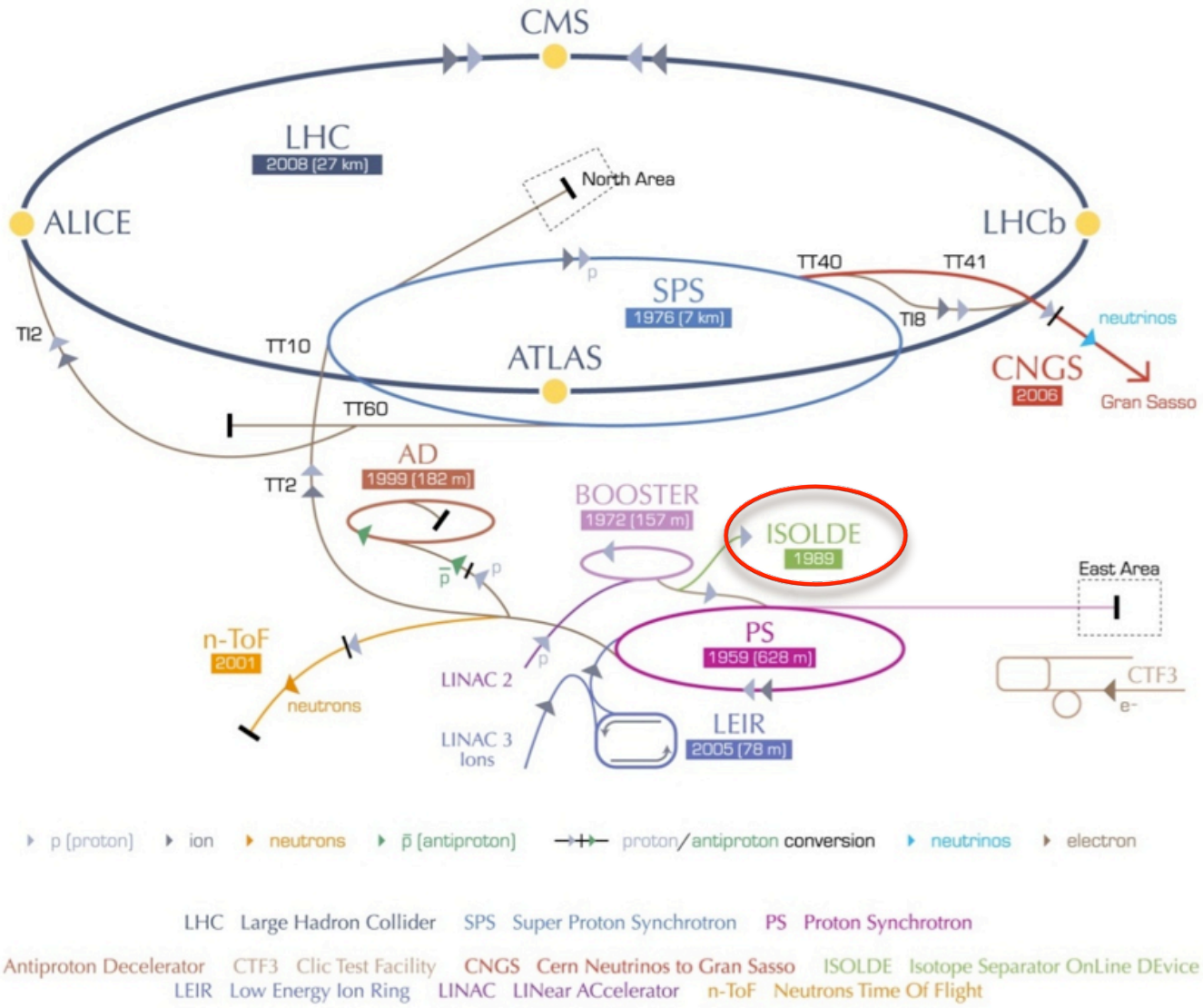
TALK OUTLINE

- Scope of HIE-ISOLDE
- Upgrade of the ISOLDE facility: HIE-ISOLDE
- R&D activities at HIE-ISOLDE
    a. RF cavities, testing and sputtering
    b. cryomodule
    c. alignment system
    d. beam diagnostics
    e. HEBT
- Outlook

ISOLDE AT CERN



ISOLDE AT CERN



HIE-ISOLDE MOTIVATION

- The High Intensity and Energy (HIE) ISOLDE project builds on the success of the REX-ISOLDE post-accelerator and will focus on the upgrade of the REX facility, but also aims to improve the target and front-end part of ISOLDE to fully profit from upgrades of the existing CERN proton injector chain (Linac4 and PSB upgrade).

  a. **higher energy beams** (post-accelerated)
  b. **more intense beams** (more beams as well as different species)
  c. **better beam quality** (high-purity, low emittance, more flexible beam parameters)

- Aim for over 10 MeV/u beam energy with increase of factor 10 in RIB intensity.

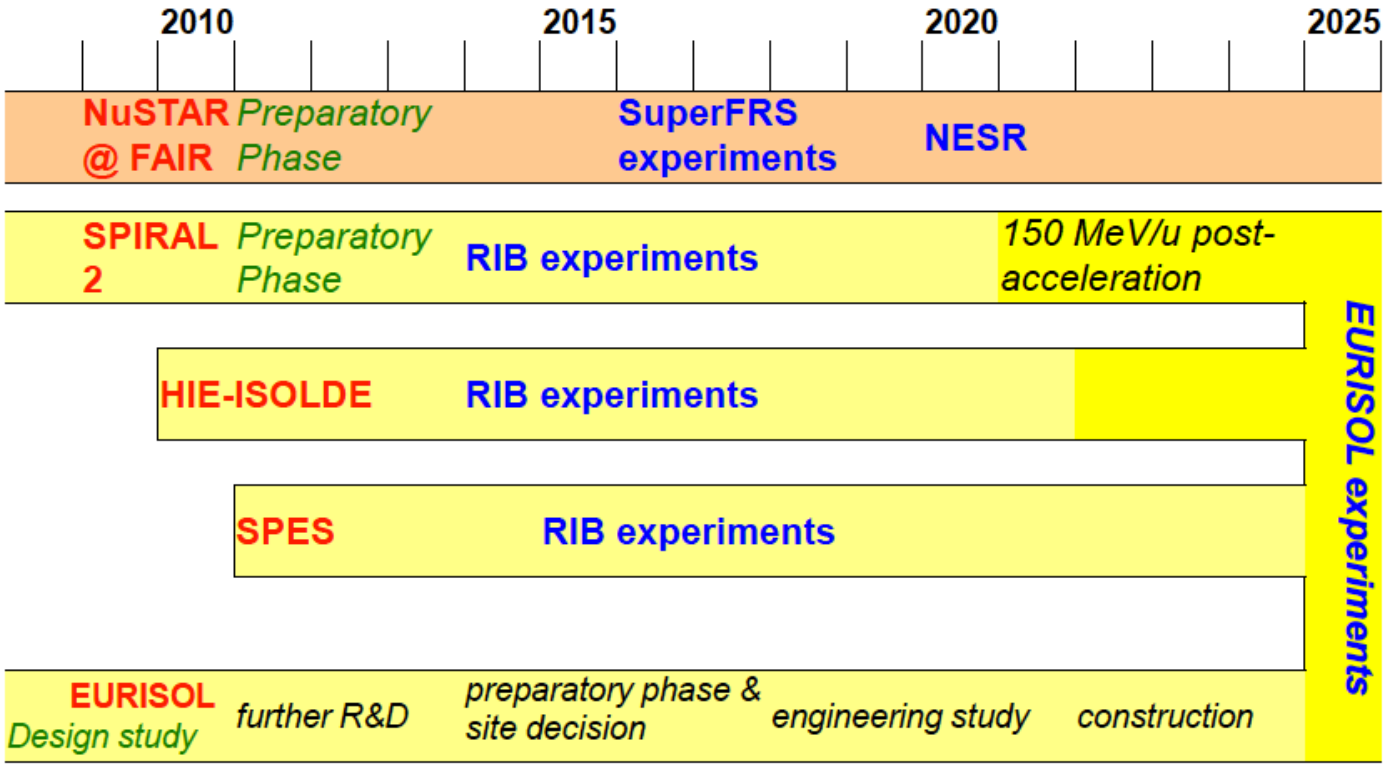
- 34 Letters of Intent for HIE-ISOLDE (May 2010) from 284 participants from 74 labs in 22 countries: **88% of letters would exploit the increase of beam energy.**

- Nuclear structure reaction physics major subject: Coulex (13), transfer (16), elastic scattering (3), fission (2).

HIE-ISOLDE AS PART OF THE EUROPEAN ROADMAP

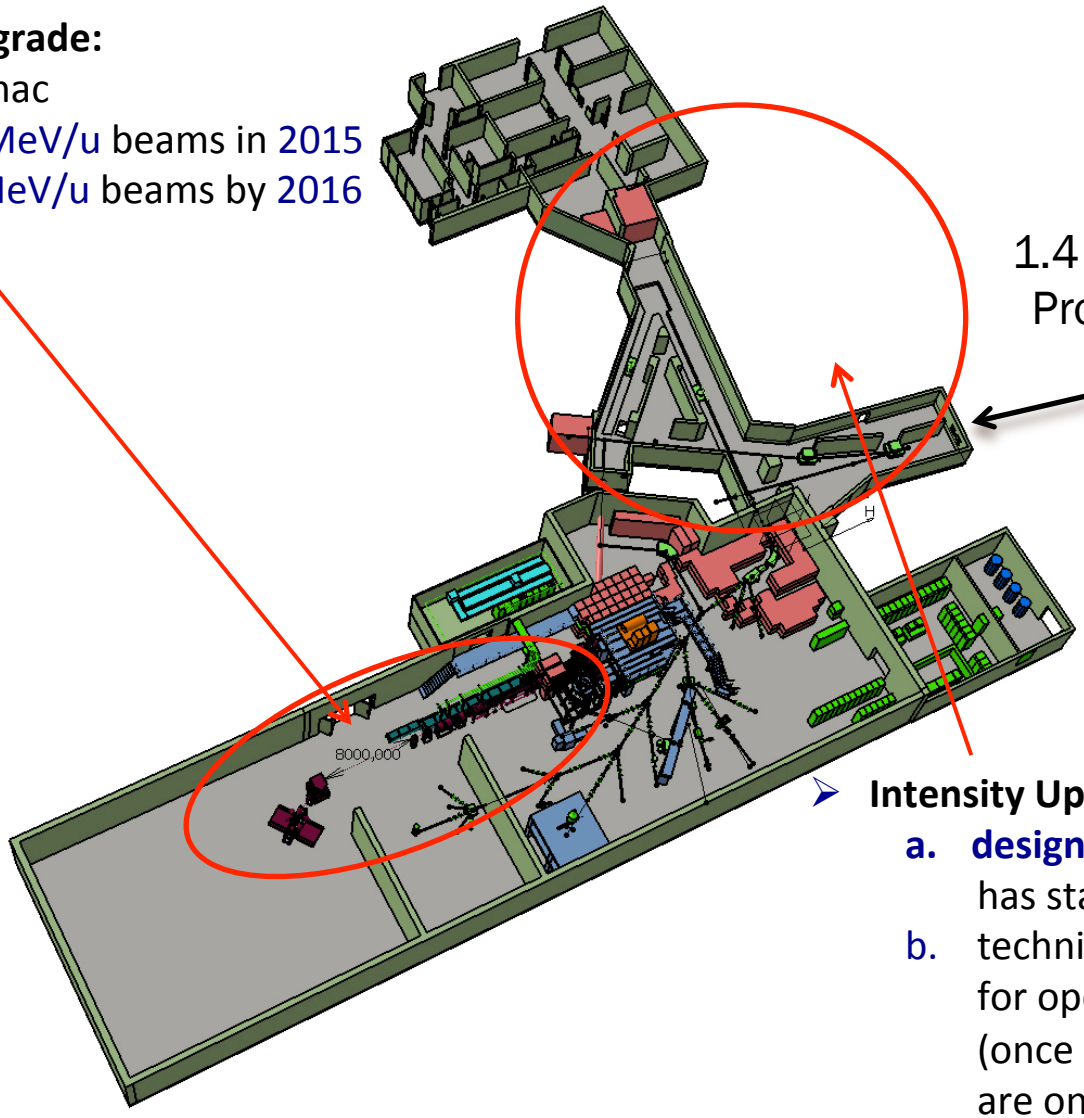
- NuPECC Long Range Plan:

HIE-ISOLDE will play an important role in the network of ISOL facilities preparing EURISOL (with SPIRAL2 and SPES)



UPGRADE OF ISOLDE

- **Energy Upgrade:**
  a. SC linac
  b. 5.5 MeV/u beams in 2015
  c. 10 MeV/u beams by 2016

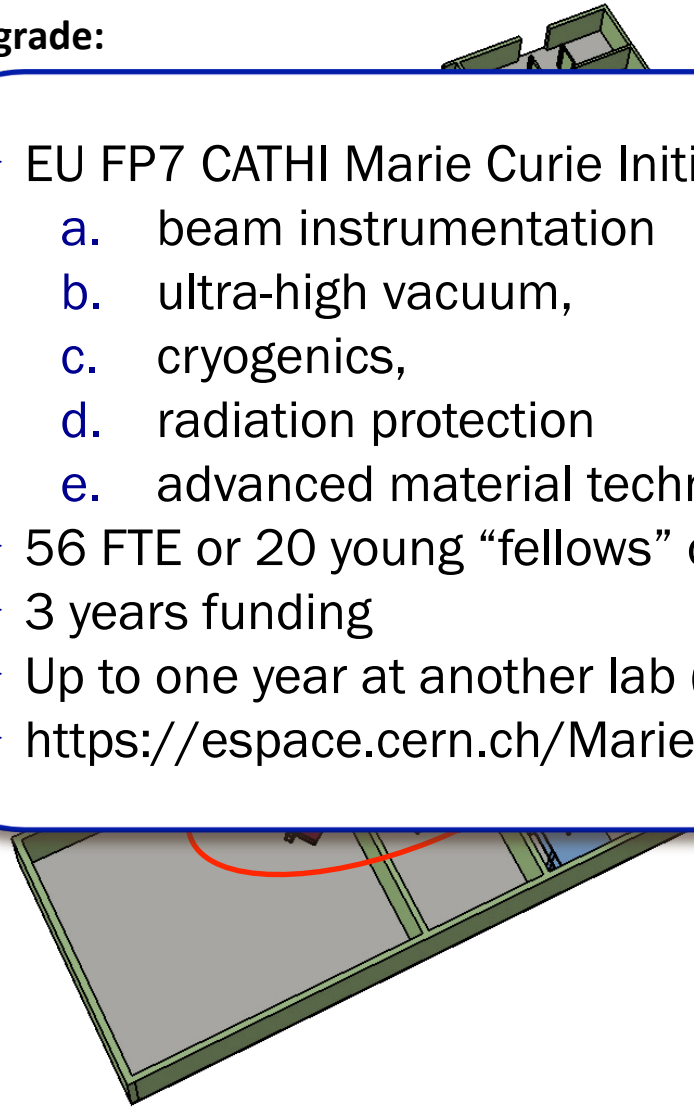


1.4 GeV protons from CERN's Proton Synchrotron Booster (PSB)
P_{av} ~ 3 kW.

- **Intensity Upgrade:**
  a. **design study** for the intensity upgrade has started this year **in 2012**
  b. technical feasibility and cost estimate for operating the facility at **10 kW** (once Linac4 and PS Booster upgrade are online)

UPGRADE OF ISOLDE

- **Energy Upgrade:**
  a. SC
  b.
  c.



- EU FP7 CATHI Marie Curie Initial Training Network:
  a. beam instrumentation
  b. ultra-high vacuum,
  c. cryogenics,
  d. radiation protection
  e. advanced material technologies
- 56 FTE or 20 young "fellows" on the project (or soon to start)!
- 3 years funding
- Up to one year at another lab (fully supported!)
- https://espace.cern.ch/Marie-Curie-CATHI

CERN's
Booster

a. **design study** for the intensity upgrade has started this year **in 2012**
b. technical feasibility and cost estimate for operating the facility at **10 kW** (once Linac4 and PS Booster upgrade are online)

REX-ISOLDE POST-ACCELERATOR

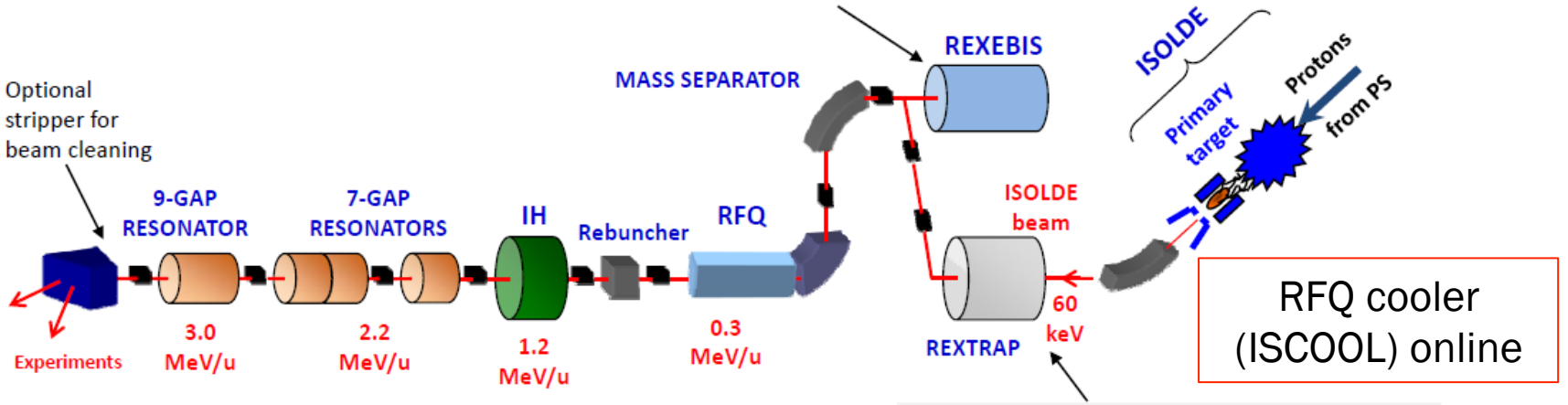
Slide courtesy of F. Wenander (BE-ABP-HSL)

* Energy from 60 kV to few MeV/u
* Operational since Oct 2001
* Until now:
  >30 elements
  close to 100 isotopes

Electron beam ion source

* 1+ ions to n+
* Super conducting solenoid, 2 T
* Electron beam <0.4 A, 3-6 keV
* Breeding time 3 to >200 ms

REX-ISOLDE layout



RFQ cooler (ISCOOL) online

Linac

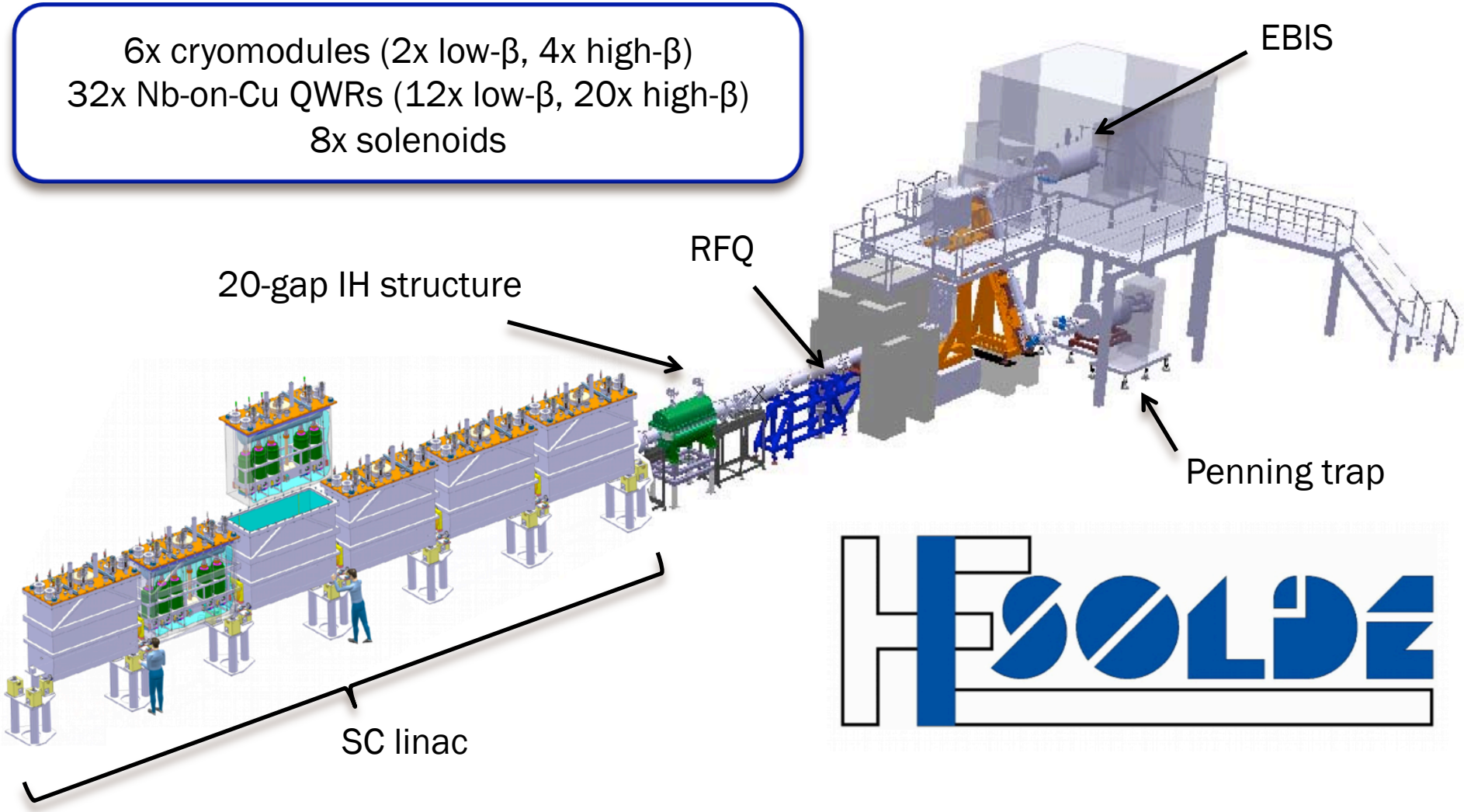
Type	normal conducting 6 accelerating cavities
Length	11 m
Freq.	101 MHz (202 MHz for the 9GP)
Duty cycle	1 ms 100Hz
Energy	300 keV/u, 1.2-3 MeV/u (variable)
A/q max.	4.5

Penning trap

* Longitudinal accumulation and bunching
* Transverse phase space cooling
* 3 T solenoid field
  + quadratic electrostatic potential
  + RF cooling
* Buffer gas filled (5E-4 mbar)
* Cooling time ~20 ms

40 MV SC POST-ACCELERATOR

6x cryomodules (2x low-β, 4x high-β)
32x Nb-on-Cu QWRs (12x low-β, 20x high-β)
8x solenoids



STAGED INSTALLATION OF SC LINAC

- REX accelerator (existing): W = 3 MeV/u

KEY:

RFQ IHS 7G1,2,3 9GP LOW-β CRYO. HIGH-β CRYO.

STAGED INSTALLATION OF LINAC

- REX accelerator (existing): W = 3 MeV/u

2x cryomodules
10x QWRs
2x solenoids

- HIE Stage 1 (2015): W = 5.5 MeV/u

Cryo-line “jumper” positions

KEY:

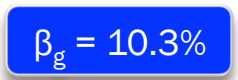
RFQ

IHS

7G1,2,3

9GP

LOW-β CRYO.



HIGH-β CRYO.

STAGED INSTALLATION OF LINAC

- REX accelerator (existing): W = 3 MeV/u

4x cryomodules
20x QWRs
4x solenoids

- HIE Stage 1 (2015): W = 5.5 MeV/u

- HIE Stage 2a (2016): W = 10 MeV/u

Cryo-line "jumper" positions

KEY: RFQ | IHS | 7G1,2,3 | 9GP | β_g = 6.3% LOW-β CRYO. | β_g = 10.3% HIGH-β CRYO.

STAGED INSTALLATION OF LINAC

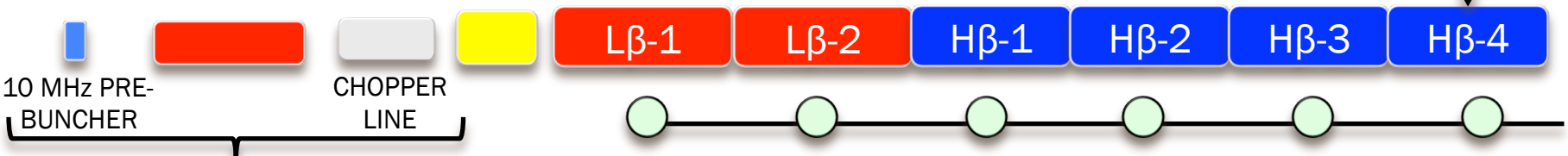
- REX accelerator (existing): W = 3 MeV/u

6x cryomodules
32x QWRs
8x solenoids

- HIE Stage 1 (2015): W = 5.5 MeV/u

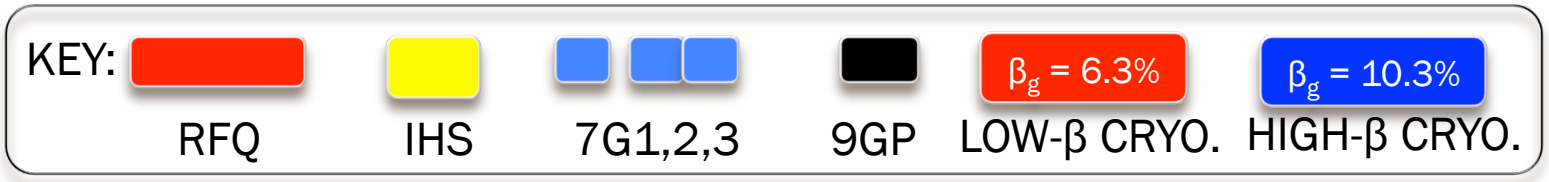
- HIE Stage 2a (2016): W = 10 MeV/u

- HIE Stage 2b (2017/18): 10 MeV/u



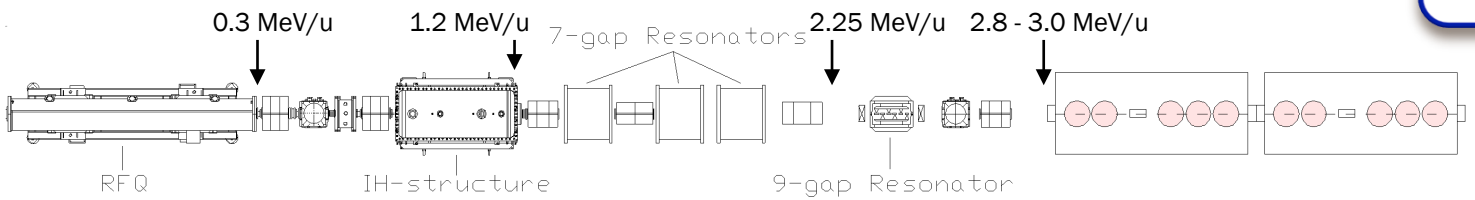
Undergoing design study for 10 MHz beam frequency for time-of-flight particle ID requested by experiments.

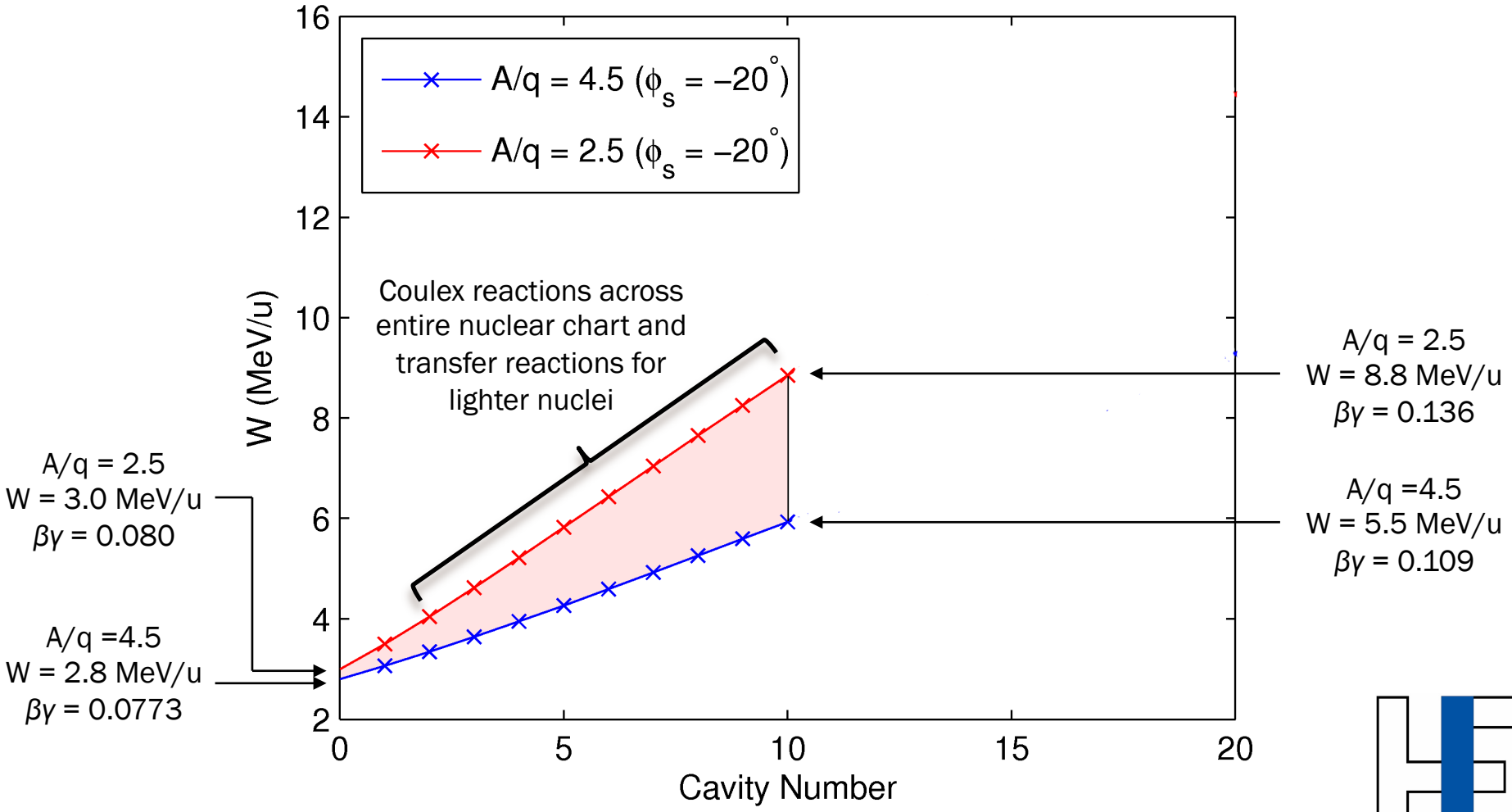
Cryoline "jumper" positions



ENERGY RANGE: STAGE 1

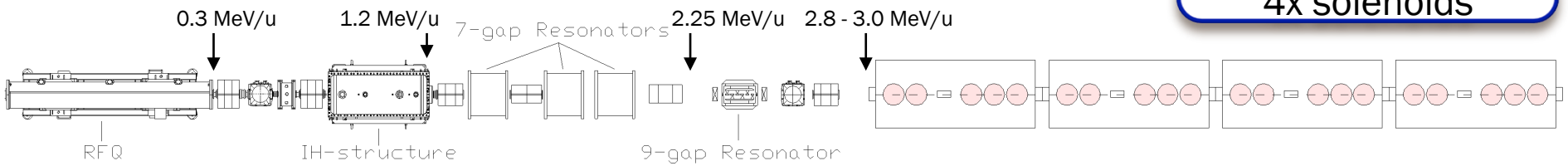
2x cryomodules
10x QWRs
2x solenoids

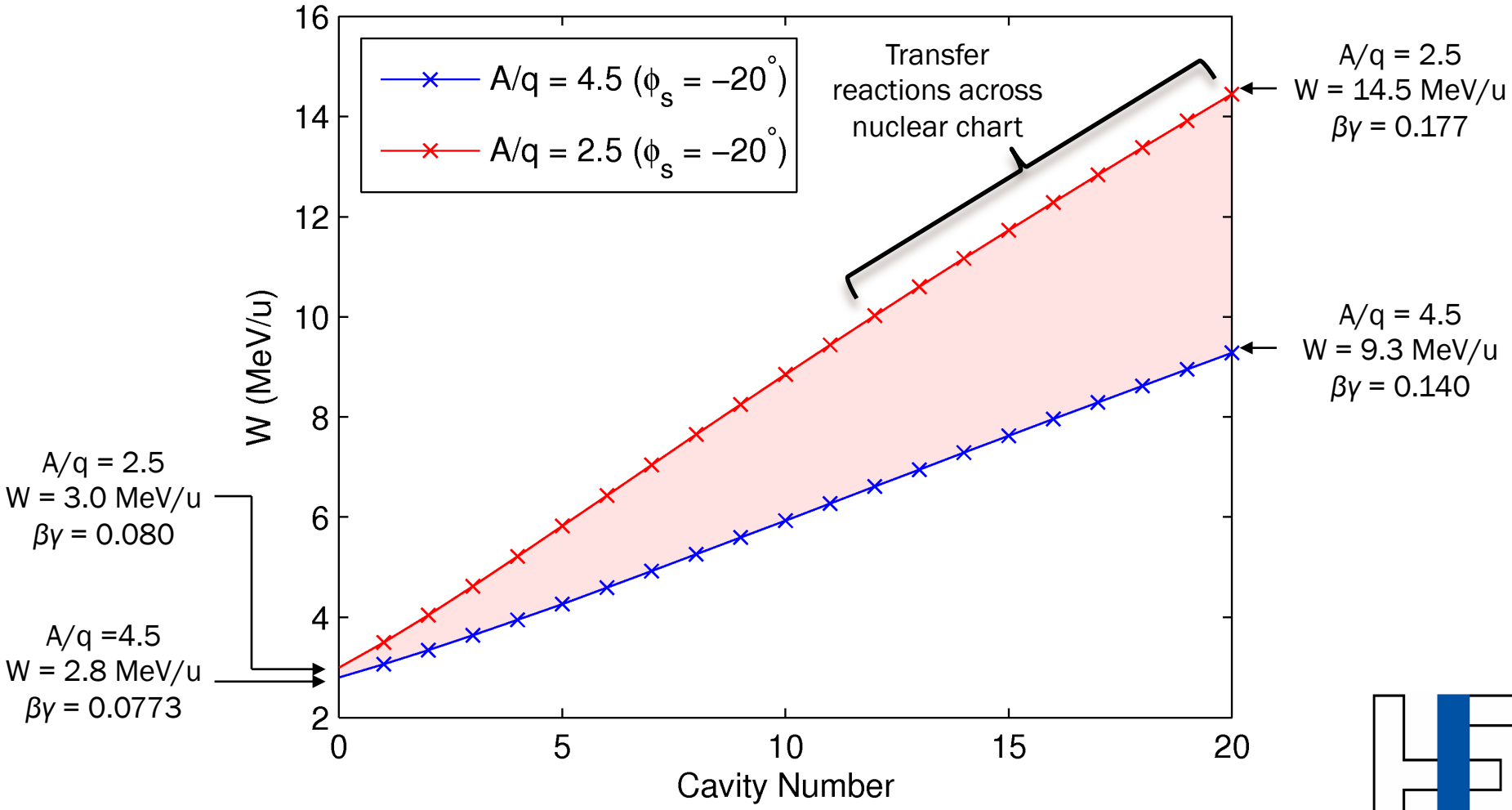




ENERGY RANGE: STAGE 2A

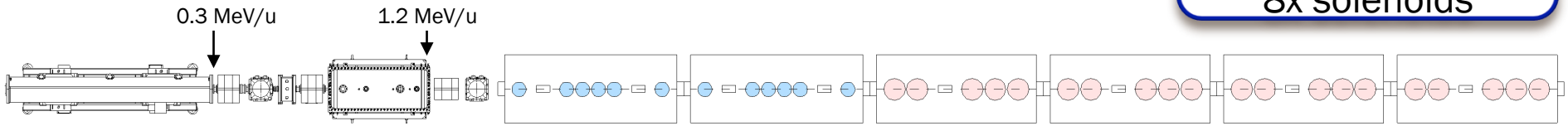
4x cryomodules
20x QWRs
4x solenoids

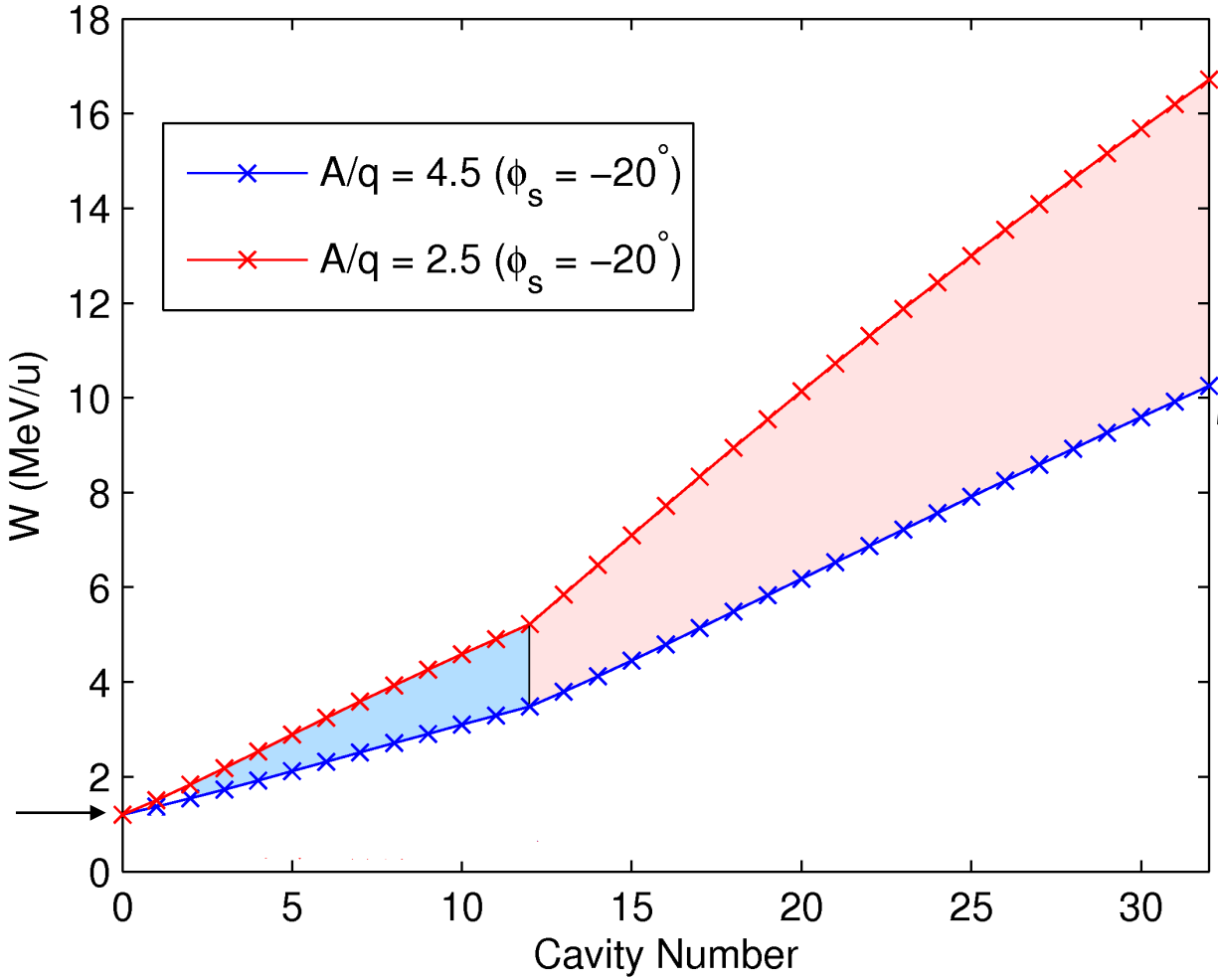




ENERGY RANGE: STAGE 2B

6x cryomodules
32x QWRs
8x solenoids





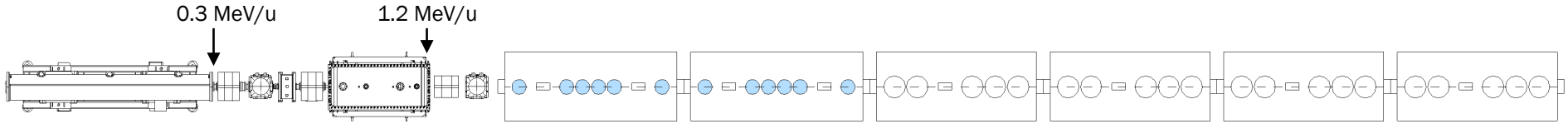
A/q = 2.5
W = 16.8 MeV/u
$\beta\gamma$ = 0.187

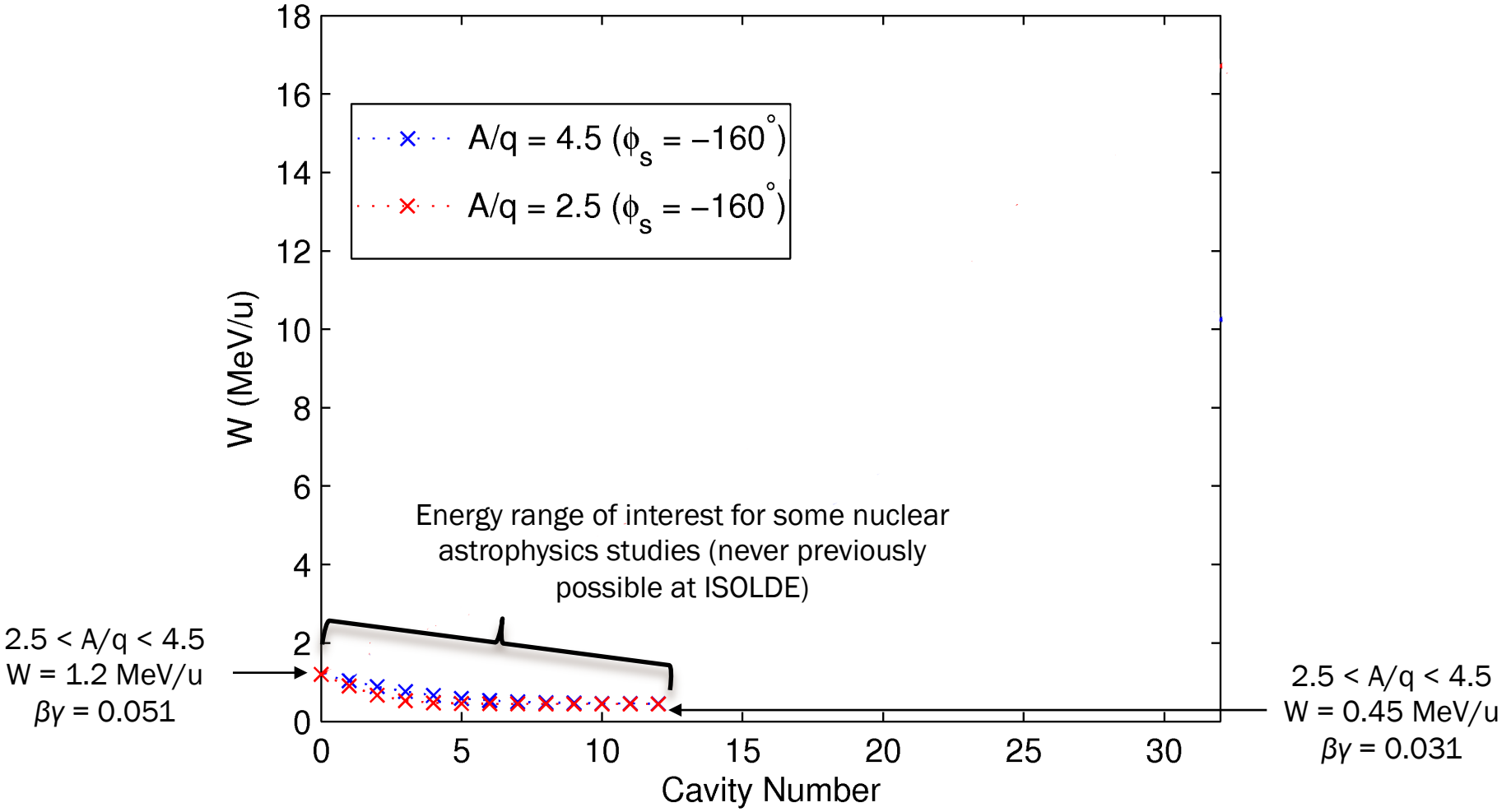
A/q = 4.5
W = 10.2 MeV/u
$\beta\gamma$ = 0.147

Highest rigidity:
W = 10 MeV/u
A/q = 4.5
$B\rho$ = 2 Tm

2.5 < A/q < 4.5
W = 1.2 MeV/u
$\beta\gamma$ = 0.051

ENERGY RANGE: STAGE 2B (DECELERATION)

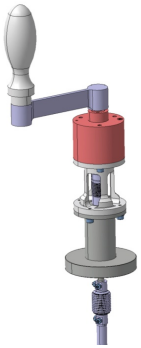




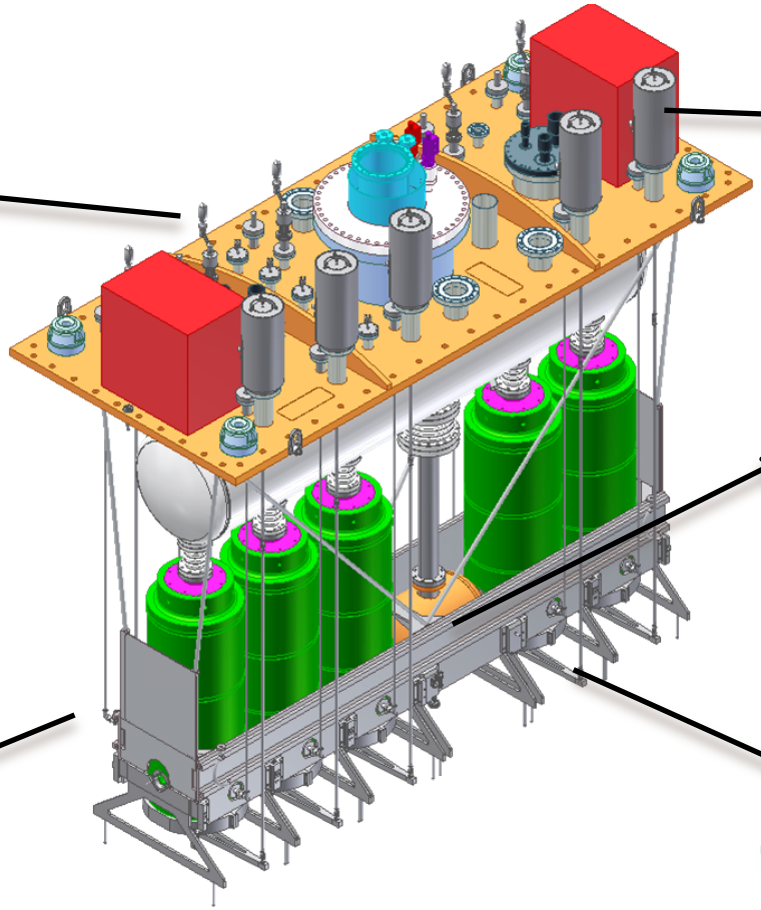
RF R&D ACTIVITIES (2009 – 2011)

Slide courtesy of O. Capatina (EN-MME-ES)

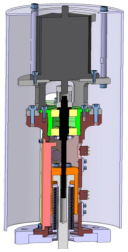
- 3x high-β cavity prototypes and 1x each RF ancillary prototype, tested in the single-cavity test cryostat.

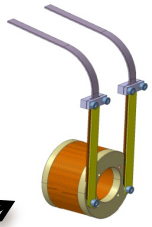


Coupler positioner



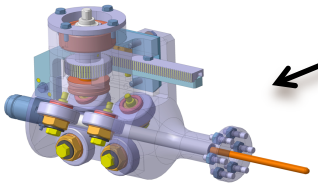
Tuner motorisation



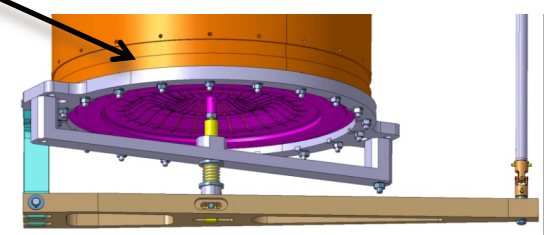


Short Prototype Solenoid (Nb_3Sn)

Variable coupler (new design underway)



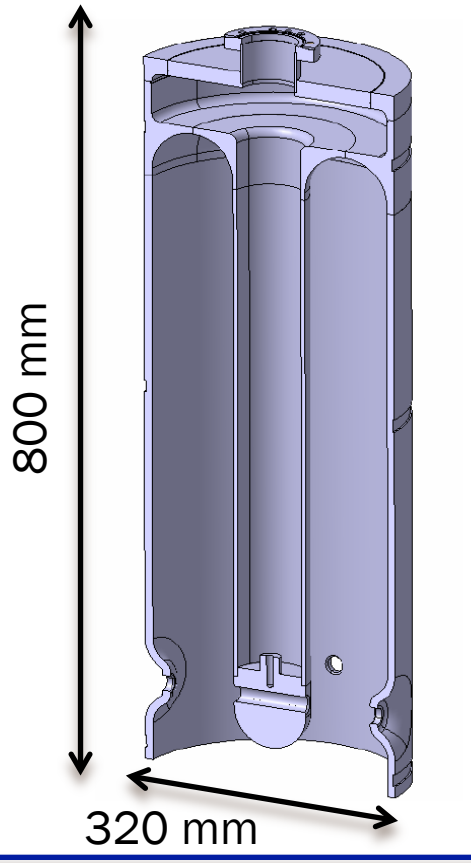
Tuner plate and actuator



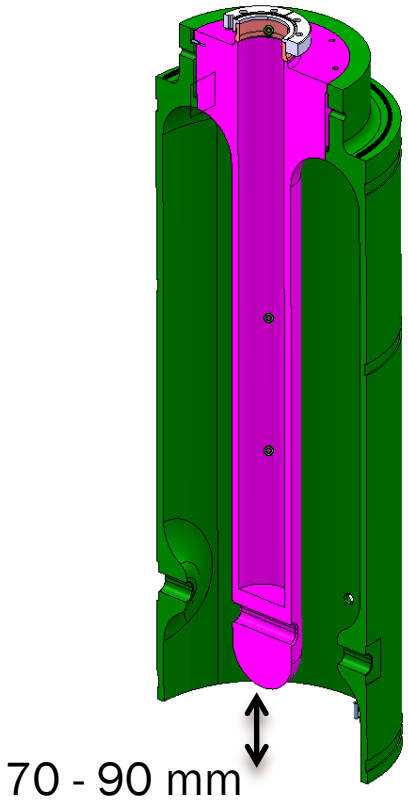
HIGH-BETA CAVITY PROTOTYPES

- Nb-on-Cu sputtered cavities, two designs:
  a. 2x rolled copper sheet (original prototype) with He reservoir
  b. 1x 3D machined copper billet (pre-series design) without He reservoir

a. old



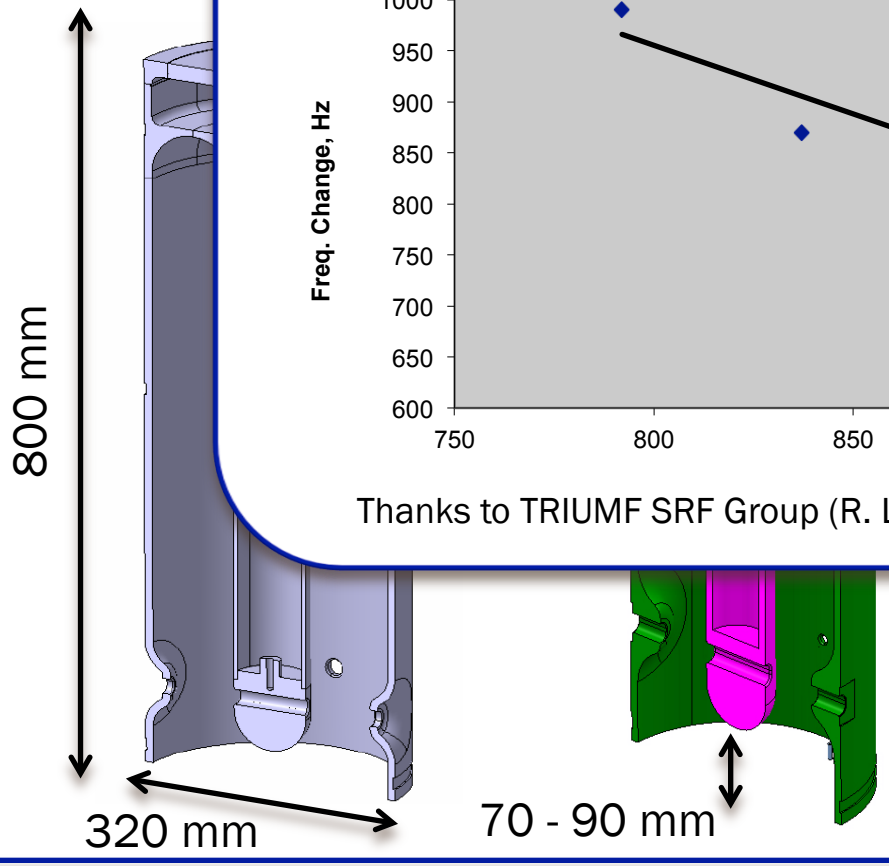
b. new

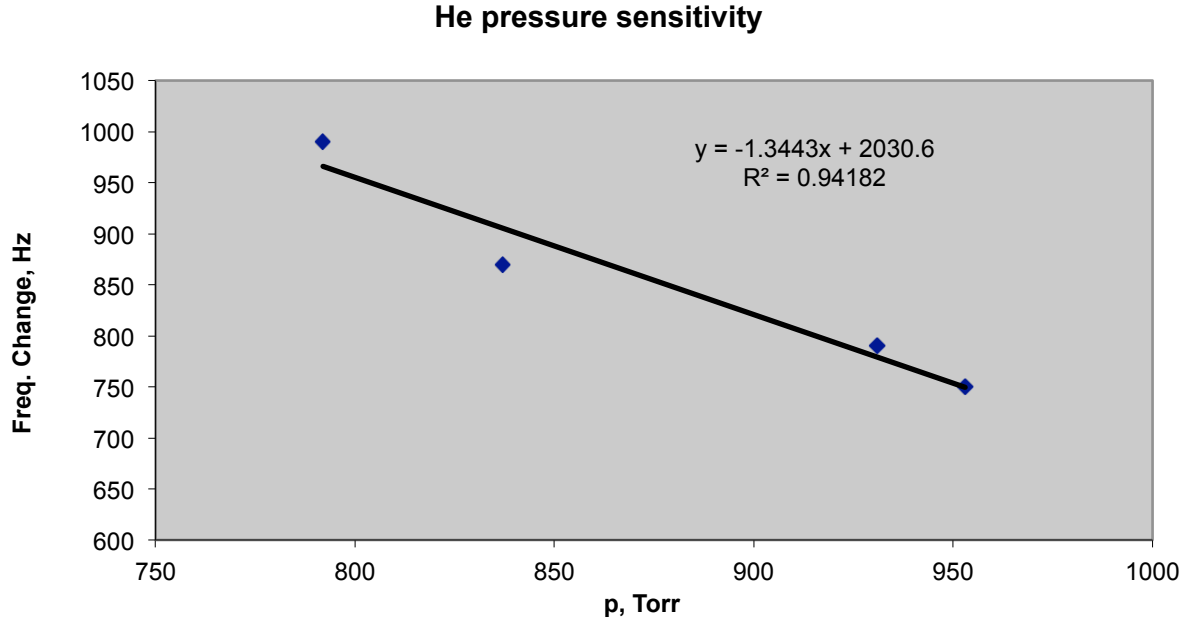


Design Parameter	Value
f_0 (MHz)	101.28
β_g (%)	10.3
E_{acc} (MV/m) = V_0/L_a	6
L_a (m)	0.3
R_{shunt}/Q_0 (Ω)	550
E_{peak}/E_{acc}	5.6
H_{peak}/E_{acc} (G/(MV/m))	100
Q_0 (at 6 MV/m, P = 10 W)	5 X 10^8
$\Gamma = R_s Q_0$ (Ω)	31
U/E^2_{acc} (mJ/(MV/m))^2	210
T (K)	4.5

HIGH-BETA CAVITY PROTOTYPES

- Nb-on-Cu sputtered cavities, two designs:
  a. 2x rolled copper sheet (original prototype) with He reservoir
  b. 1x [illegible] reservoir





Thanks to TRIUMF SRF Group (R. Laxdal and Vladimir Zvyagintsev *et al.*)

	Value
	101.28
	10.3
	6
	0.3
	550
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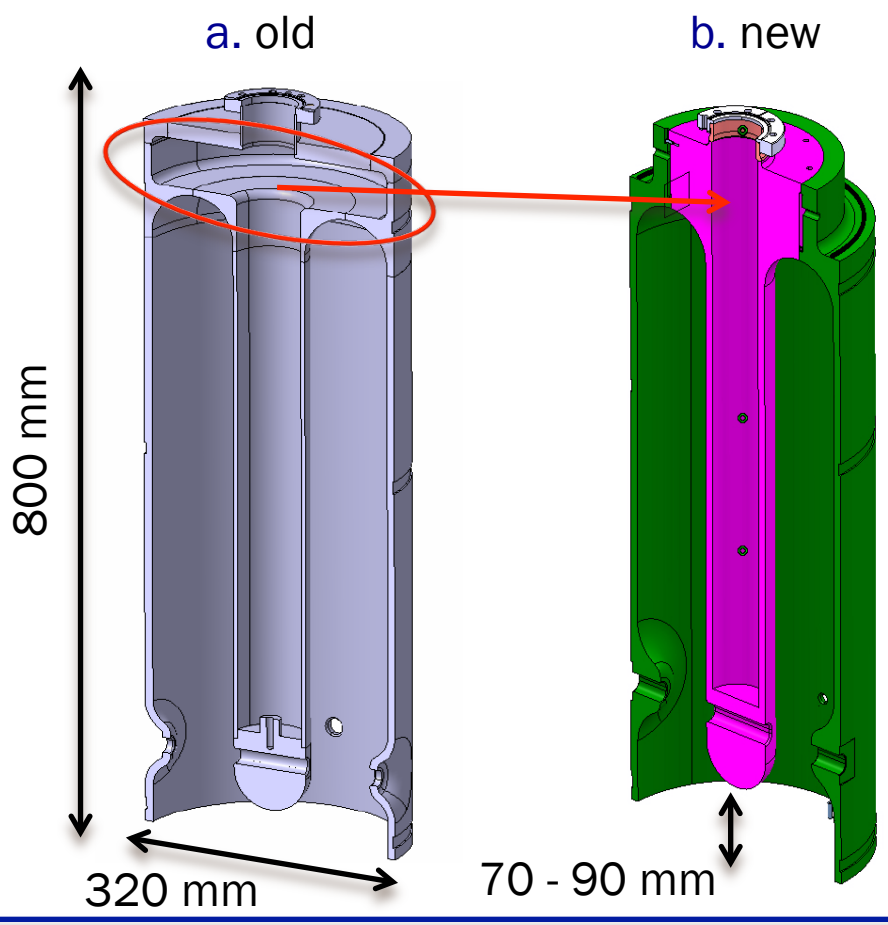

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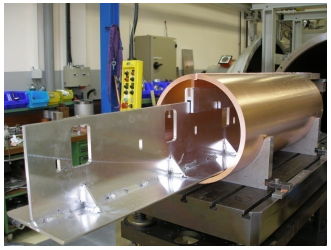
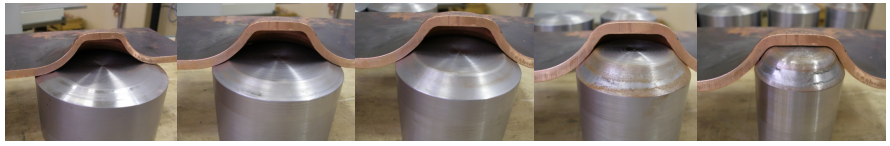
$\Gamma = R_s Q_0$ (Ω)	31
U/E^2_{acc} (mJ/(MV/m))^2	210
T (K)	4.5

HIGH-BETA CAVITY PROTOTYPES: Q1,2 + 3

OLD,
Q1 + Q2

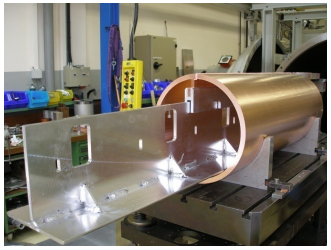


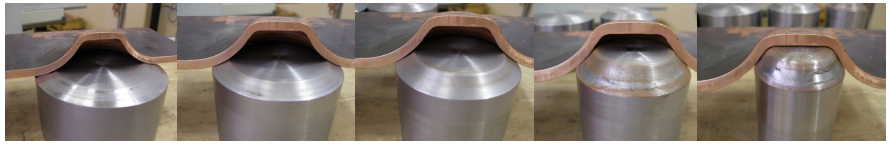


HIGH-BETA CAVITY PROTOTYPES: Q1,2 + 3

NEW, Q3

OLD,
Q1 + Q2

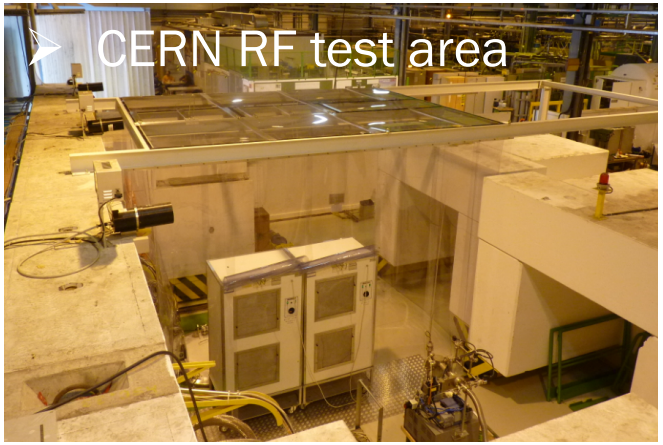




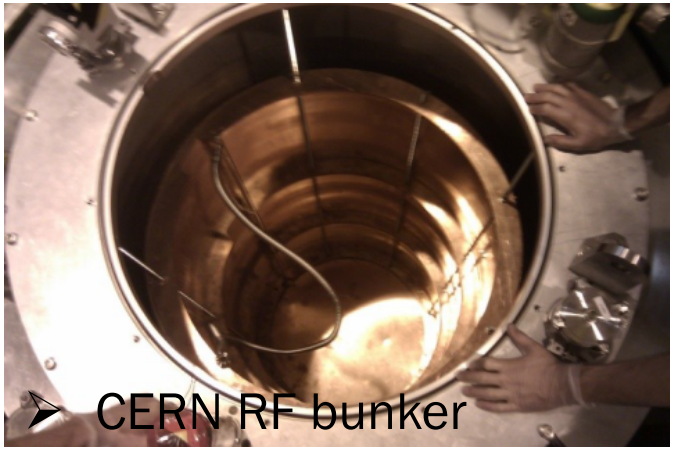
RF TEST FACILITY (SM18)

Slide courtesy of W. Venturini Delsolaro (BE-RF-SRF)

➢ Test cryostat

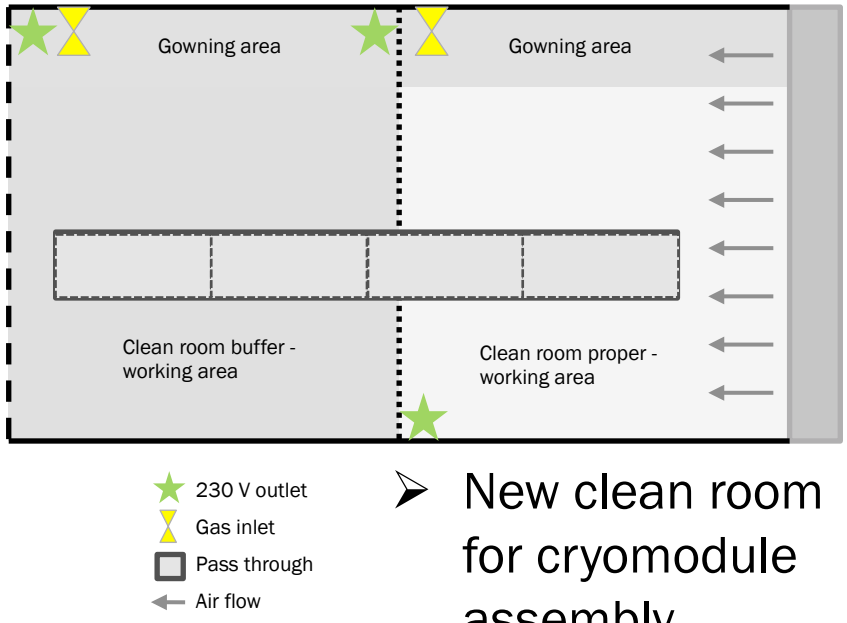


➢ CERN RF test area



➢ CERN RF bunker

➢ Clean room assembly at SM18

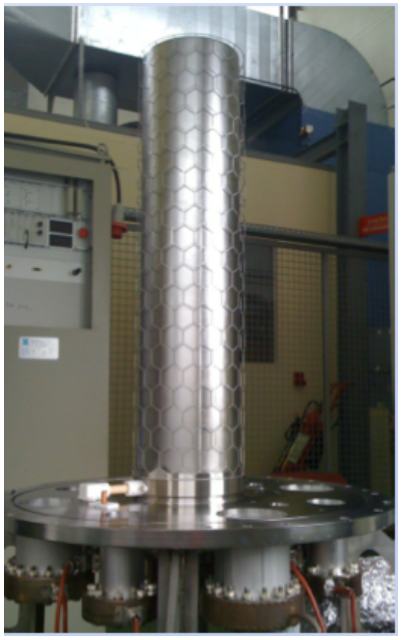


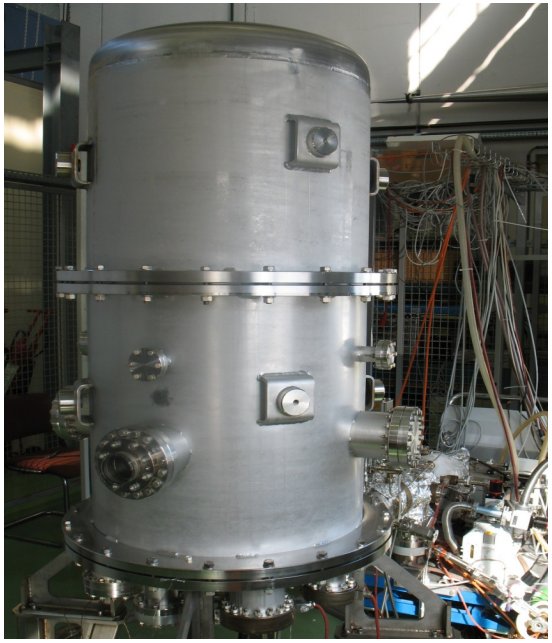
➢ New clean room for cryomodule assembly

QWR COATING FACILITY

Slide courtesy of S. Calatroni (TE-VSC-SCC)

- Apparatus capable of both magnetron and diode sputtering technique.
- Decision made last year to focus on a single sputtering technique for RF cavity tests: follow high-temperature diode sputtering.
- Magnetron sputtering will continue on samples and special Cu “dummy” cavity.

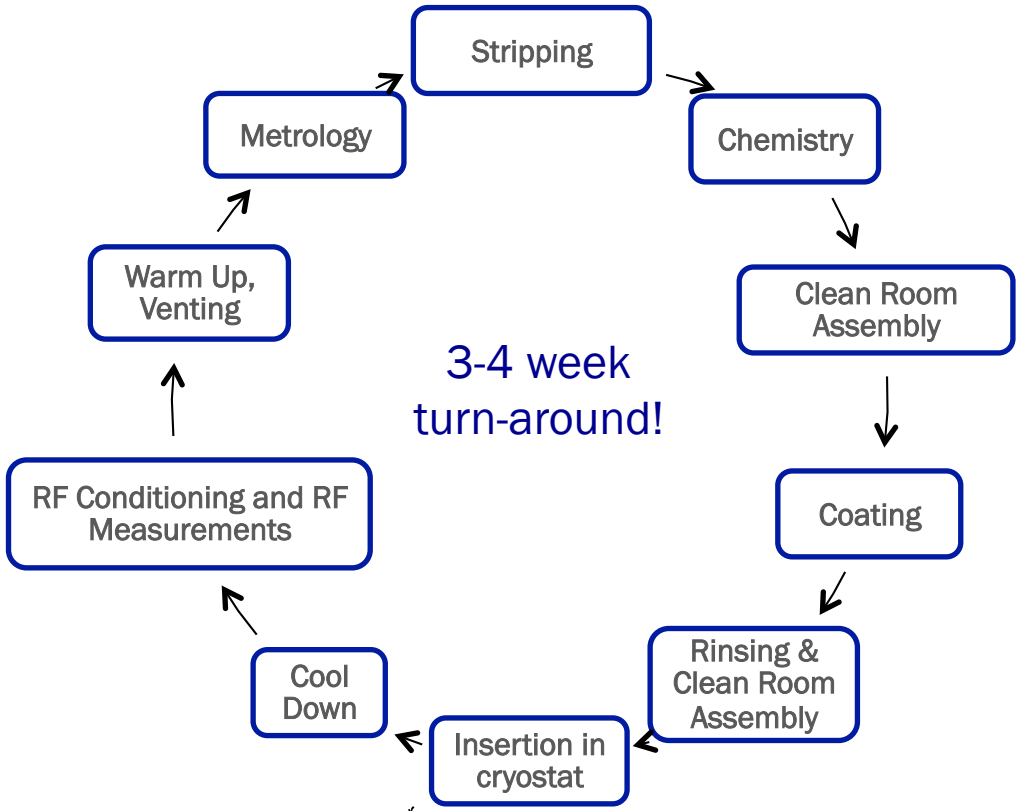


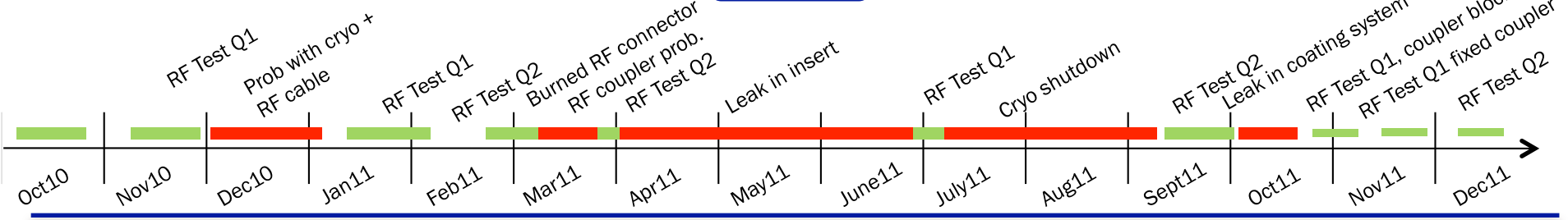



RF TESTS THROUGH 2011

Slide courtesy of W. Venturini Delsolaro (BE-RF-SRF)

- Sputtering and RF testing working in tandem: 3-4 week turn-around achieved.

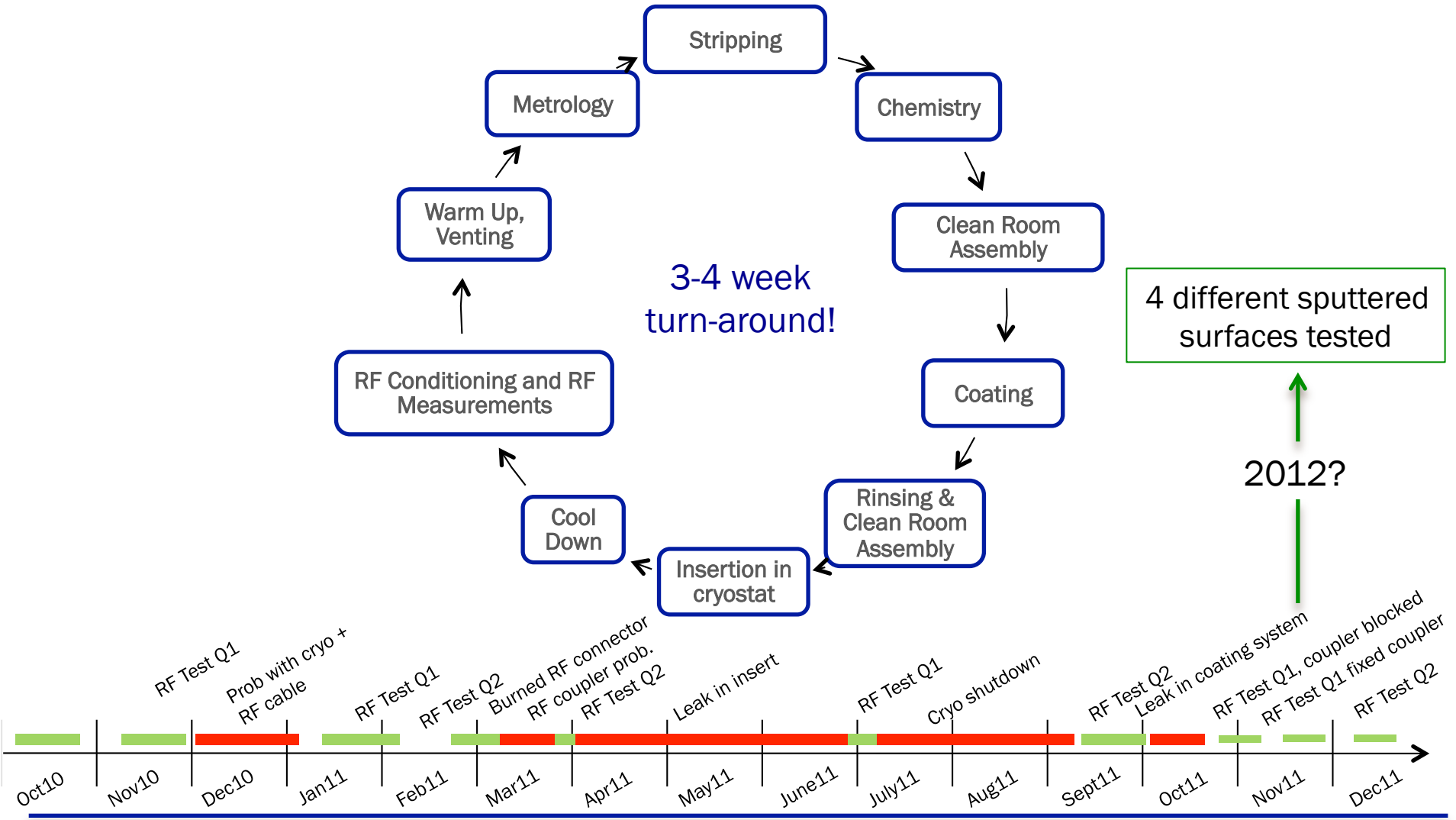




RF TESTS THROUGH 2011

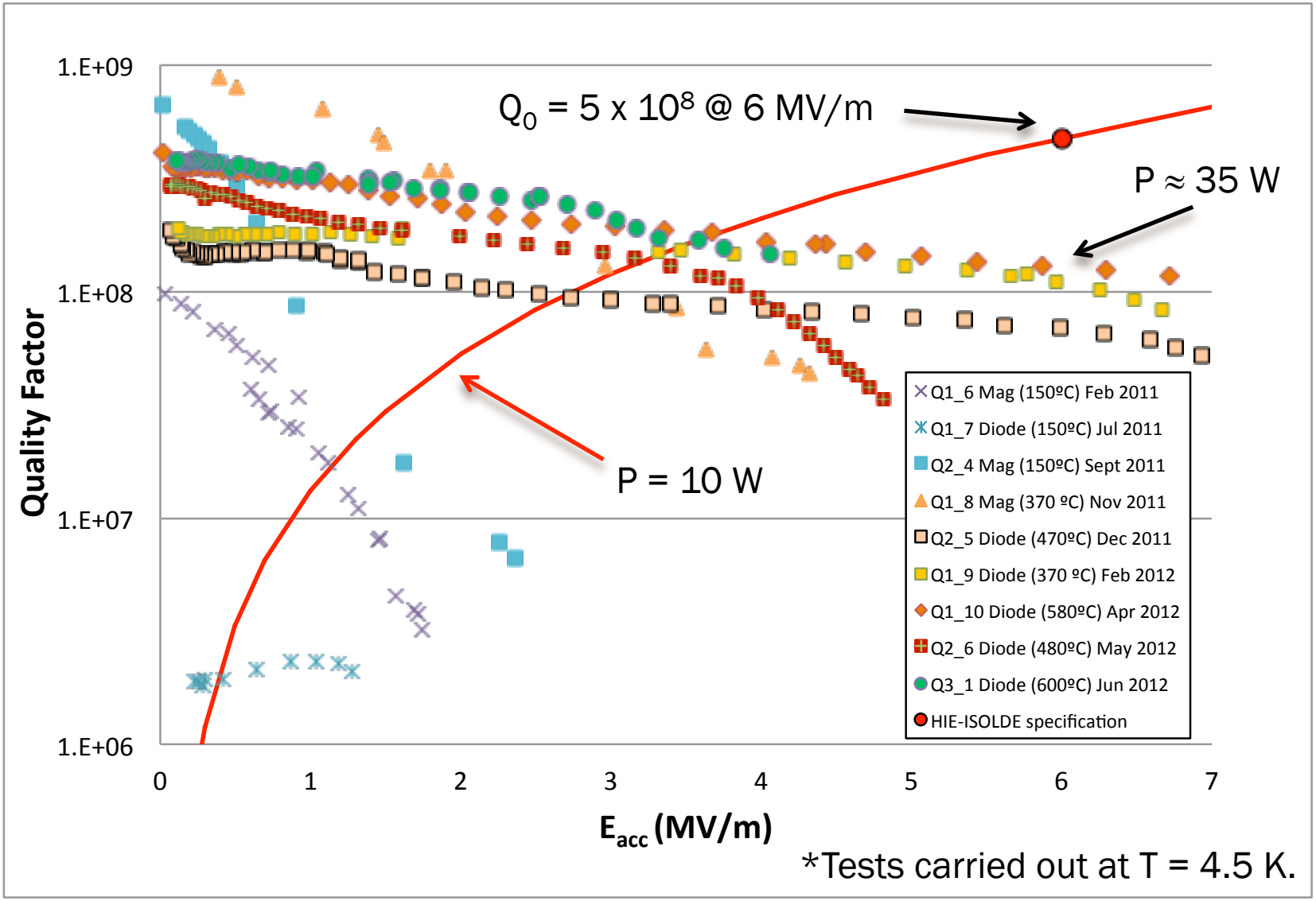
Slide courtesy of W. Venturini Delsolaro (BE-RF-SRF)

- Sputtering and RF testing working in tandem: 3-4 week turn-around achieved.



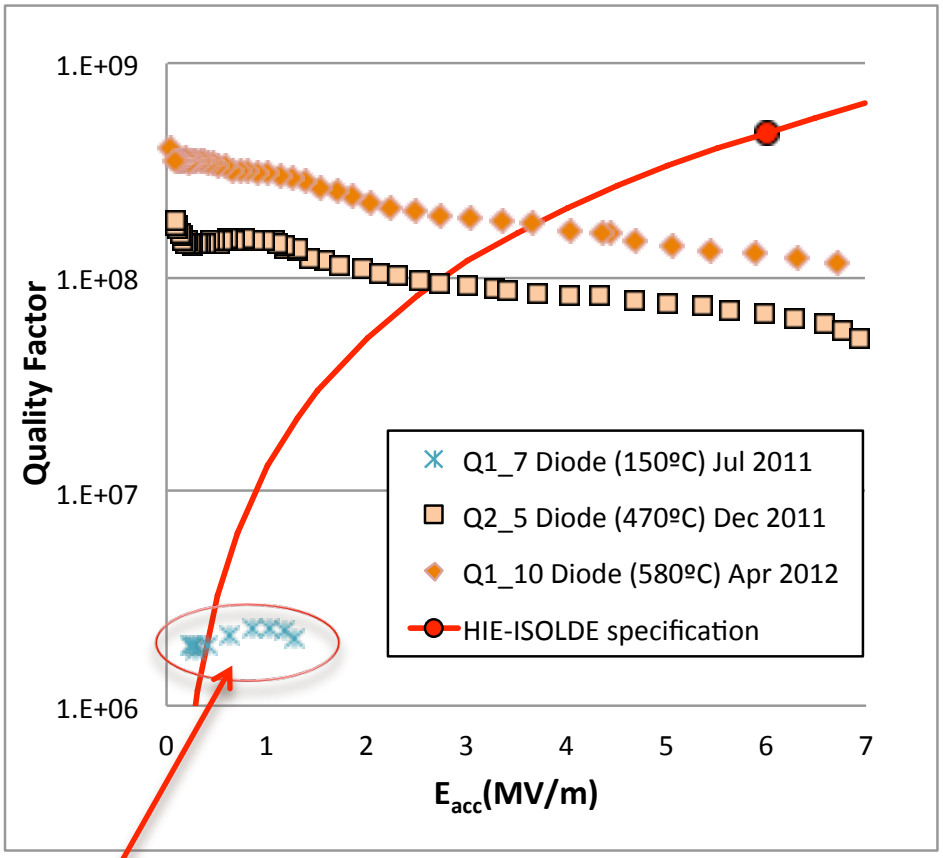
CAVITY PERFORMANCE TO DATE*

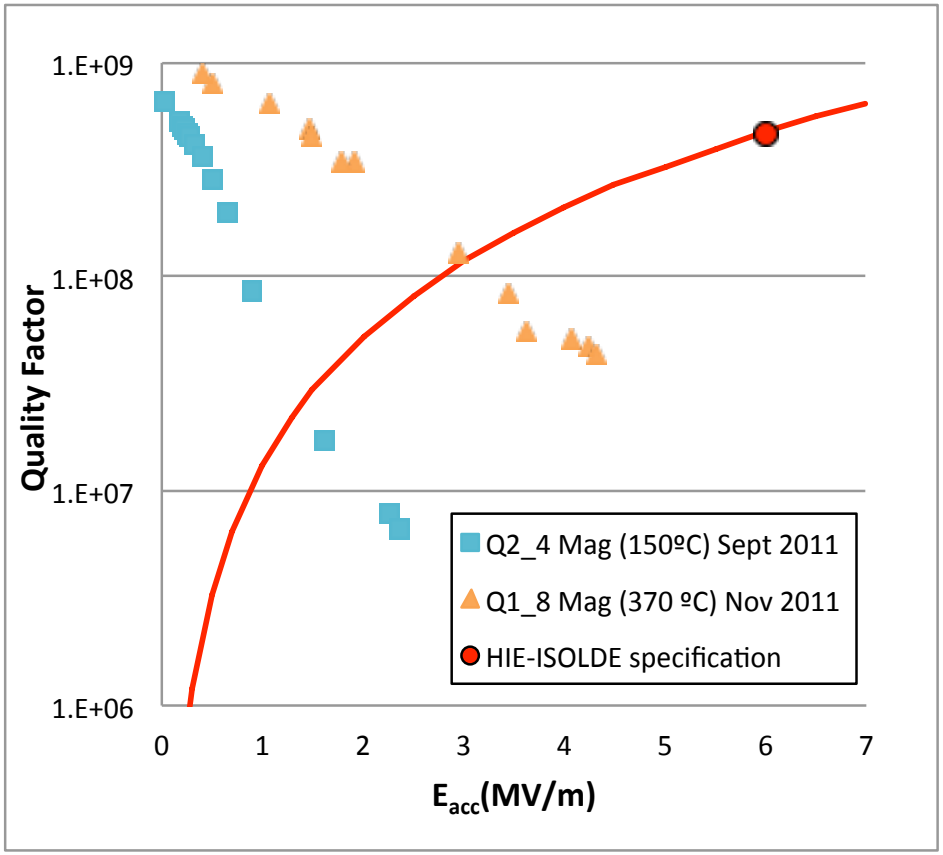
Slide courtesy of W. Venturini Delsolaro (BE-RF-SRF)



CAVITY PERFORMANCE TO DATE

Slide courtesy of W. Venturini Delsolaro (BE-RF-SRF)





Diode sputtering
Final substrate T = 470°C and 580°C

problem with coupler

Magnetron sputtering
Final substrate T = 150°C and 370°C
(at least x2 factor RRR)

FUTURE TESTS

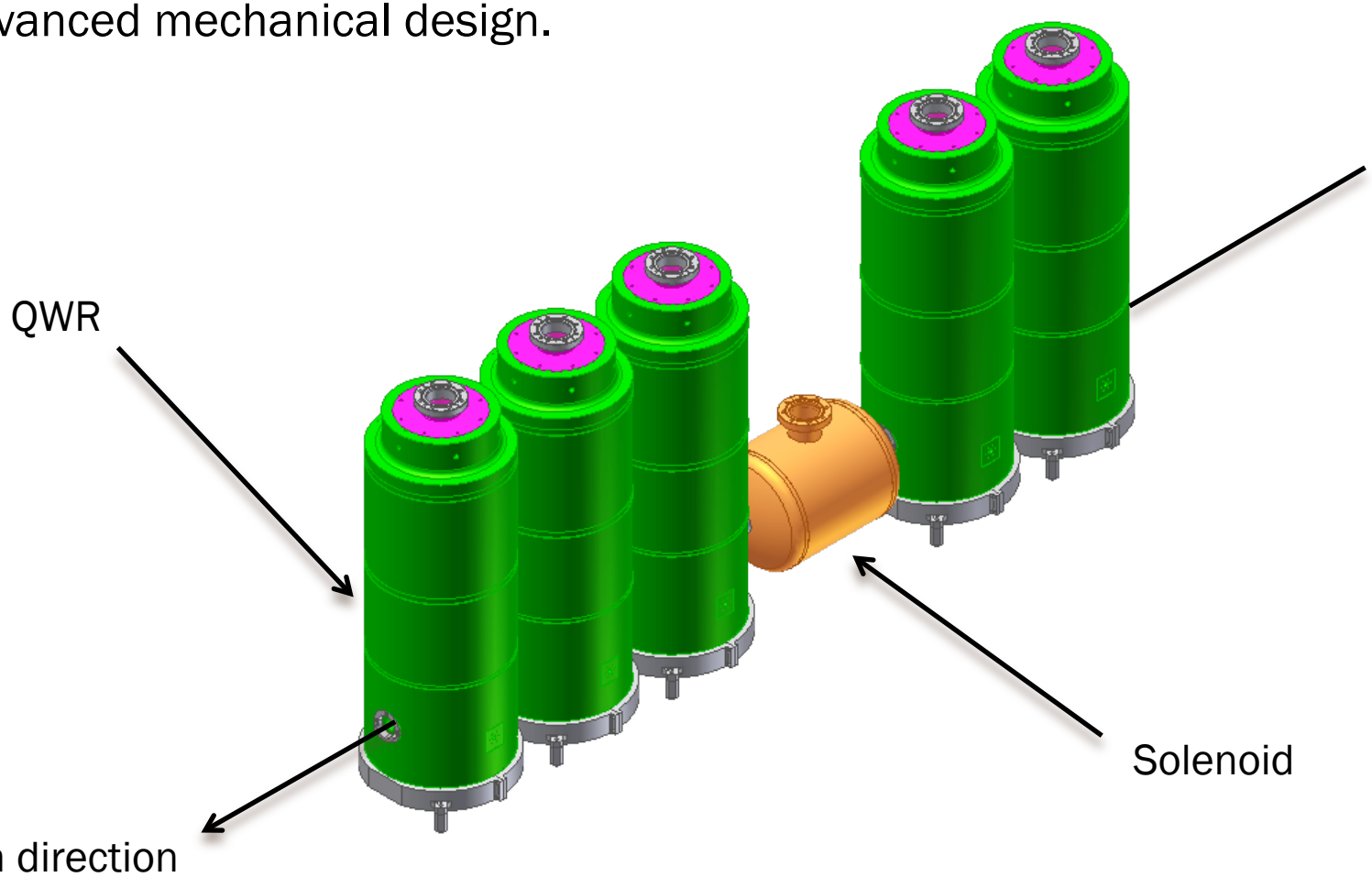
- At least factor 2 increase in RRR (in RF critical region) observed by not cooling the substrate:
  a. with cooling cavity kept at ~150°C, without reached 300°C at finish.
  b. installing heaters to pre-heat cavity before sputtering.
  c. new power supply, currently 4 kW, going up to 8 kW.
  d. carefully monitoring mechanical stability (studied effect on beam).
  e. sputter gas purification (NEG)

- Procurement of solenoid on hold until effect of stray field on cavity is tested using a permanent magnet actuated close to the cavity in test-cryostat. Important for choice of SC magnet:
  a. NbTi
  b. Nb_3Sn

CRYOMODULE

Slides courtesy of L.R. Williams and Y. Leclercq (TE-MSC-CMI)

- R&D focused on the high-β cryomodule: 5 QWR SC cavities and 1 solenoid
- Advanced mechanical design.



CRYOMODULE

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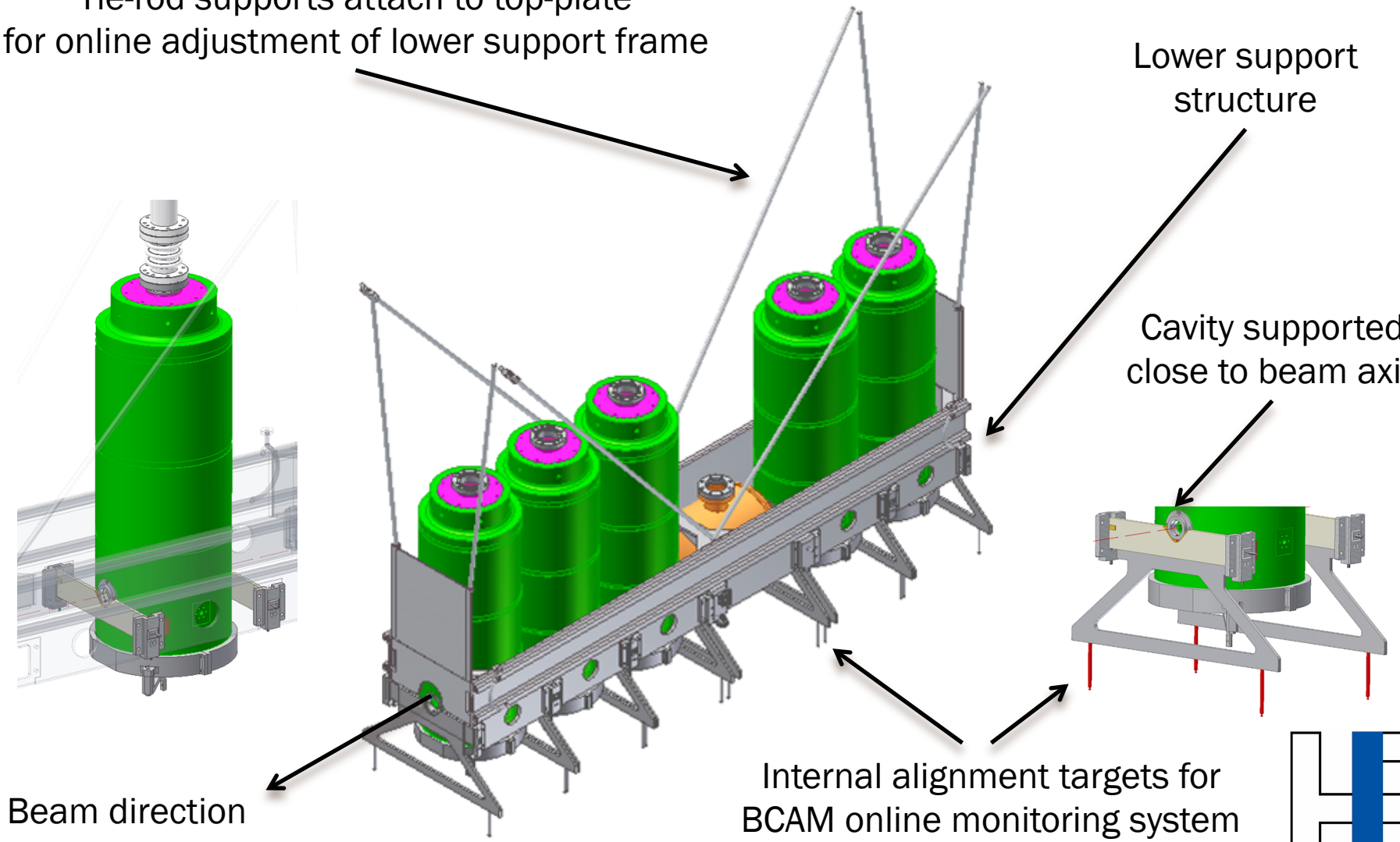

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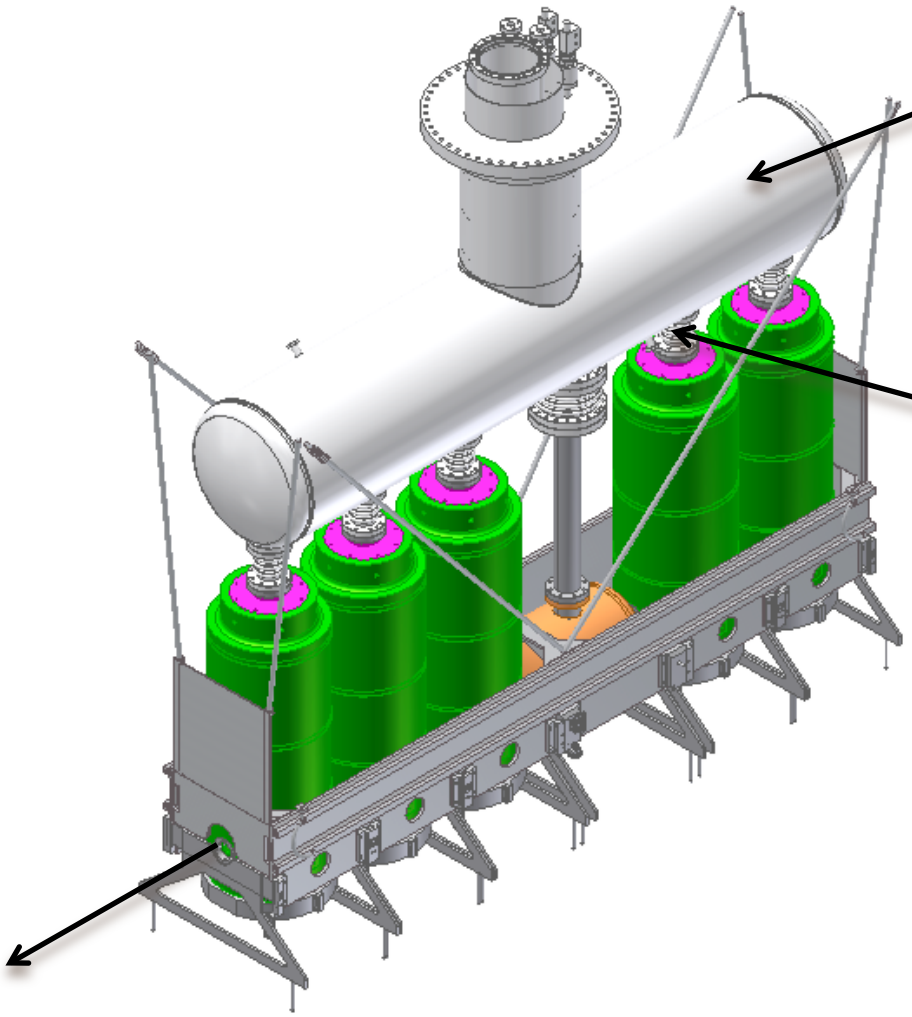

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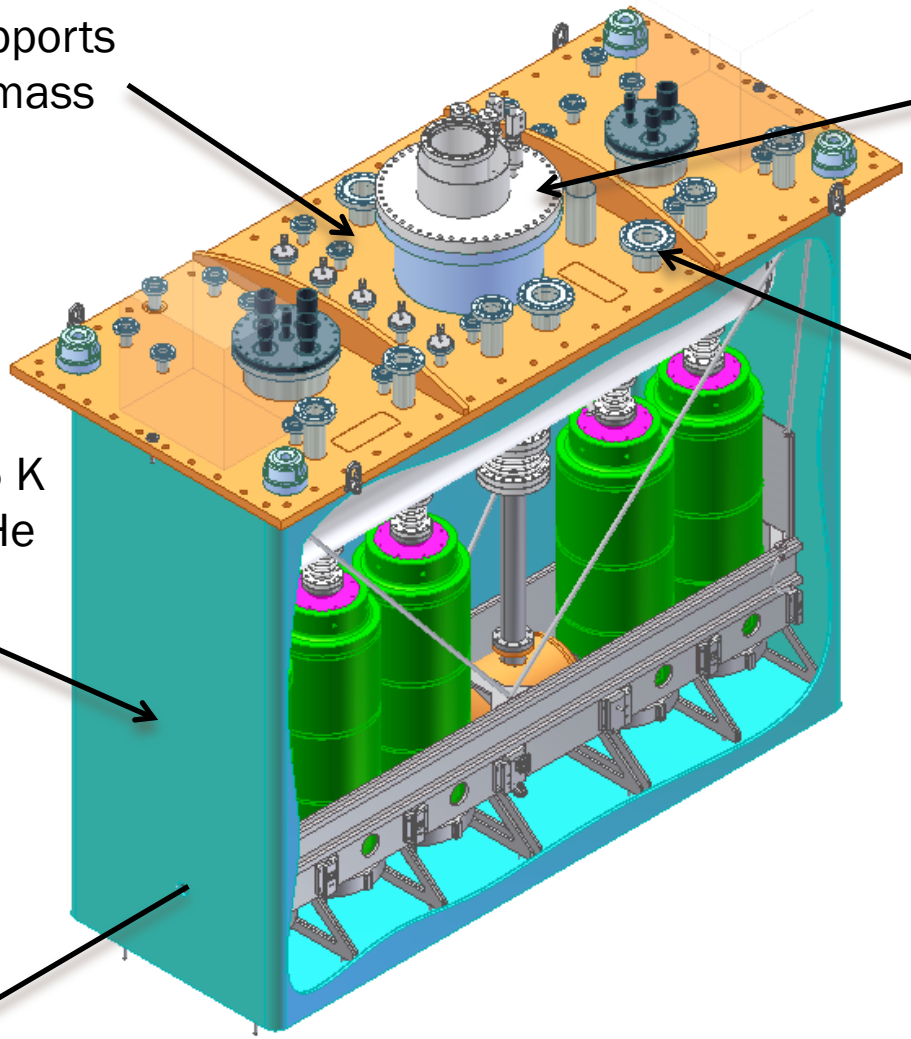

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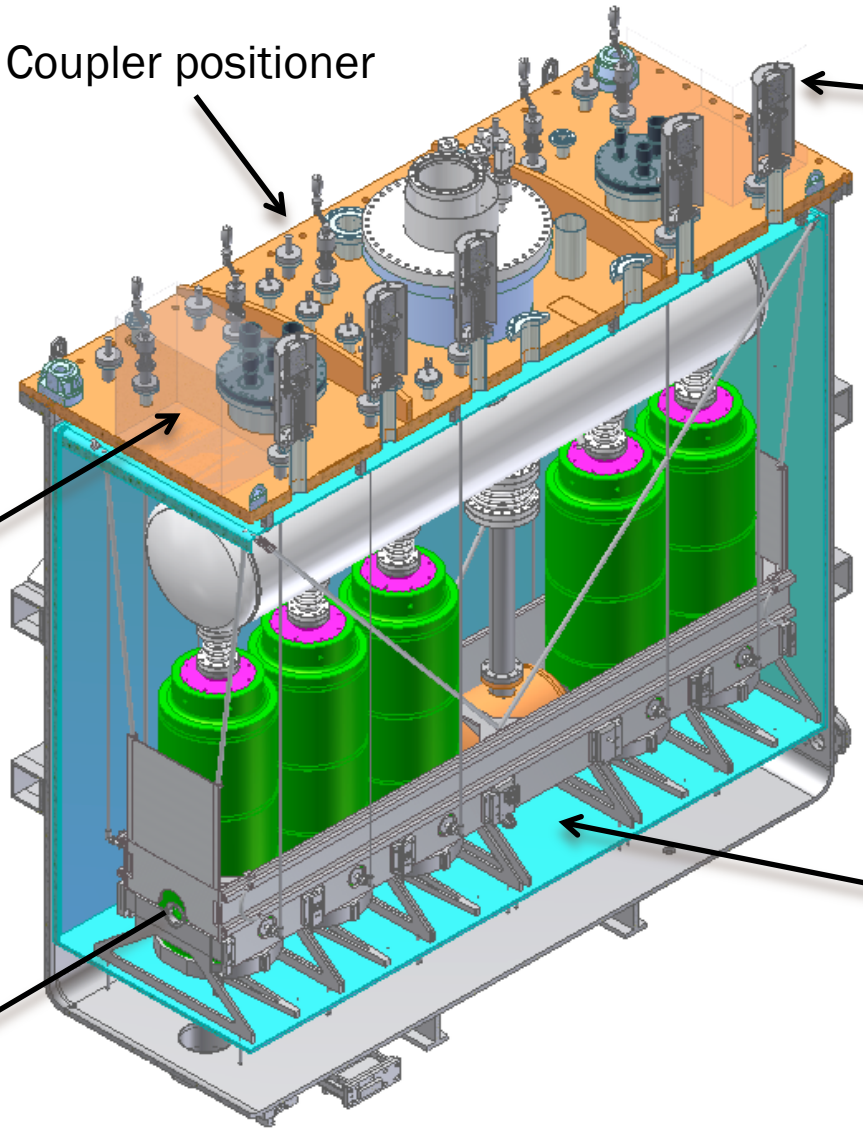

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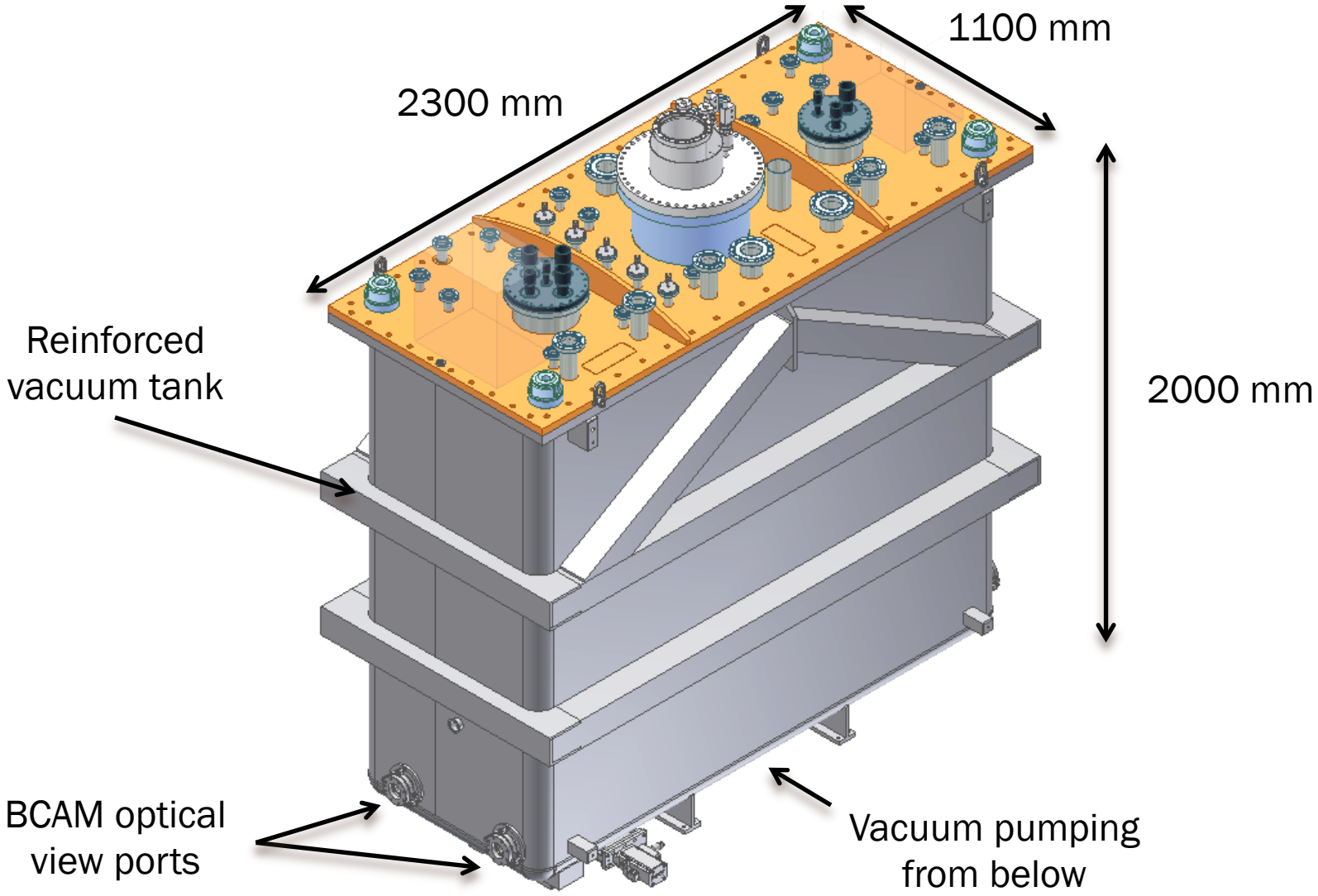
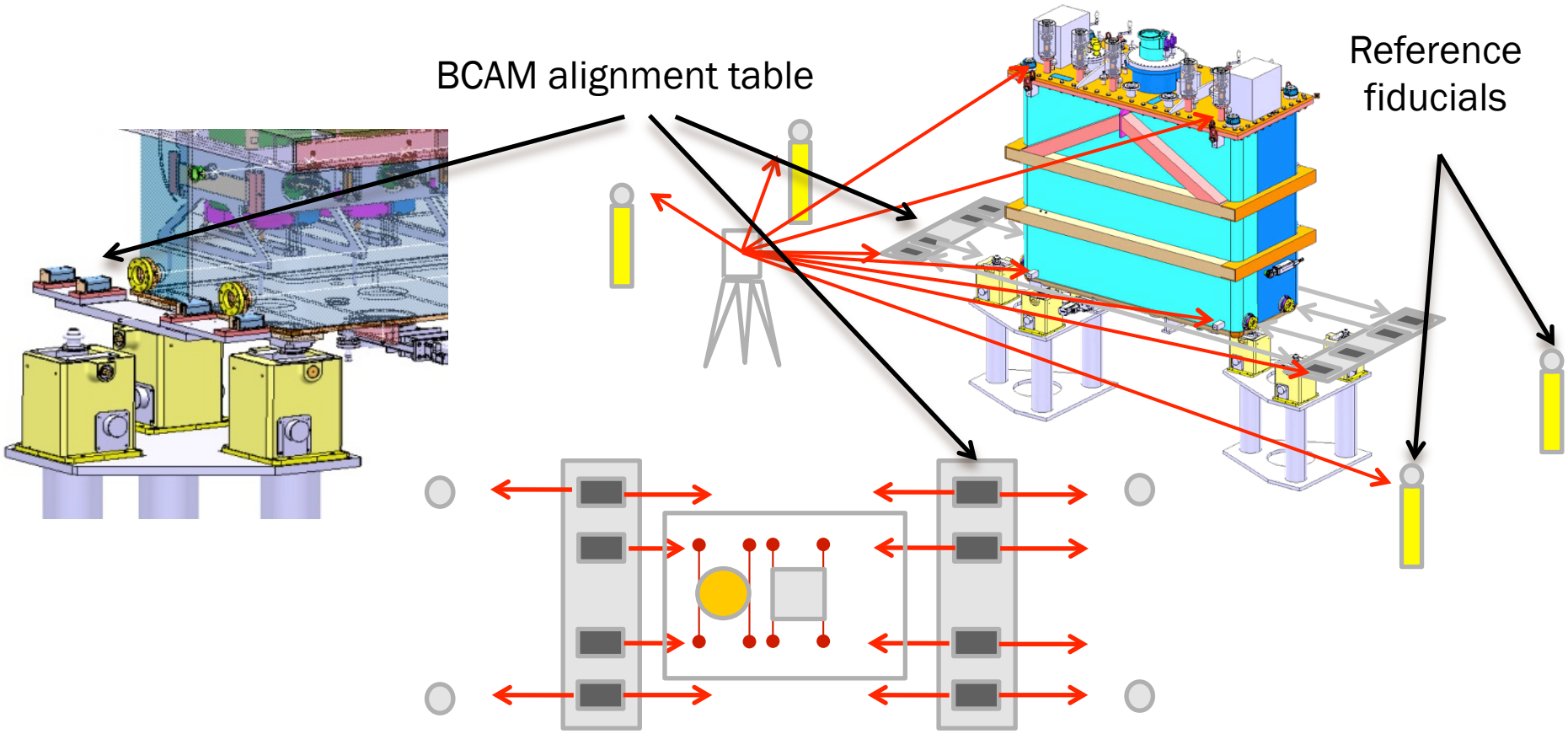


BCAM ALIGNMENT SYSTEM

Slides courtesy of J.-C Gayde (BE-ABP-SU)

- BCAM (CCD camera): developed in 1999 by K. Hashemi (Brandeis Univerisity) for ATLAS muon detector alignment (CERN-LHC) with Open Source Instruments.



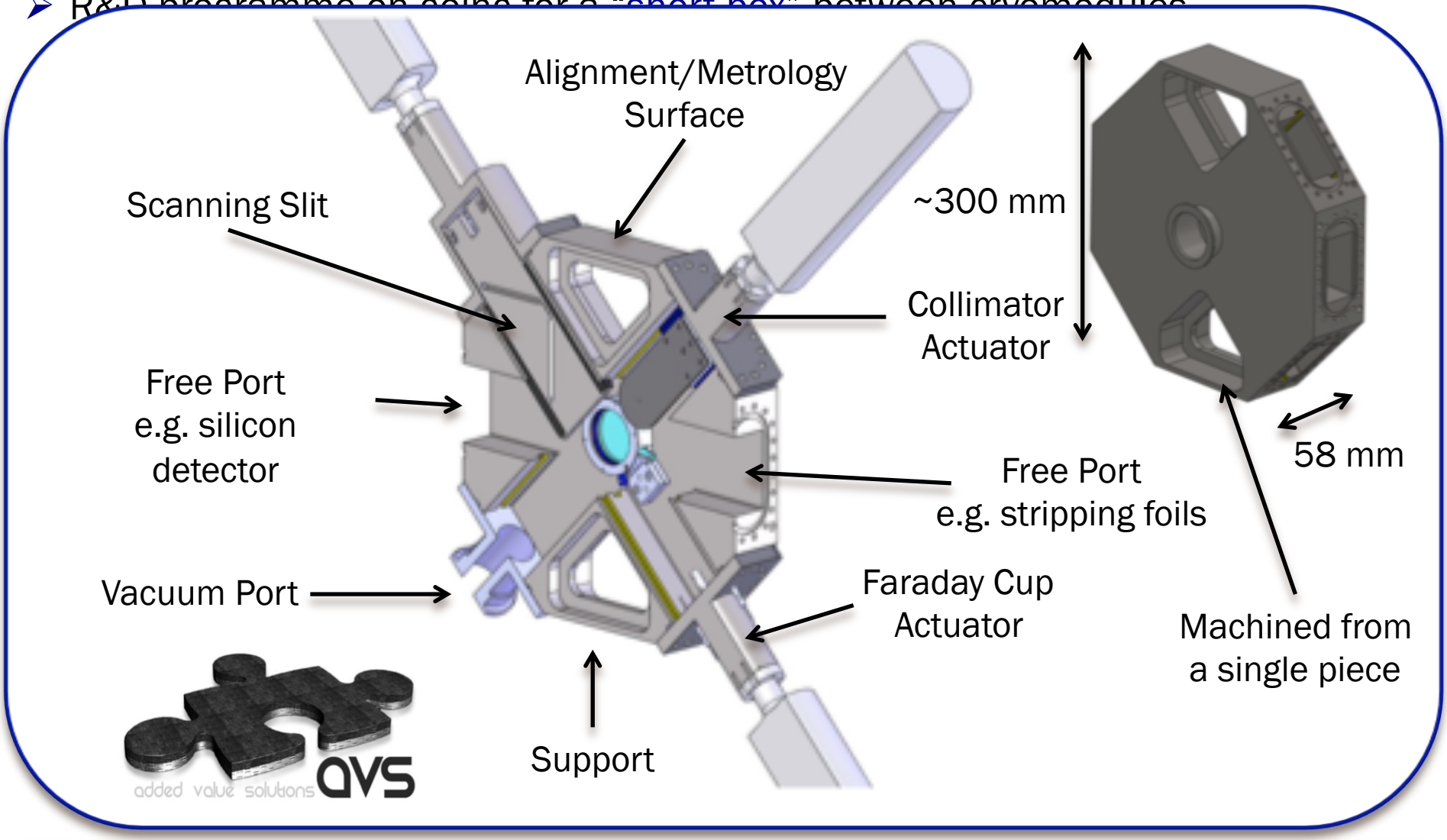
- Large-scale use of this system is proven at ATLAS experiment (~1000 BCAMs).

BEAM DIAGNOSTICS

- R&D programme on-going for a "short-box" between cryomodules.
- Design also being implemented in HEBT where more functionality is needed.
- Collaboration between CERN and Added Value Solutions (AVS) as an in-kind contribution supported by the Spanish government (CDTI).
- Functional specification:
  a. Current monitor (Faraday cup: 1 - 500 pA): Faraday cup being prototyped.
  b. Beam position ($\sigma = \pm 0.2$ mm)
  c. Transverse beam profiler (scanning slits)
  d. Longitudinal profiler (Si detector): System already prototyped and proof-of-principle achieved, now software applications being made for phasing the SC linac.
  e. Low-current emittance measurements (RIBs): adjacent "short-boxes" using slit-grid technique with single-particle detectors.

BEAM DIAGNOSTICS

- R&D programme on going for a "short box" between cryomodules



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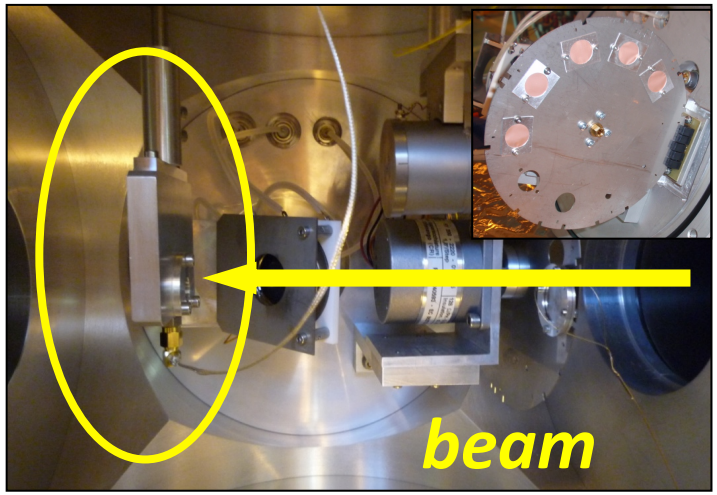
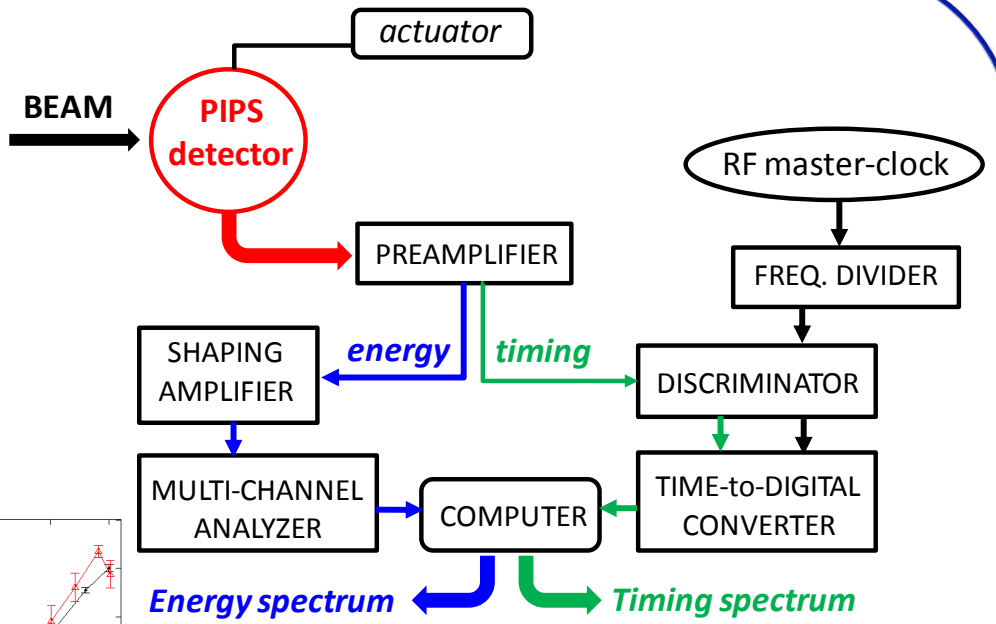
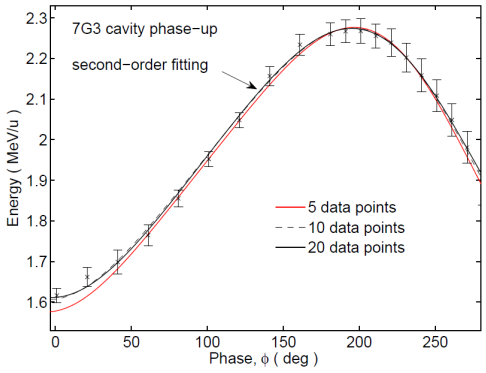
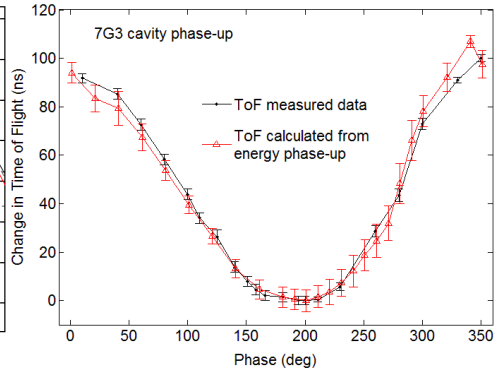


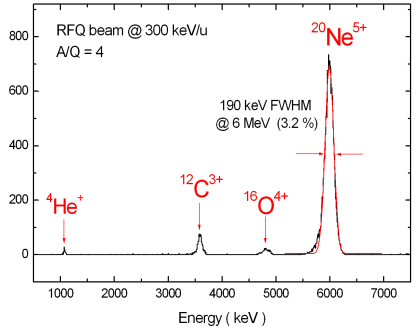


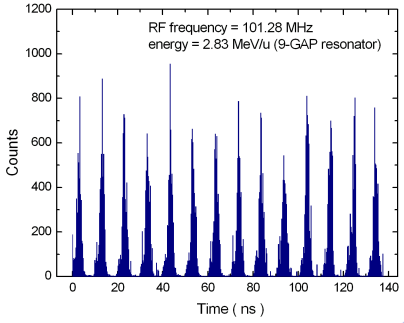


ΔW cavity phasing



ToF cavity phasing





Slide courtesy of F. Zocca (BE-BI-PM)

BEAM DIAGNOSTICS

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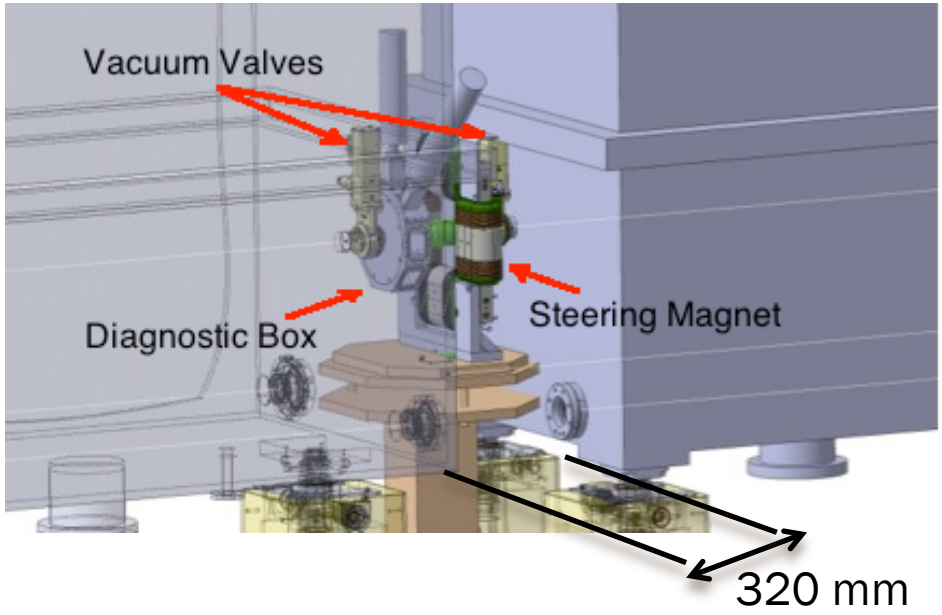
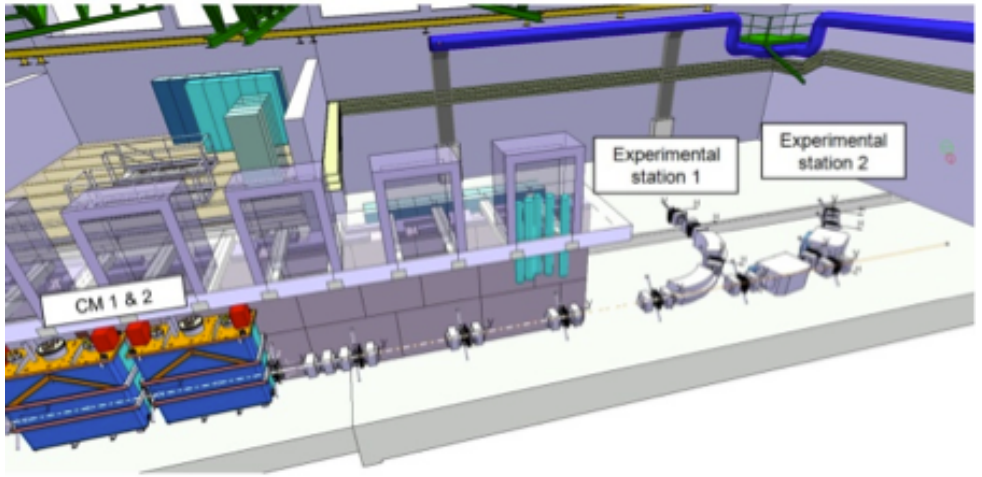
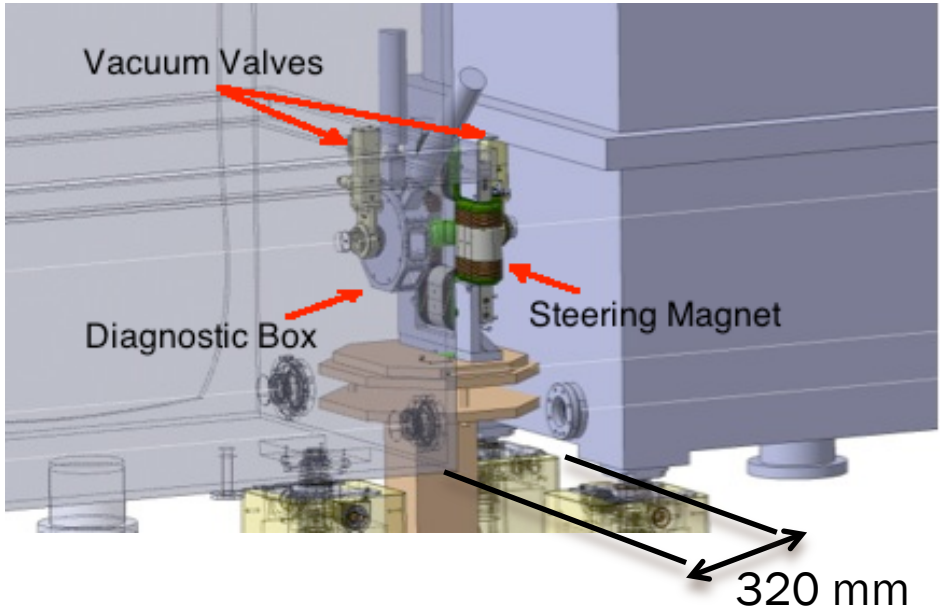
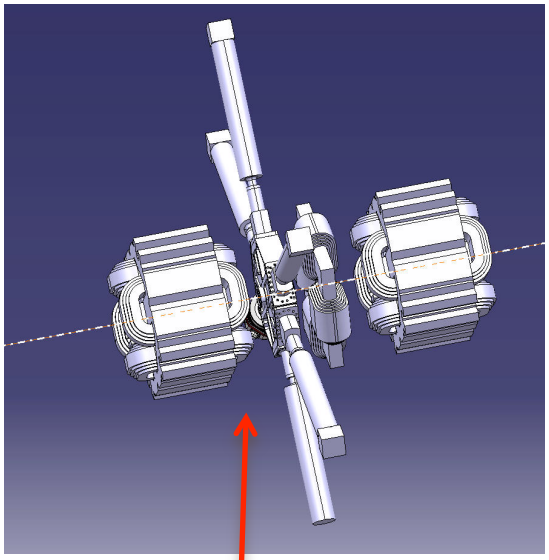
INTER-TANK SPACE AND DOUBLET INSERTION BEWTEEN MAGNETS IN HEBT

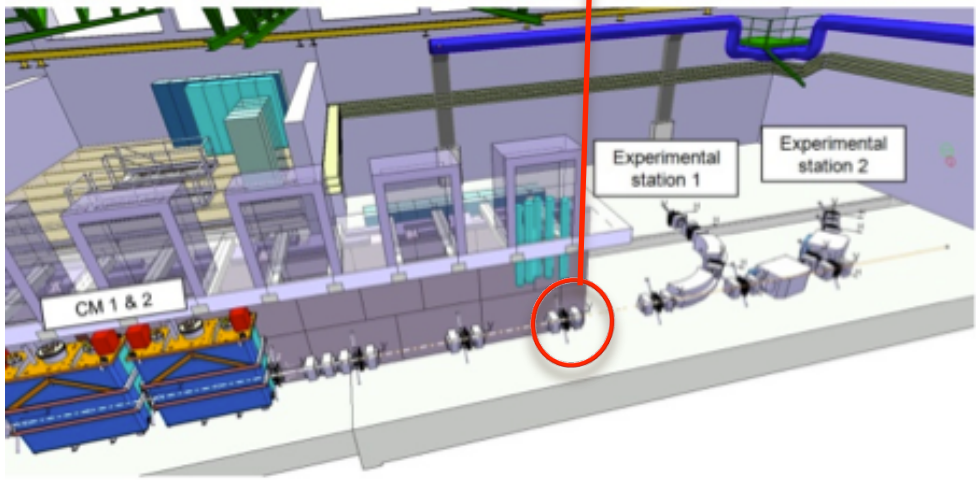




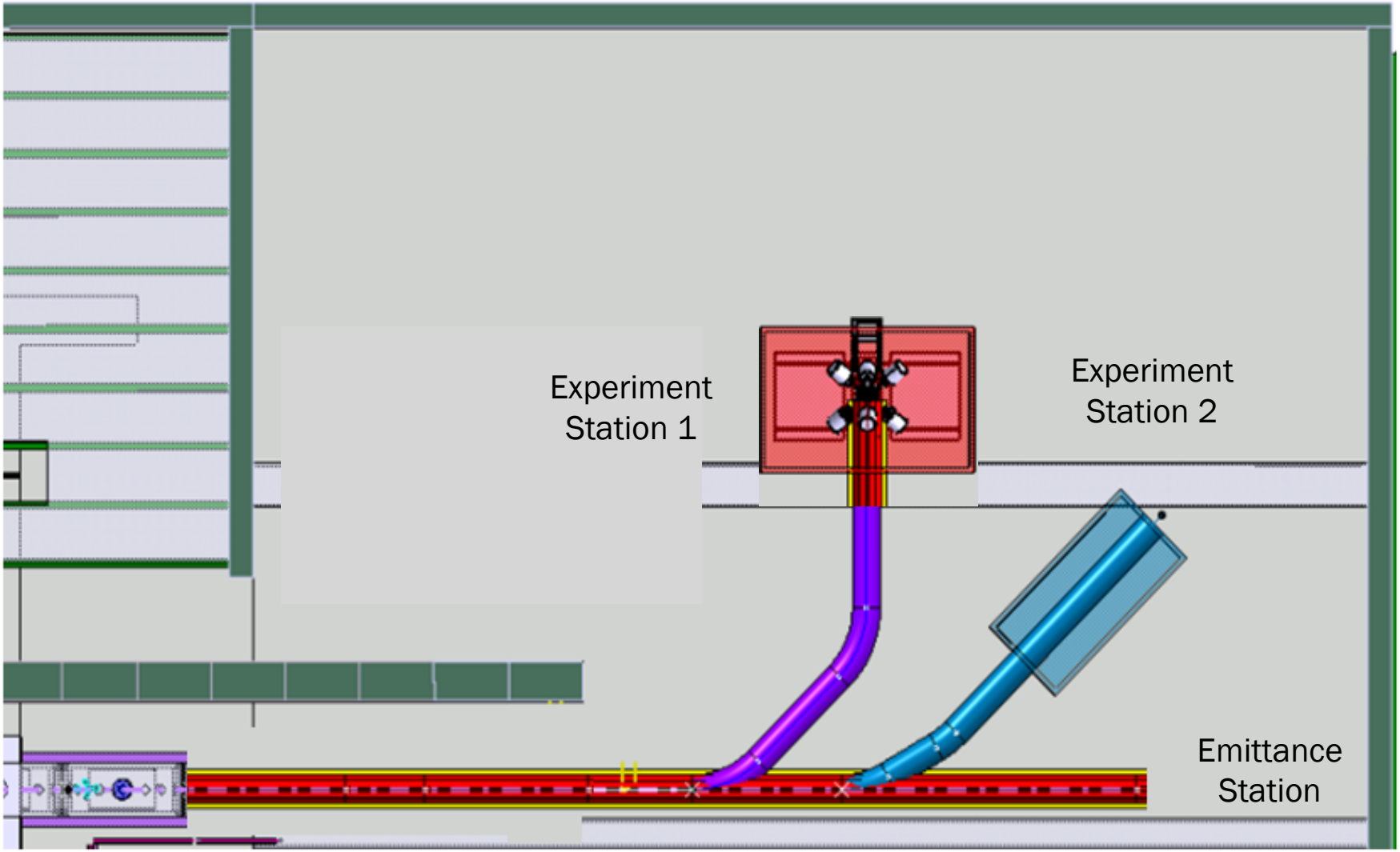
INTER-TANK SPACE AND DOUBLET INSERTION BEWTEEN MAGNETS IN HEBT



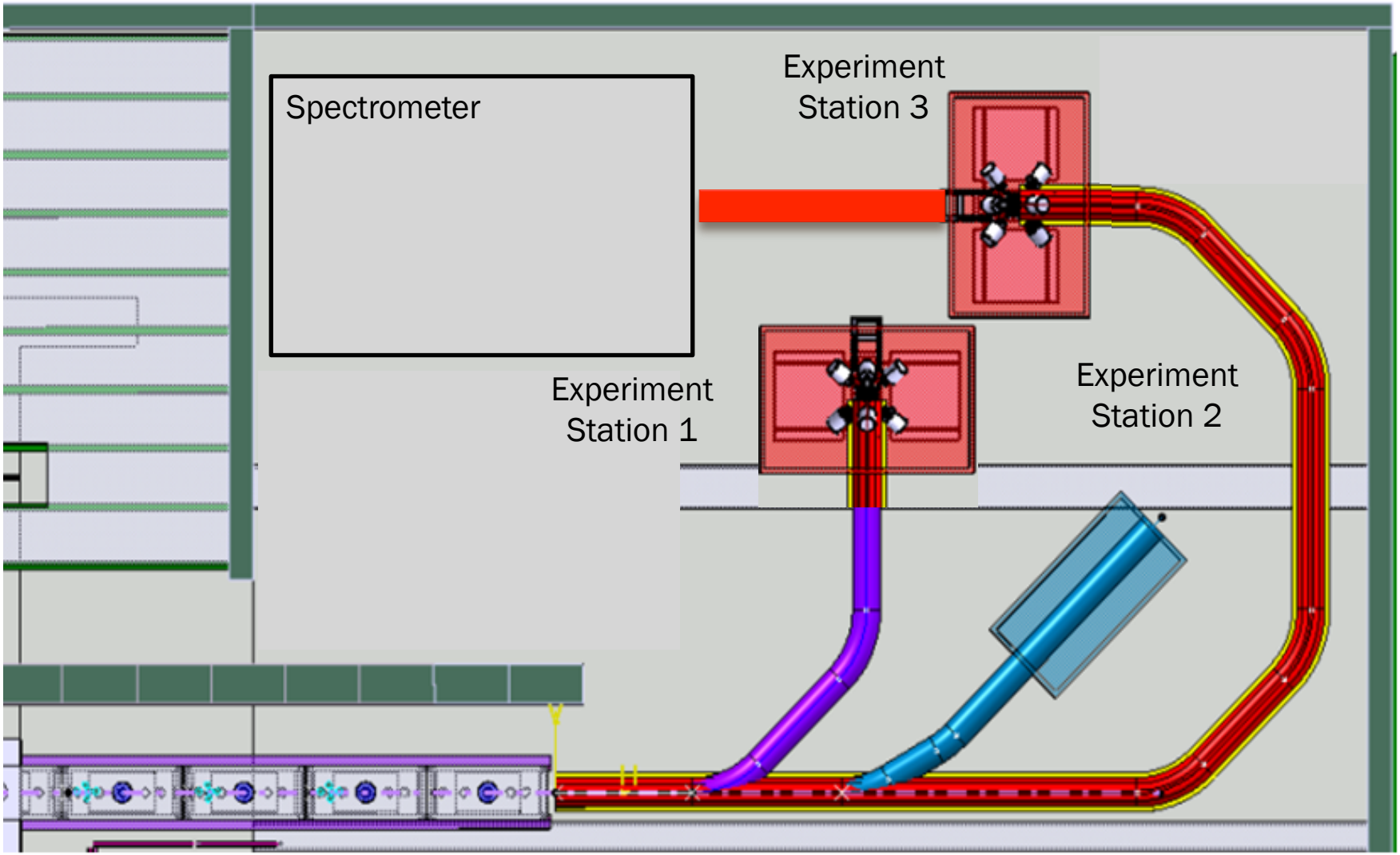




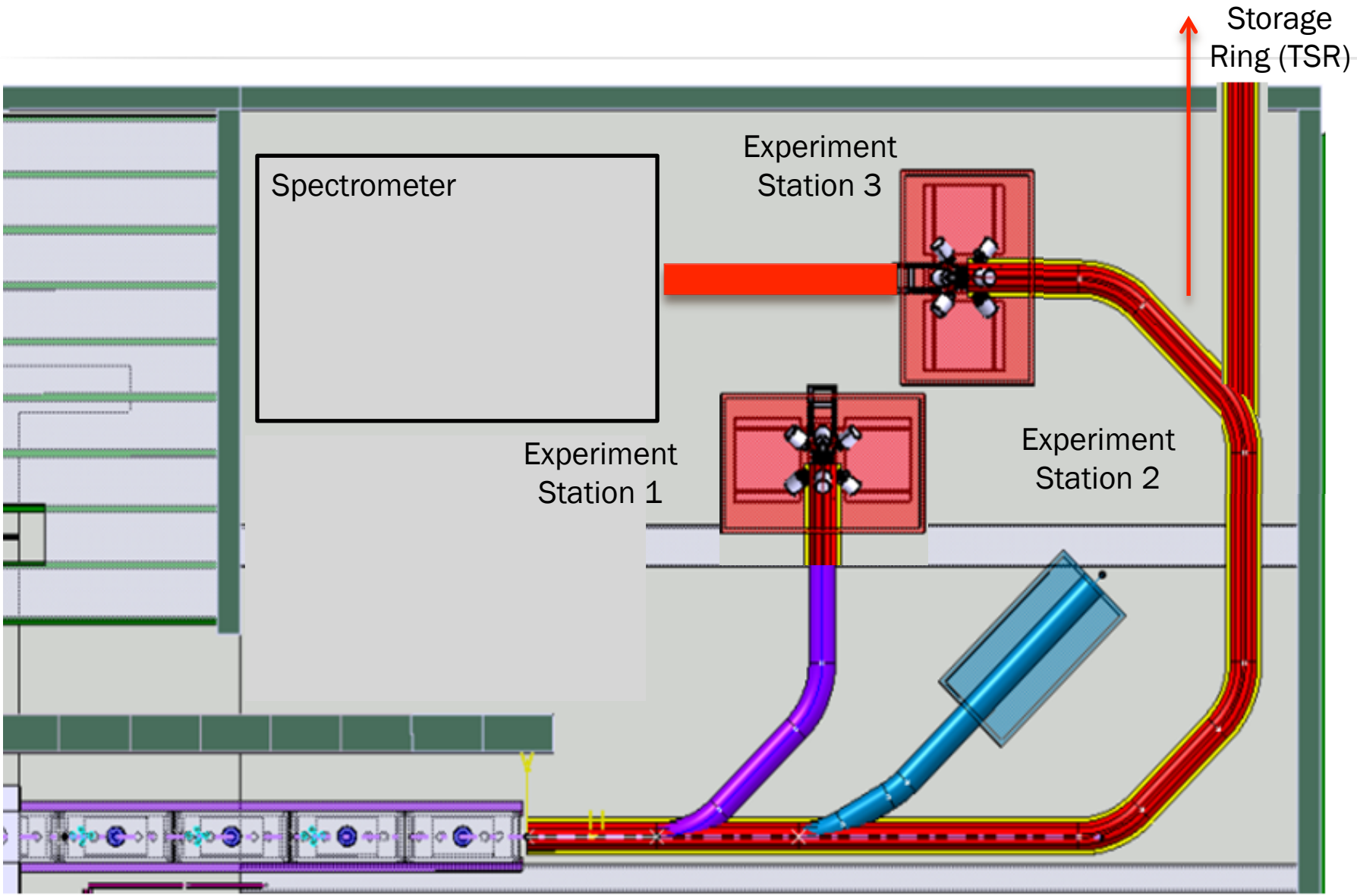
HEBT: STAGE 1


Experiment
Station 1
Experiment
Station 2
Emittance
Station

HEBT: STAGE 2B

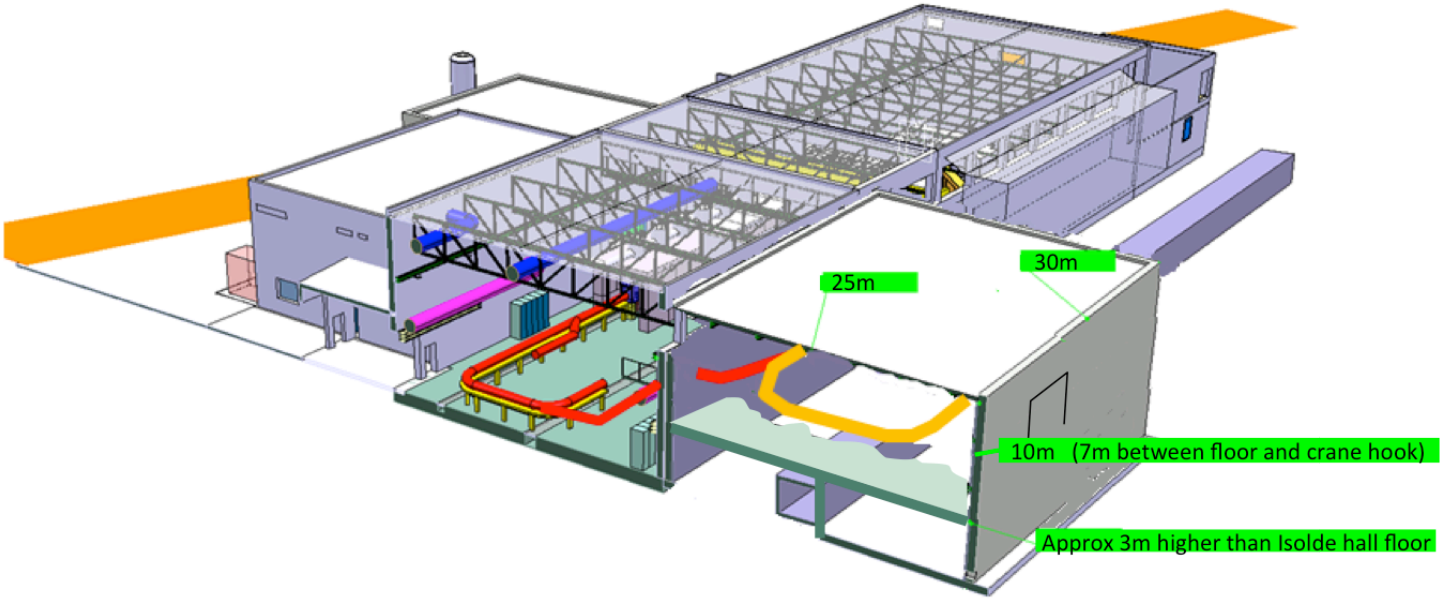


HEBT: STAGE 2B + TSR



TSR @ HIE-ISOLDE

- In principle, bringing the TSR (currently in operation at MPIK, Heidelberg) to CERN has been approved.
  a. Multi-pass “in-ring” experiments (~1 MHz)
  b. Cooled extracted beam (e-beam cooler), high-res experiments.
  c. “Beam stretcher” can avoid high instantaneous rates from EBIS pulse by accumulating and slow-extracting.



- For more information: M. Grieser *et al*., *Eur. Phys. J. ST* **207**, pp. 1-117 (2012).

CIVIL ENGINEERING: NEW BUILDINGS

Slide courtesy of E. Siesling (BE-OP-PSB)

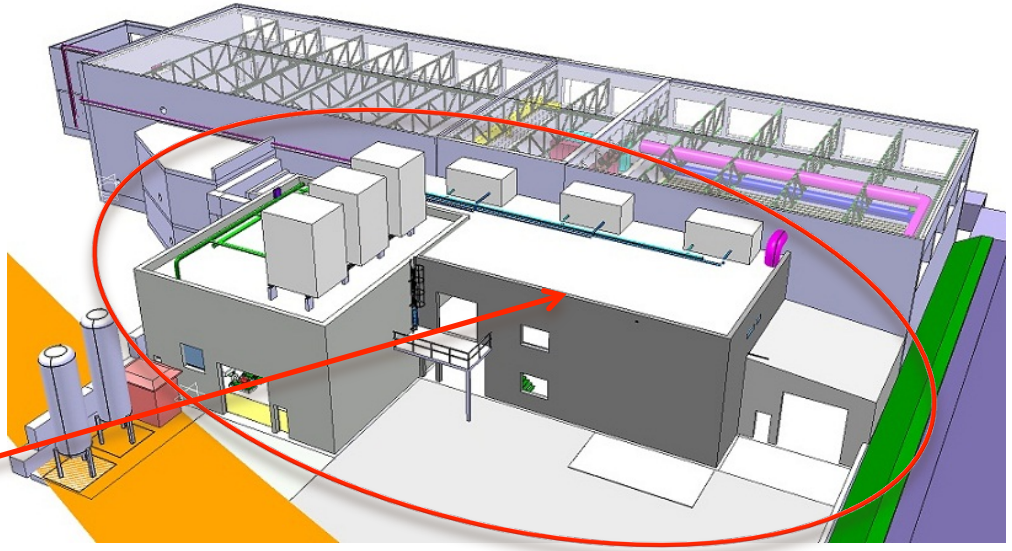
- Construction has already started!

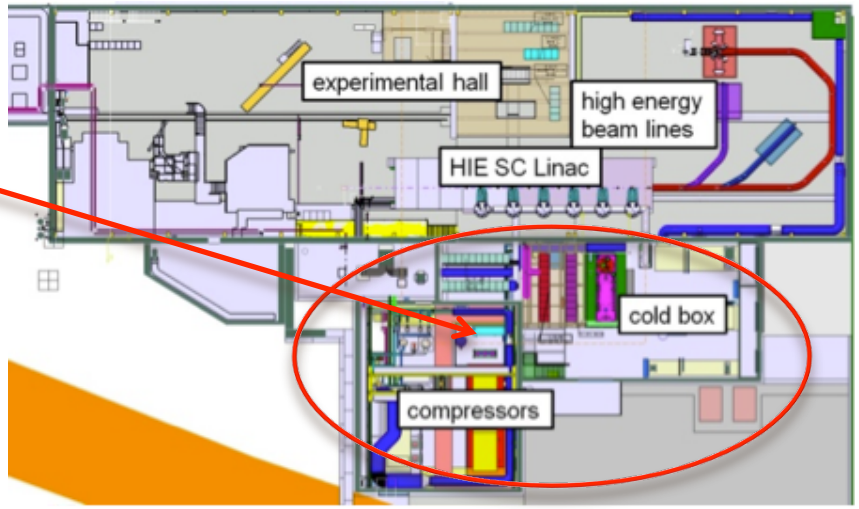
CIVIL ENGINEERING: NEW BUILDINGS

Slide courtesy of E. Siesling (BE-OP-PSB)

- Construction has already started!

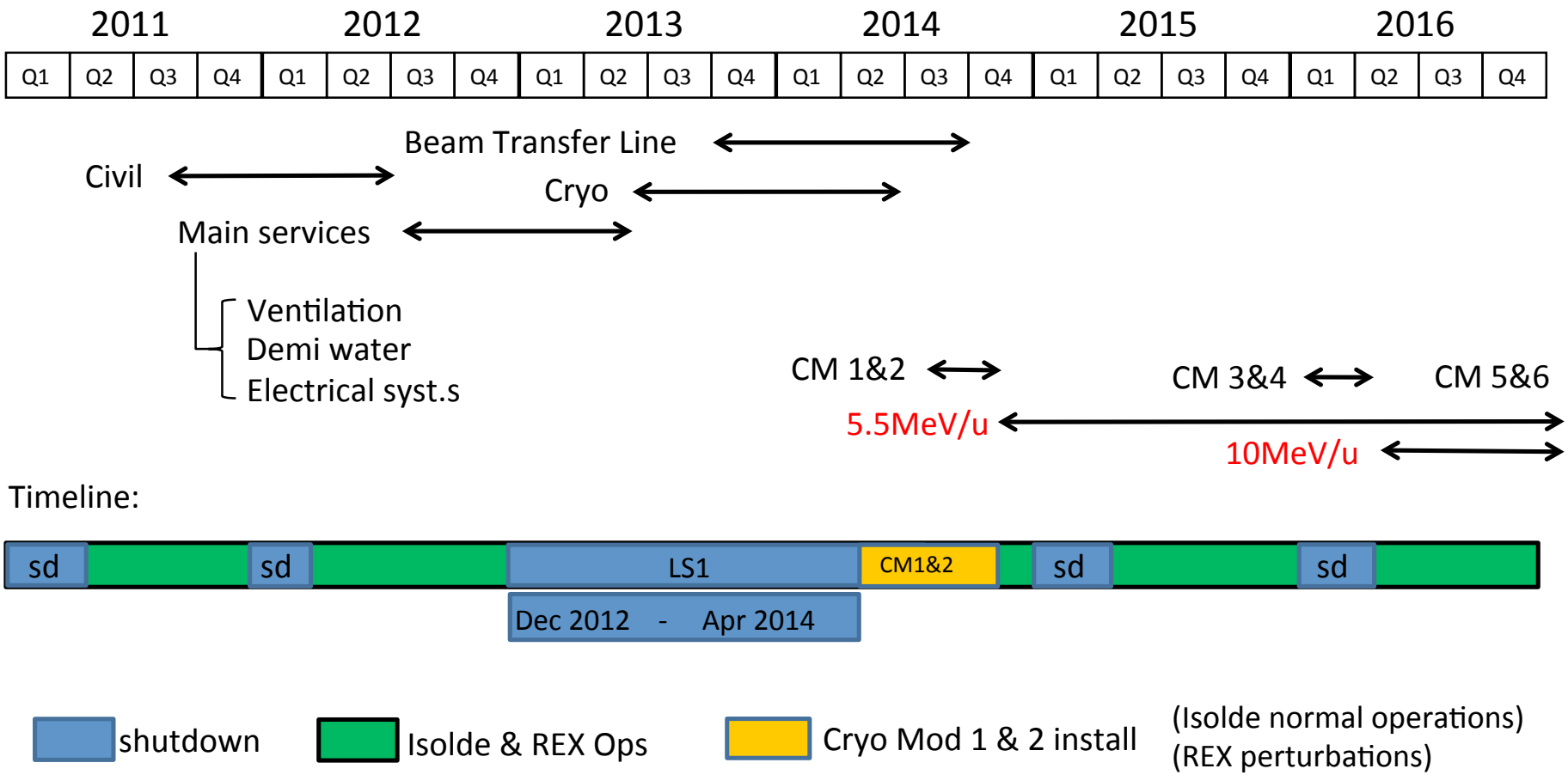
- Concrete pouring for foundations of new buildings now going in (last week).





PLANNING

Slide courtesy of Y. Kadi (EN-HDO)



OUTLOOK

- Development of the sputtering “recipe” is on-going and cavity Q-factor making steady progress.
- Completion of civil engineering works by end of Q3 2012.
- Procurement of first series of 10 high-β cavities already launched.
- Procurement of first cryomodule and HEBT components by the end of Q3 2012.
- First 5.5 MeV/u beams in 2015, followed by 10 MeV/u in 2016.
- Full energy variability and (optional) 10 MHz beam frequency in 2017/18.

THANK YOU!

For further information please visit:

HIE-ISOLDE website: http://hie-isolde.web.cern.ch/hie-isolde

CATHI-ITN website: https://espace.cern.ch/Marie-Curie-CATHI

ACKNOWLEDGEMENTS

- The ISOLDE Collaboration
- The HIE-ISOLDE project team and groups with the CERN Accelerator and Technology Sector, and who contributed to this presentation.
- The Swedish Knut and Alice Wallenberg Foundation (KAW 2005-0121)
- The Belgian Big Science program of the FWO (Research Founders Flanders) and the Research Council K.U. Leuven.
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- The Spanish Programme “Industry for Science” from CDTI.