



Super-FRS Status

M. Winkler

NUSTAR Annual Meeting, GSI, March 2 - 4, 2016

Outline

- 1) Super-FRS Layout**
- 2) Civil Construction**
- 3) Magnets, Testing and Local Cryogenics**
- 4) Target Area and Components**
- 5) Beam Instrumentation**
- 6) Summary**

Super-FRS Layout

Design Parameters:

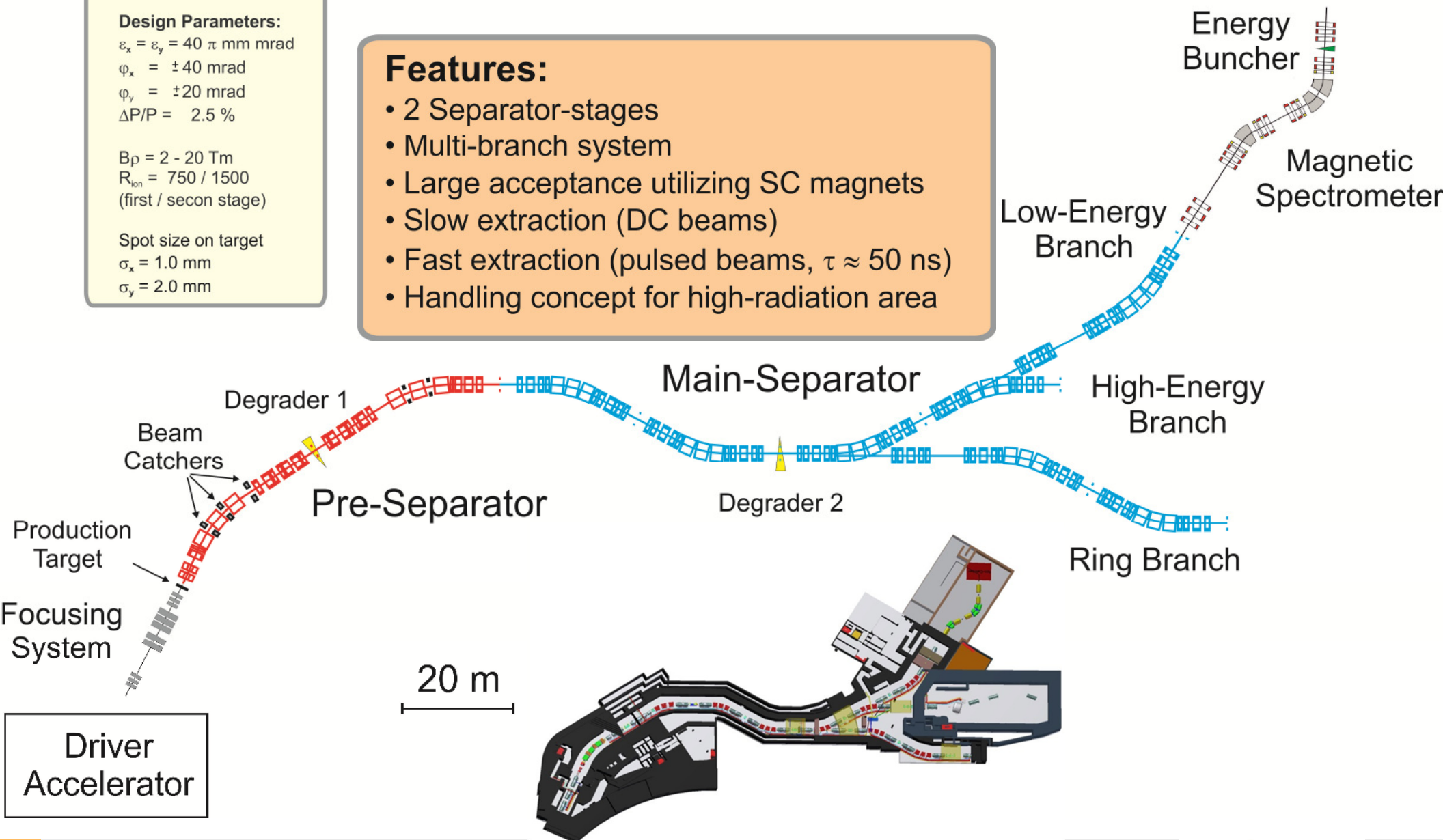
$$\begin{aligned}\varepsilon_x = \varepsilon_y &= 40 \pi \text{ mm mrad} \\ \phi_x &= \pm 40 \text{ mrad} \\ \phi_y &= \pm 20 \text{ mrad} \\ \Delta P/P &= 2.5 \%\end{aligned}$$

$$\begin{aligned}B\rho &= 2 - 20 \text{ Tm} \\ R_{\text{ion}} &= 750 / 1500 \\ &(\text{first} / \text{second stage})\end{aligned}$$

$$\begin{aligned}\text{Spot size on target} \\ \sigma_x &= 1.0 \text{ mm} \\ \sigma_y &= 2.0 \text{ mm}\end{aligned}$$

Features:

- 2 Separator-stages
- Multi-branch system
- Large acceptance utilizing SC magnets
- Slow extraction (DC beams)
- Fast extraction (pulsed beams, $\tau \approx 50 \text{ ns}$)
- Handling concept for high-radiation area



Civil Construction I (Overview)

- New building milestones available
- Execution planning: resuming
 - CR target area shielding
- Route planning: resuming
- Review 2015 → consider LEB cave

Build. 006a (Service building)

- Technique (PS, controls, ...)
- Experimental preparation
- Control room, electronics
- Cryo distribution box
- Detector gas supply

Build. 006b

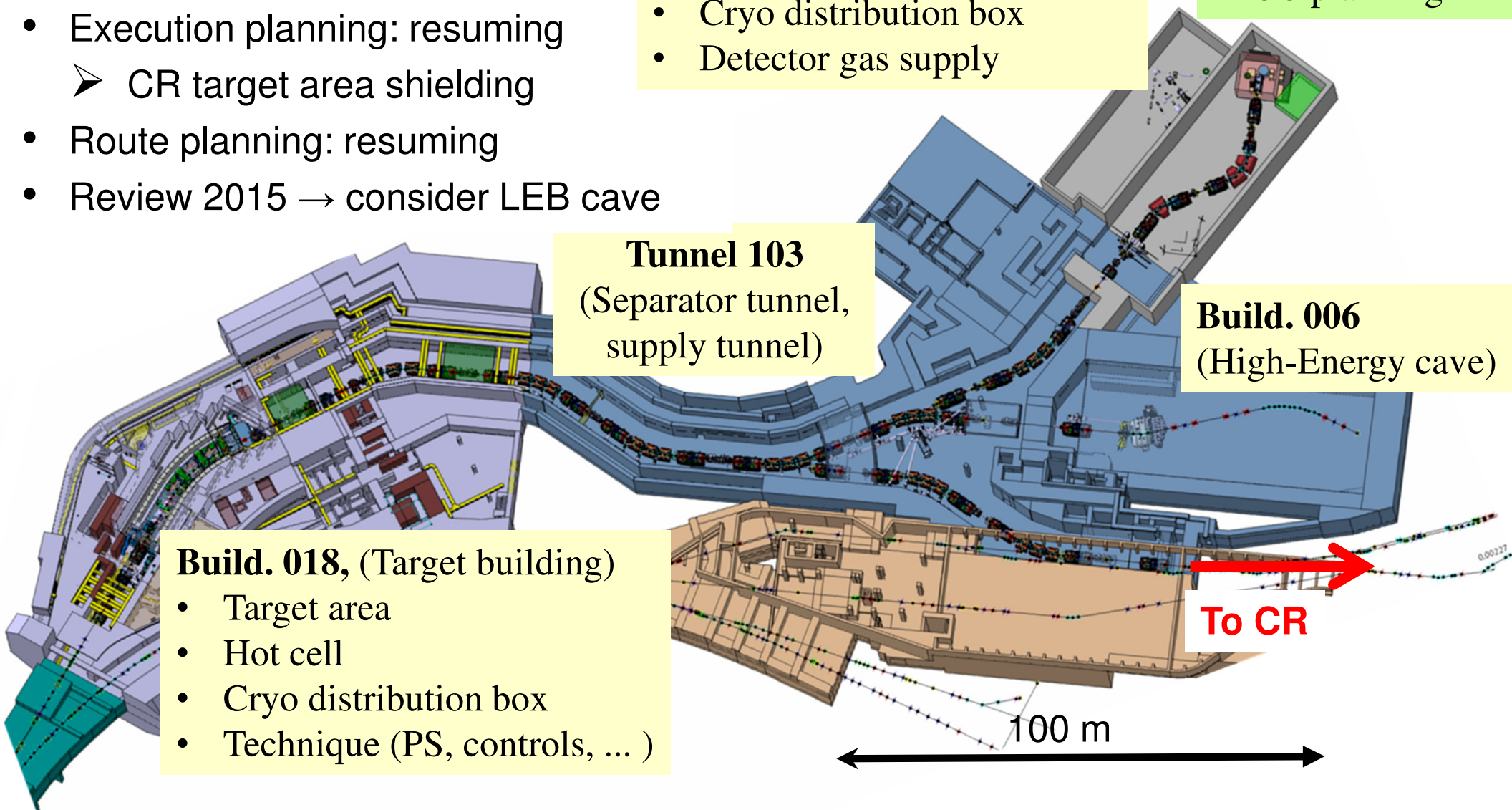
(Low-Energy cave)
was basically missing
in CC planning

Tunnel 103 (Separator tunnel, supply tunnel)

Build. 006 (High-Energy cave)

Build. 018, (Target building)

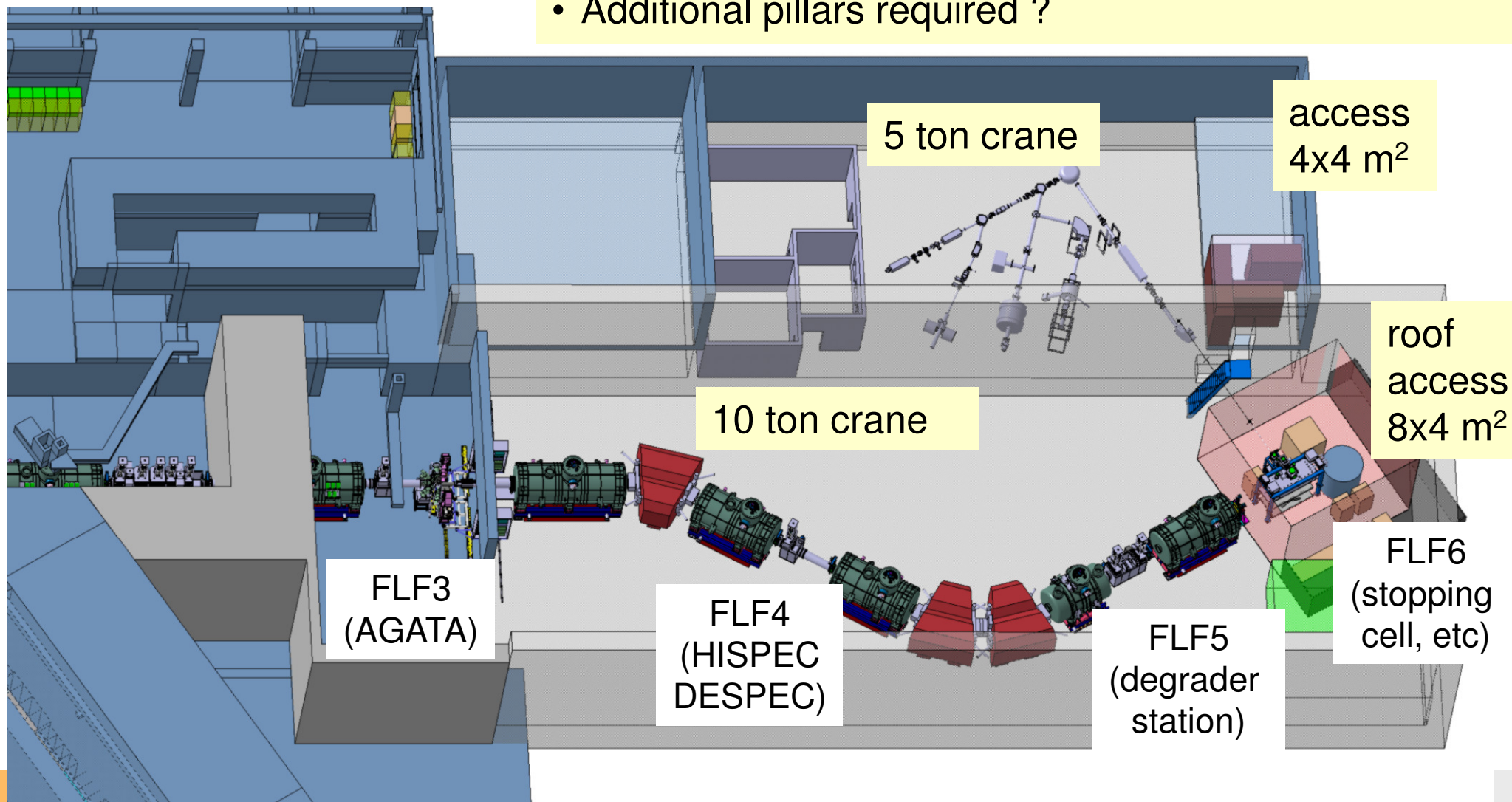
- Target area
- Hot cell
- Cryo distribution box
- Technique (PS, controls, ...)



Civil Construction II

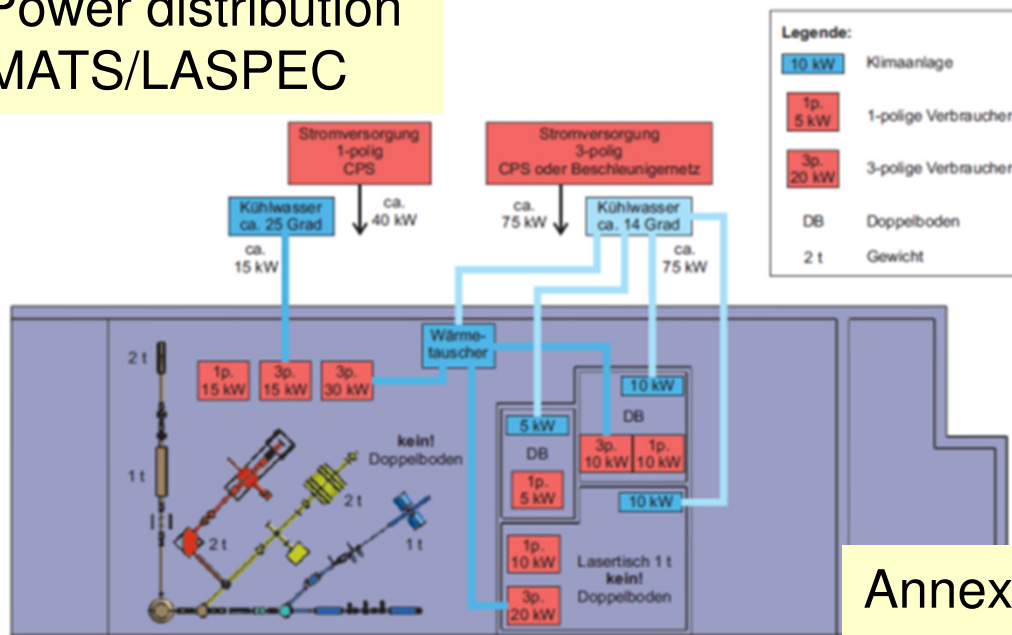
(Status LEB Cave)

- ✓ (Re-)start planning with FSB: end 2015
- ✓ Kick-off with architects & planner: Jan. 28, 2016
 - Consolidation of infrastructure-related requirements
- Consolidation of infrastructure-related requirements
- Cryo-distribution to be detailed
- Additional pillars required ?

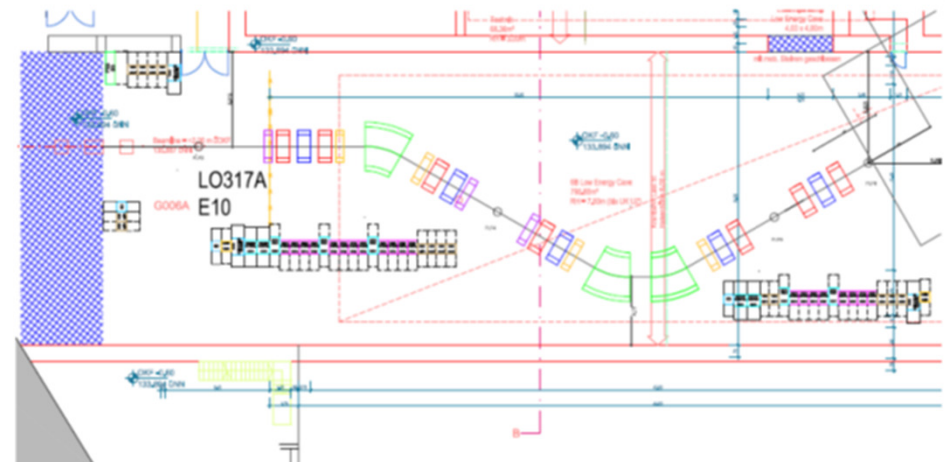


Civil Construction III (LEB, 'room-data')

Power distribution MATS/LASPEC

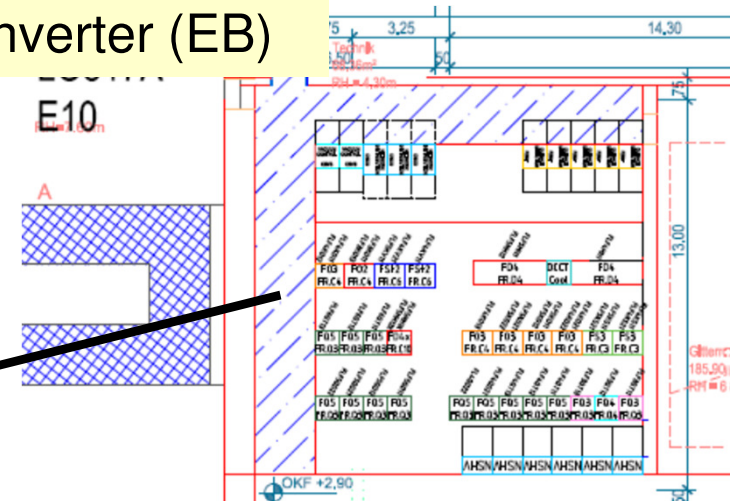
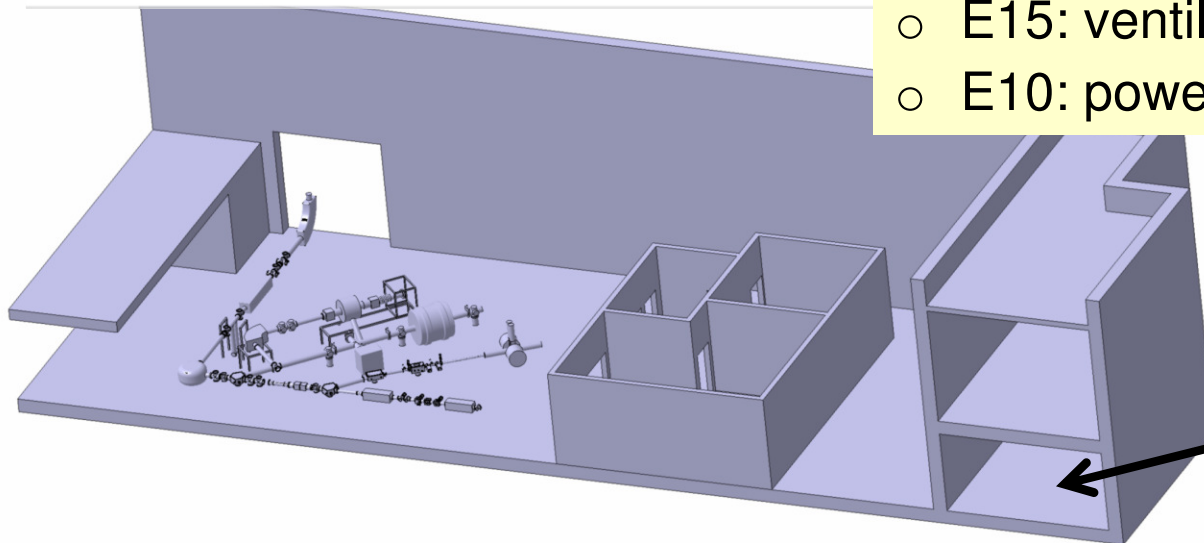


Rack planning EB cave



Annex space

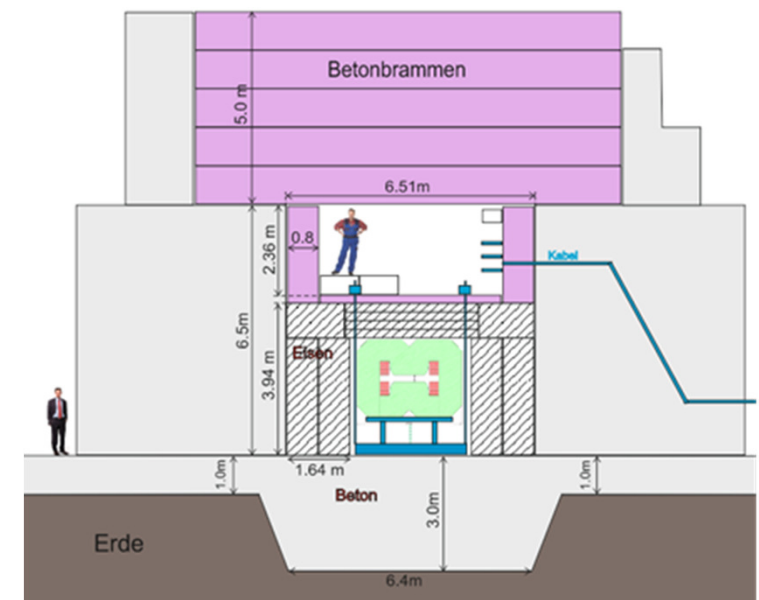
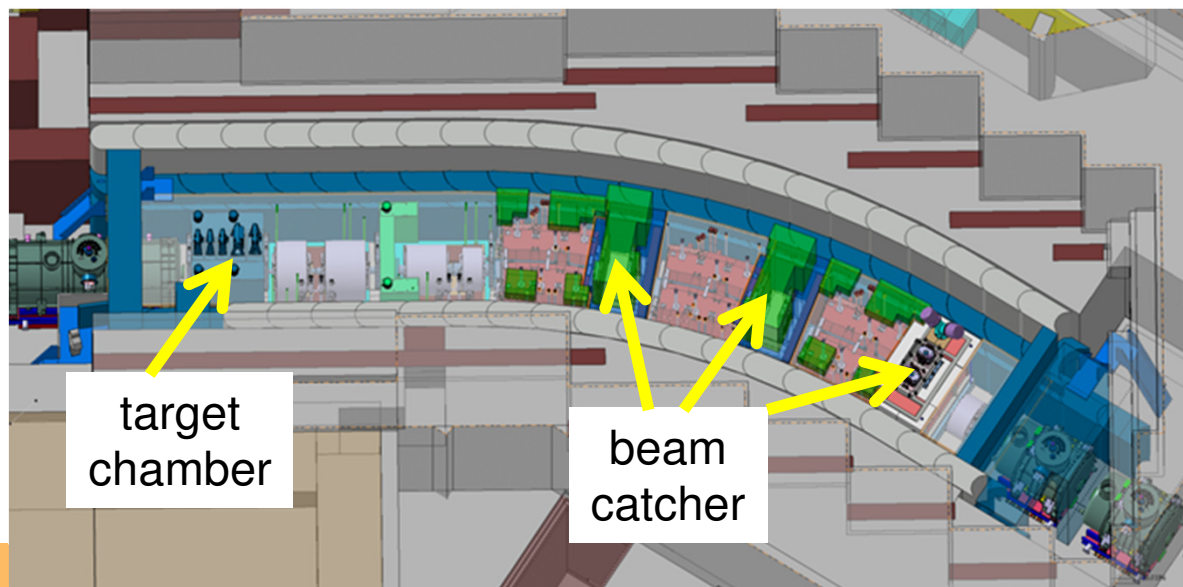
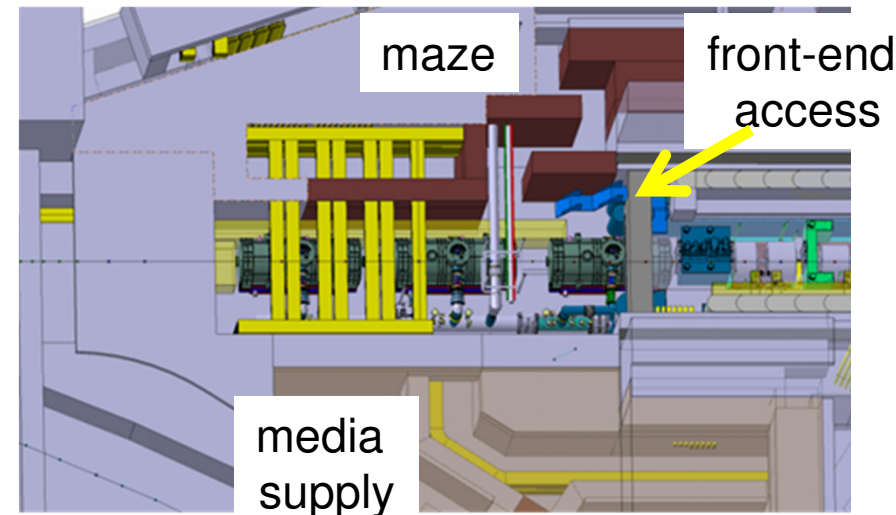
- E15: ventilation plant
- E10: power converter (EB)



Civil Construction IV

(CR Target Area)

- Detailing of target area shielding planning
 - advanced overhead crane design
 - advanced planning of maintenance-tunnel
- Main measures
 - adapt shielding of beam-tunnel
 - height and shielding of maintenance-tunnel
 - route planning considered
 - slab shielding of maintenance-tunnel
 - front-end access to maintenance-tunnel

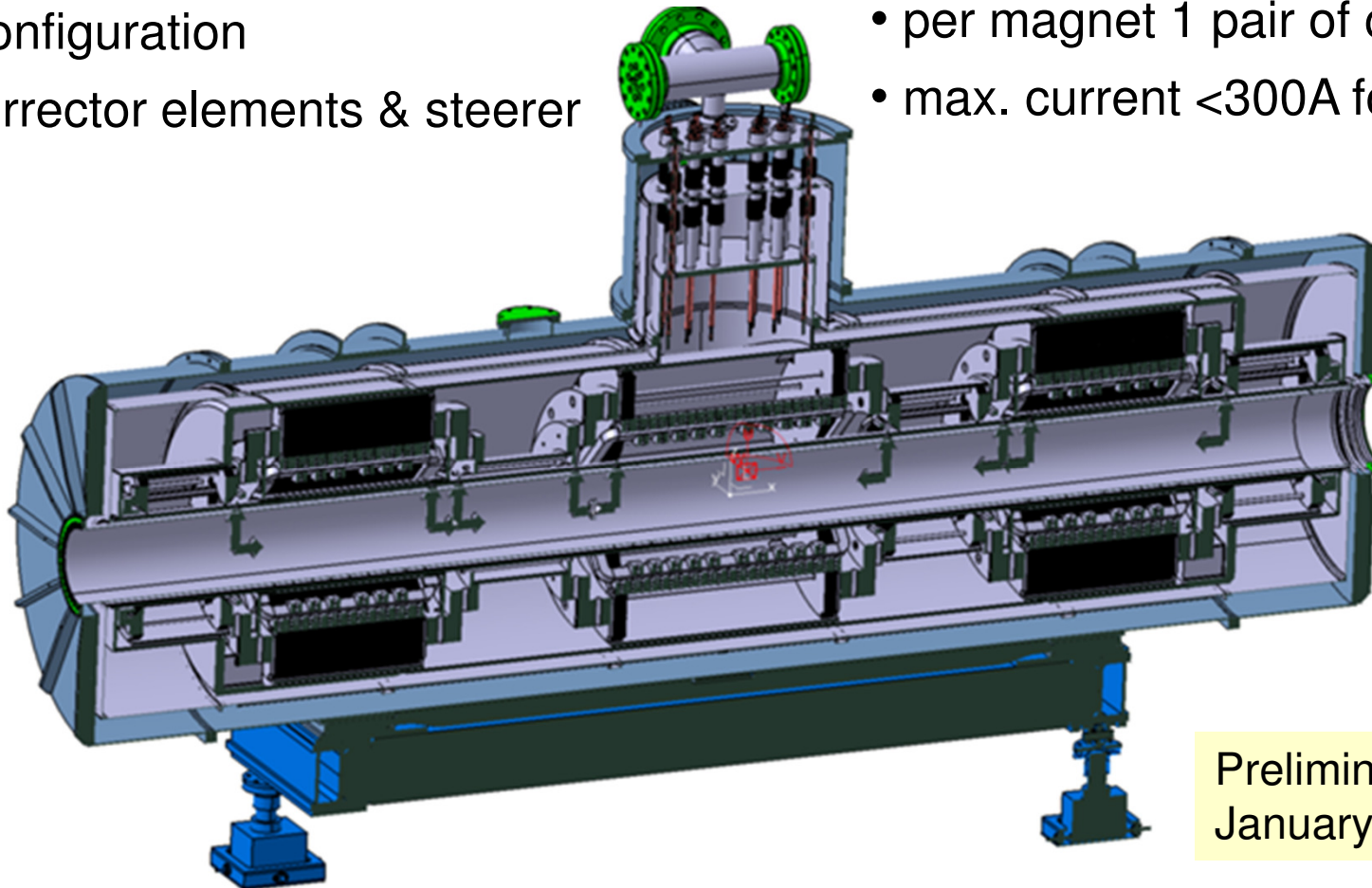


Magnets I

(SC Multiplets, Overview)

- 25 long multiplets (mainly MS)
 - Quadrupol triplet
- 8 short multiplets (PS)
 - QS configuration
- include corrector elements & steerer

- iron dominated, cold iron (≈ 40 tons)
- common helium bath, LHe ≈ 1.300 l
- warm beam pipe
- per magnet 1 pair of current leads
- max. current < 300 A for all magnets



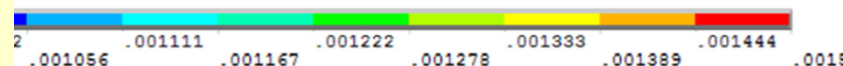
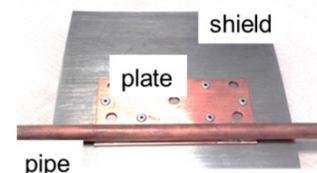
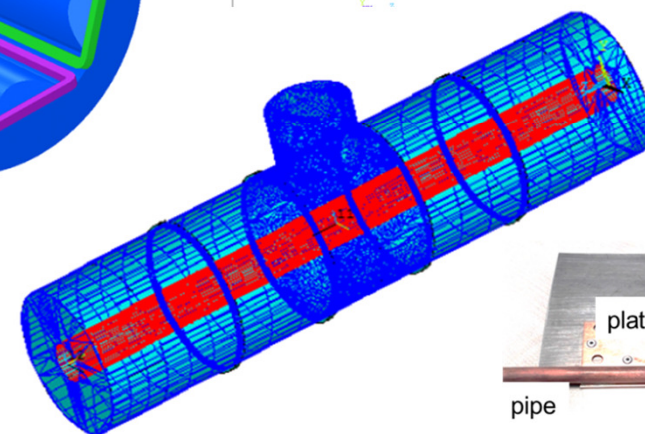
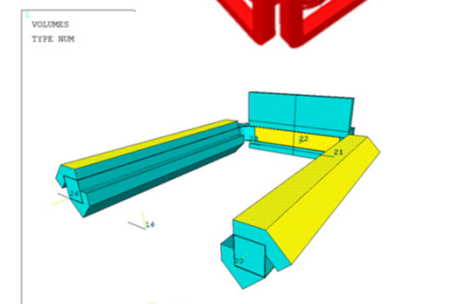
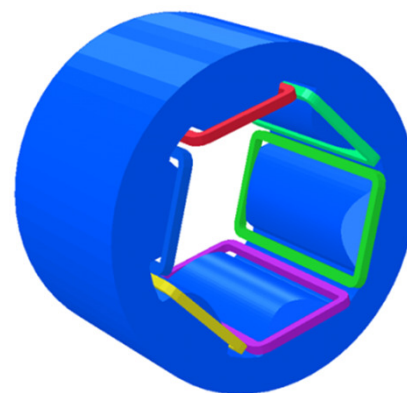
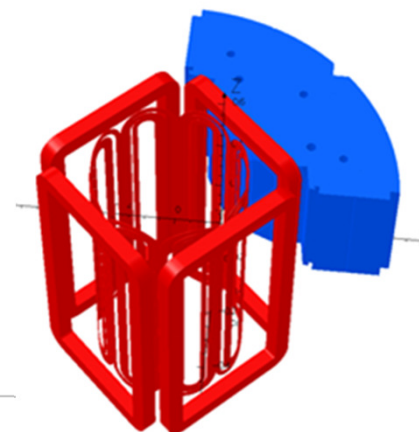
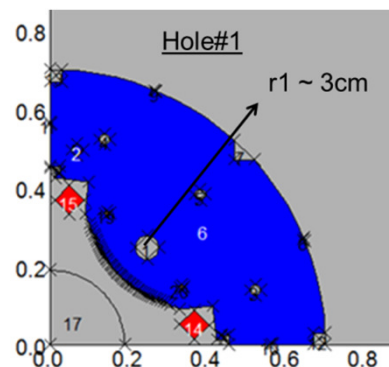
Preliminary ASG Modell,
January 2016

Magnets II

(SC Multiplets, Status)

- ✓ Contract award July 1st, 2015
 - Winning company: ASG Genoa
- ✓ Kick-off: July 15, 2015
- Magnetic field optimization
(pole shape, chamfers, Purcell filter)
- Sensitivity analysis
- Coil structural analysis
- Quench analysis
- Beam pipe analysis
- Thermal shield analysis
- Preliminary 3D model available
(long pre-series multiplet)

Preliminary Design Review planned for April 2016
(→ start ordering material for FoS multiplets)

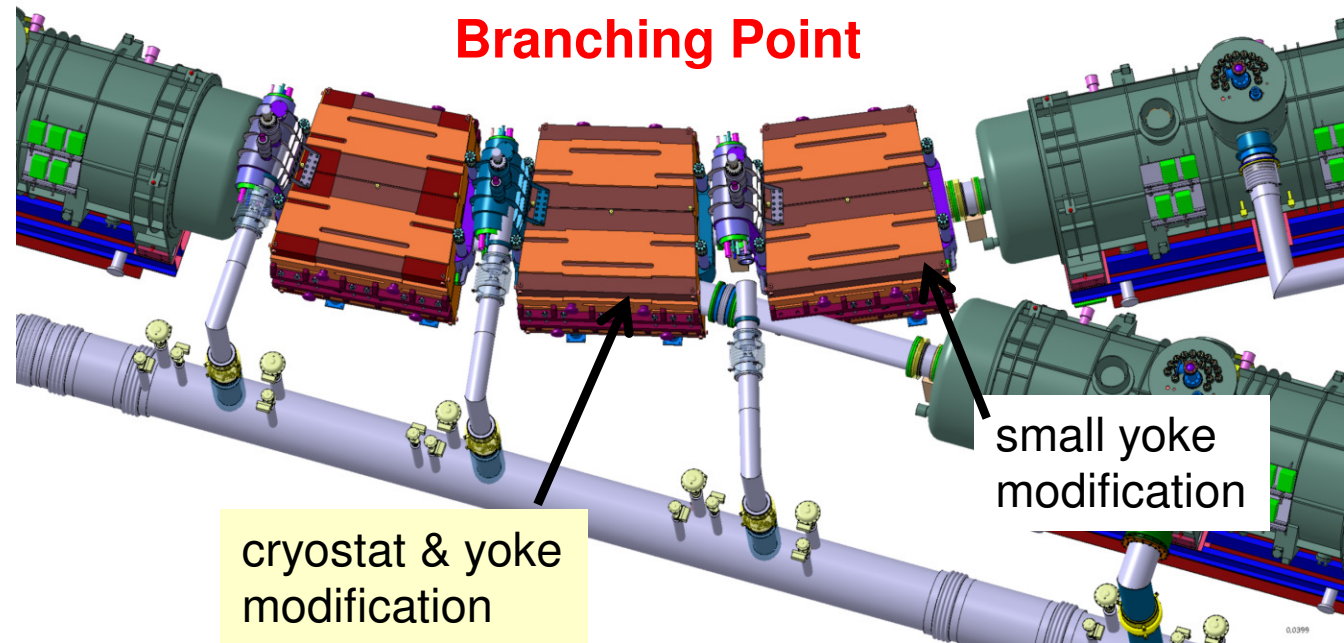
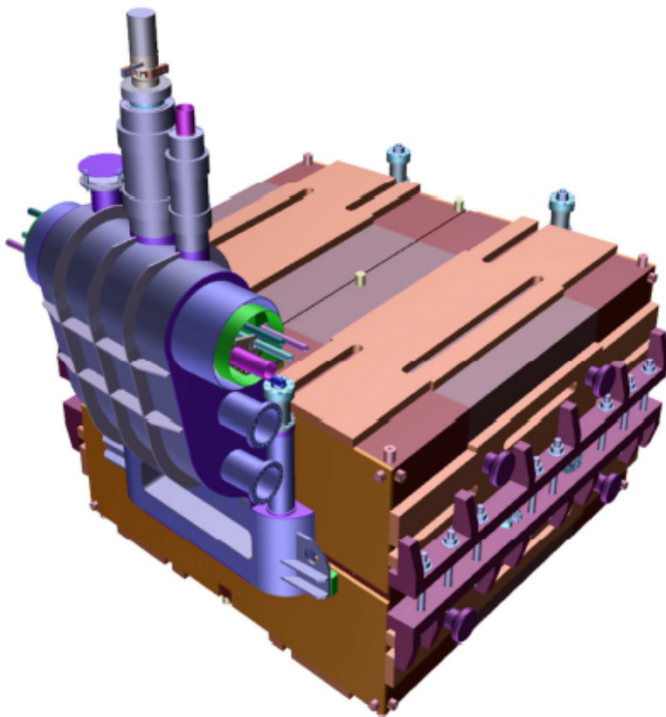


Magnets III

(SC Dipole Magnets, Status)

Scope

- 3 dipole units 11°
- 21 dipole units 9.75°
 - 3 times modified cryostat
- Warm iron, SC coil
- Aperture $\pm 190\text{mm} \times \pm 70\text{mm}$
- Weight: 50 to 60 ton



Branching Magnets:

- needs special design for yoke & cryostat
 - additional R&D contract with CEA; ready to sign → kick-off in Q2/2016 ?
 - integration of y-shape vacuum chamber to reinforce cryostat (DS established)

Magnets IV

(SC Dipole Magnets, Status)

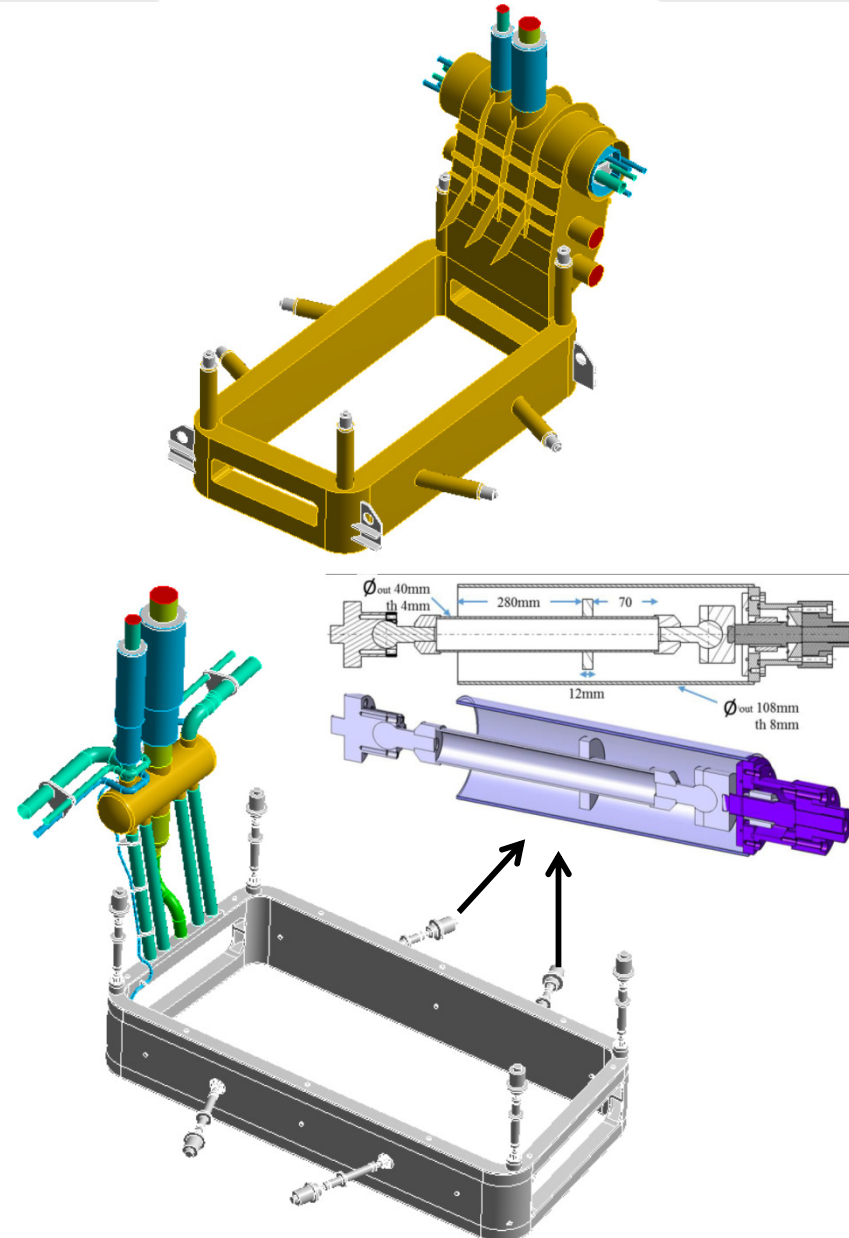


Design Status (branching dipoles not included):

- Collaboration agreement with CEA/Saclay:
 - **TCC still under preparation**, includes
 - Detailed design, Technical follow-up
- ✓ Technical Kick-off 01/2014
 - starting from IMP prototype, IMP visited 04/2014
 - PDR & FDR (includes external advisor)
- ✓ 3D Model & 2D definition drawings available
- Conceptual Design Report ready, release process tbd
 - Design includes all safety aspects (20 bar design)
- Detailed Specification ready, release process tbd
- Tender can only be opened after signing TCC

SC Wire Tendering (closed):

- ✓ Contract award 05/2015
- ✓ Winning Company: Luvata, Fi
- ✓ 1st batch delivered (-> FOS dipole)
 - rest: production to be released



Overall schedule SC multiplets

- ✓ Contract closed 07/2015
- ✓ Design phase running
 - PDR 04/2016 → order material
 - FDR 10/2016 → start FOS production
- FAT of FOS short multiplet 07/2017
 - SAT @ CERN, FOS SM 12/2017
 - SAT ok → start series production
- FAT of FOS long multiplet 10/2017
 - SAT @ CERN, FOS LM 05/2018
- Series testing @ CERN:
 - Q3/2018 – Q3/2021

Overall schedule SC dipoles:

- ✓ Pre-bidder conferences Q4/2014
- ✓ Technical documents are available but not yet released
- Tender ready to open
 - requires that TCC is signed
 - by FAIR, in Q2/2016)
- Contract award expected Q4/2016
- FAT FOS: Q1/2018
- SAT (CERN): Q3/2018
 - > release of series
- Production and Testing of series:
 - Q1/2019 – Q3/2021

Magnets VI

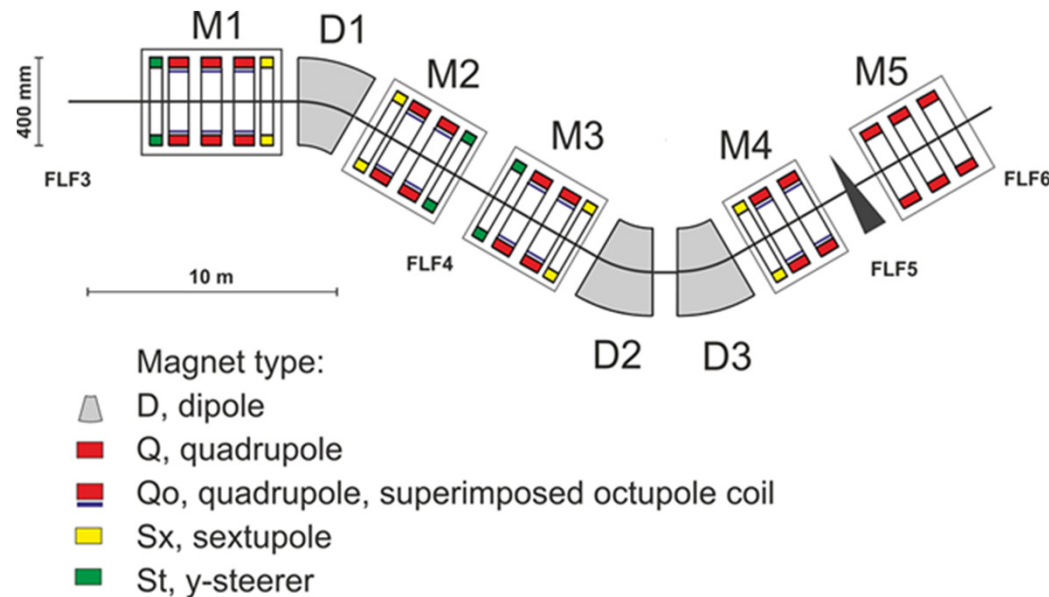
(Energy Buncher Magnets)



Scope:

(according new EB IOL, 2015)

- Maximum Beam rigidity: 7 Tm
- 3 dipole units with 30° deflection angle
 - superferric, warm iron, SC coils
 - large good field aperture:
 $x = \pm 250\text{mm}$, $y = \pm 70\text{mm}$
 - required field quality $\Delta B/B = 1 \times 10^{-4}$
- 5 multiplets, QD or QT configuration
 - superferric, cold iron
 - include corrector elements & steerer
 - magnet parameters like that of separator



S-shape EB layout

- Flexible operation
- Intermediate focal plane FLF4
- Enlarged experimental areas

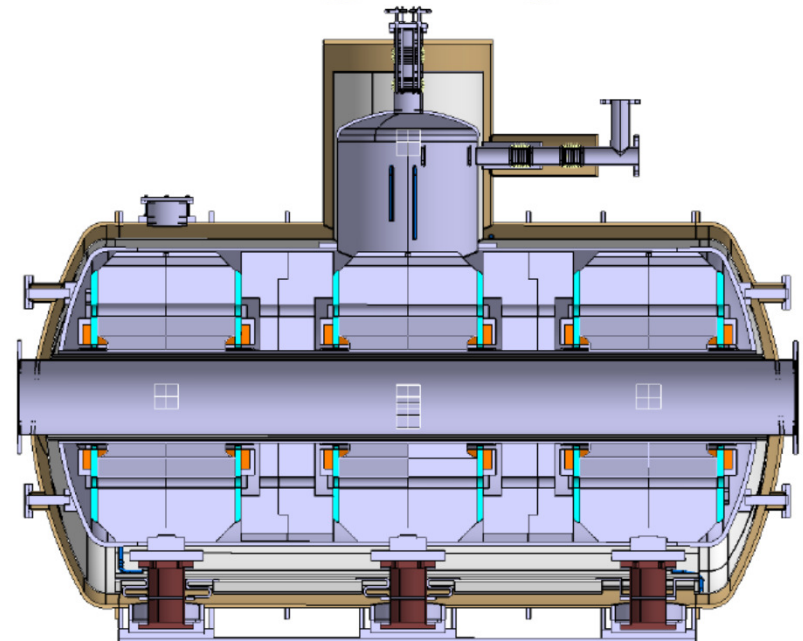
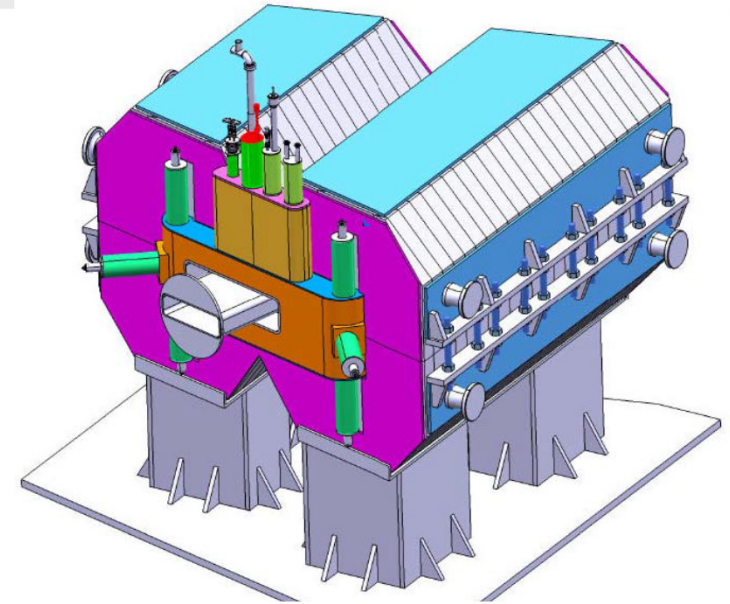
Magnets VII

(Energy Buncher Magnets)



Overall status:

- Collaboration partner VECC (in-kind, Council)
- Regularly meetings (V-conf) established
- Parameters of individual magnets fixed
- Conceptual Design Reports (draft) submitted
 - 1) Dipole magnet (75 ton iron + cryostat)
 - 2) Multiplets (including individual magnets)
- Reports includes aspects on:
 - magnetic field design,
 - conductor selection, coil design including quench analysis
 - cryostat design including cold mass supports
 - safety relief design
 - heat loss analysis
- Review v-conf done, update expected in March
- next steps: India will do cost evaluation



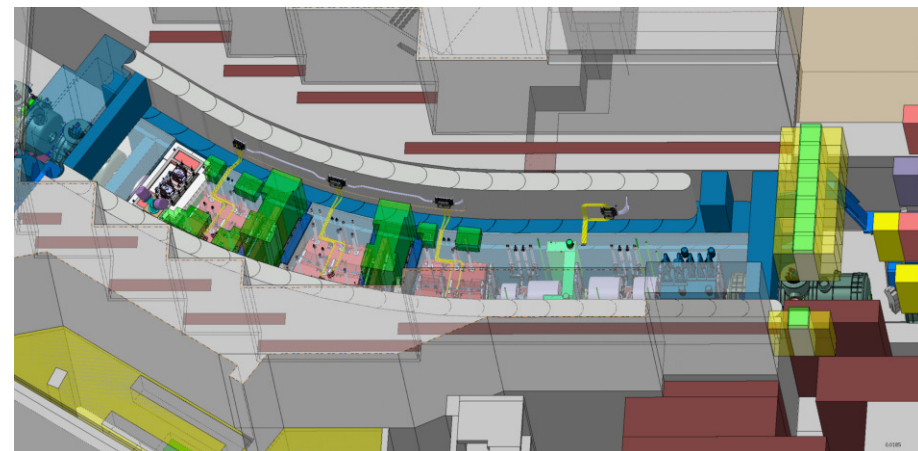
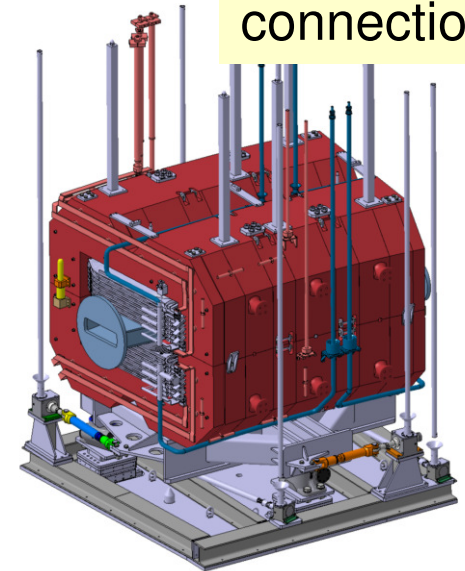
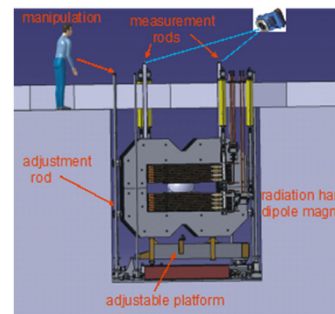
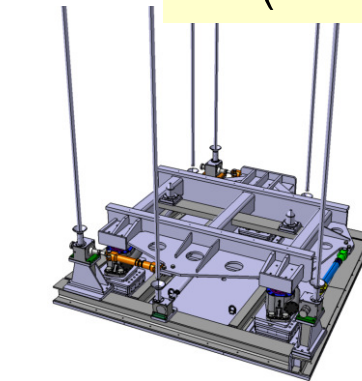
Magnets VI

(Radiation Resistant Magnets)

new support structure
(lubricants free)

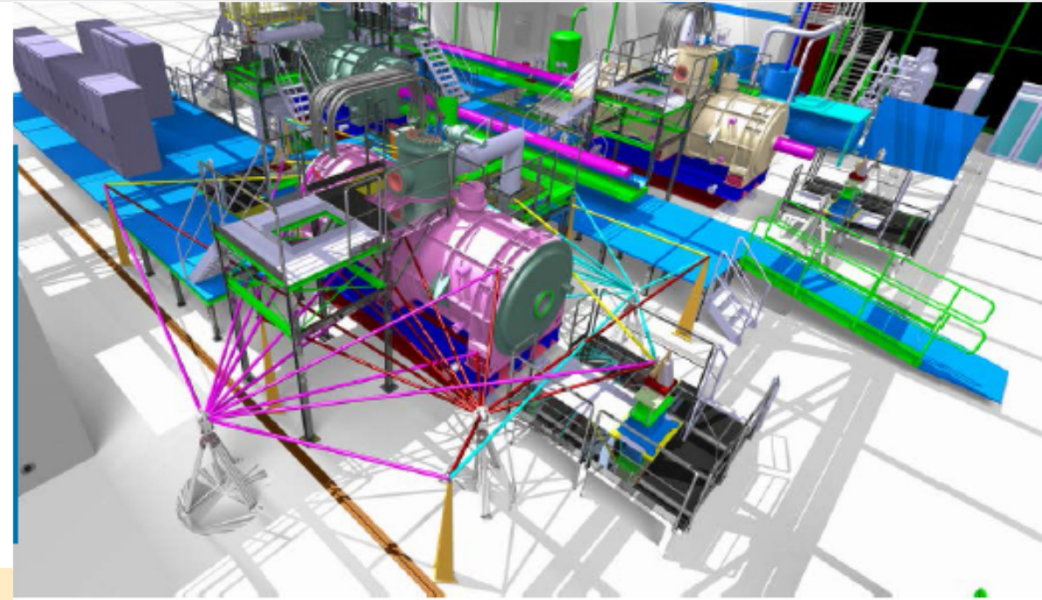
new media
connection

- Magnets located in the target area
- Normal conducting magnets using MIC cable
- 3 dipole units, 3 quadrupoles, 2 sextupoles
- ✓ Prototype dipole (95 ton) built and tested
- ✓ Remote connectors under revision
- Modification of remote alignment
 - ✓ Re-design (in-house) done
 - ✓ Construction running, ready 05/2016
 - Repetition of alignment test
 - (same alignment concept to be used for other components in target area)
- Finalizing specification
- Tendering of magnets via FAIR (Q3/2016)



Magnet Testing @ CERN

- Scope (separator magnets):
 - ✓ 24 Dipoles (PS & MS)
 - ✓ 31 Multiplets (+ 2 spare)
 - does not include EB magnets
- Place: CERN building 180; includes:
 - testing area, preparation area
 - control room, offices

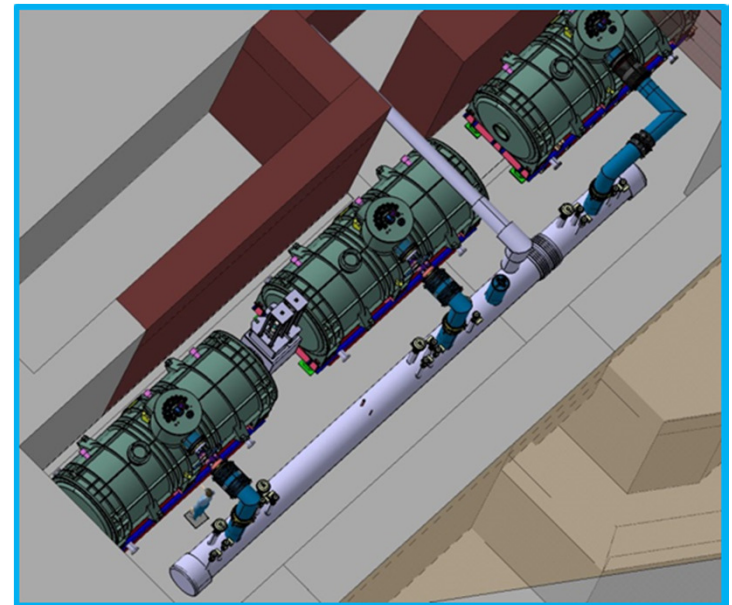
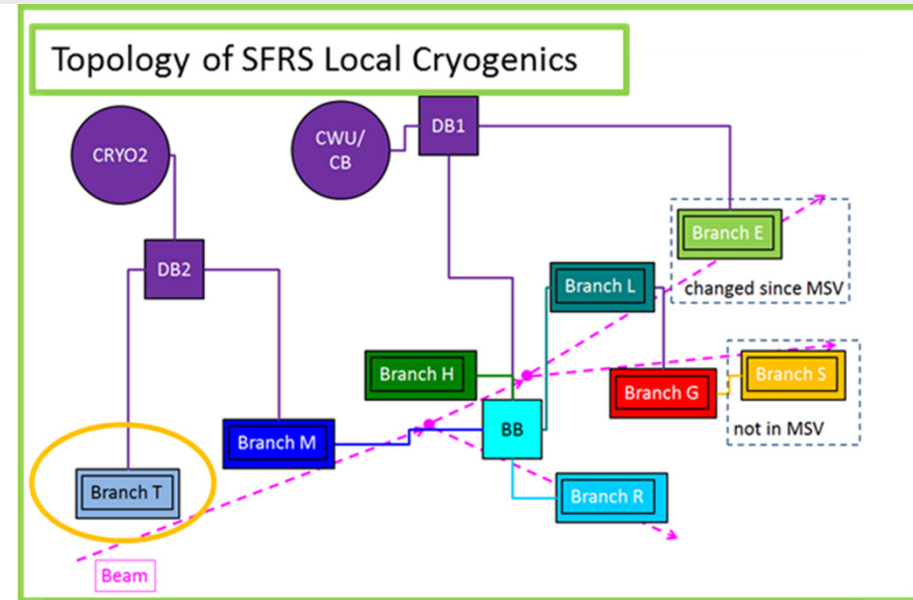


- 3 universal test benches
- Facility ready in Q4/2016
- agreed on detailed list on magnetic field and survey measurements
- Workshops on testing interfaces:
 - Current Lead Interfaces
 - Cryogenic Interfaces
 - Magnet Floor Interface
 - Control Interface

Local Cryogenics I

Cryo Supply Branch T

- Polish in-kind (WrUT)
- First system to be developed: cryo supply for Branch T (focusing system, in front of target area)
- Connected to Cryo DB2 via transfer line
- Conceptual design established, includes:
 - Two Feedboxes for three long multiplets
 - Special (multi-bend) Jumper for third multiplet
- Layout/Routing of internal piping and valve in order to allow for all cryo modes (cooldown, normal operation, warmup, quench, ...)





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Local Cryogenics III

Heat Loads and Cool Down Time

Table 8: Total heat load budget for the Super-FRS magnets and cryo infrastructure.

Static heat loads	Heat loads of Super-FRS machine including (HRS+EB)			Heat loads of Super-FRS machine including EB			Heat loads of Super-FRS machine without (HRS+EB)		
	4.5 K [W]	50 K to 80 K [W]	Liquefaction [g/s]	4.5 K [W]	50 K to 80 K [W]	Liquefaction [g/s]	4.5 K [W]	50 K to 80 K [W]	Liquefaction [g/s]
Magnet cryostats	765	8716	8.4	701	7872	8.0	596	6639	6.8
Local cryogenic distribution	864	5722		772	5097		667	4366	
Total	1628	14438		1474	12969		1263	11005	

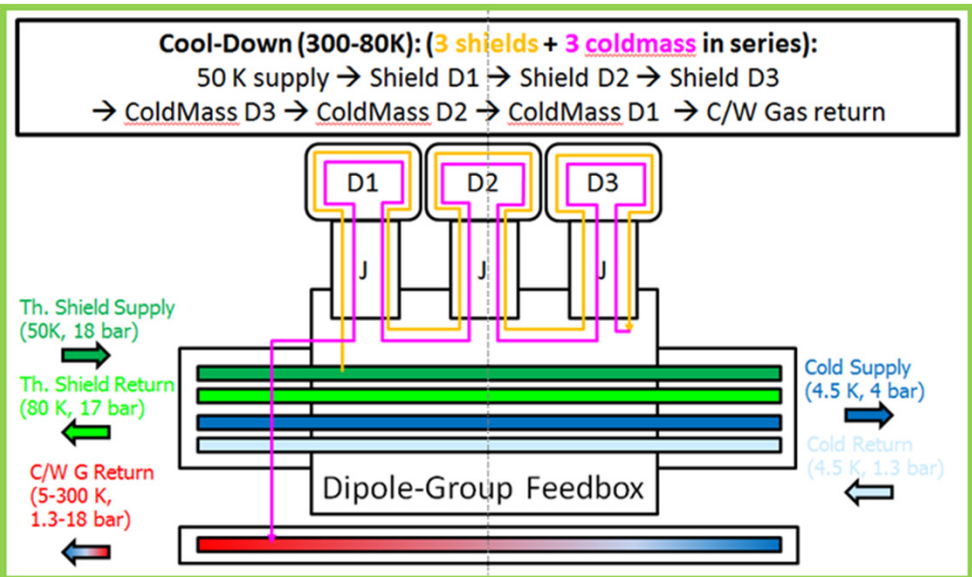
EDMS Link: [https://edms.cern.ch/ui/file/1552771/6/F-TN-CR-02e SuperFRS Heat Loads v1 7.pdf](https://edms.cern.ch/ui/file/1552771/6/F-TN-CR-02e%20SuperFRS%20Heat%20Loads%20v1%207.pdf)

Table 9: Total cool-down time including the liquid-helium filling of the Super-FRS.

Cool-down scenarios	No. 0	No. 1	No. 2	No. 3
Cold mass weight in one cool-down batch [tons]	1432	1302	992	605
	Super-FRS magnets including (HRS+EB)	Super-FRS magnets including EB	Super-FRS magnets without (HRS+EB)	Super-FRS magnets without Ring-, LE-branch + EB, and HRS
Total cool-down time including LHe filling [days]	33	30	23	14

Super-FRS Heat-Loads Document (Technical Note)

- Contributions from Magnets and from Local Cryogenics
- Total Liquid-Helium Volume and total Cold Mass
- Demand towards Cryo-Plant in terms of
 - heat load onto 4.5K circuit,
 - heat load onto 50K circuit,
 - load onto liquefaction rate (for Current Leads)
- Summary of Heat Loads and Cooldown time for different Super-FRS scope scenarios

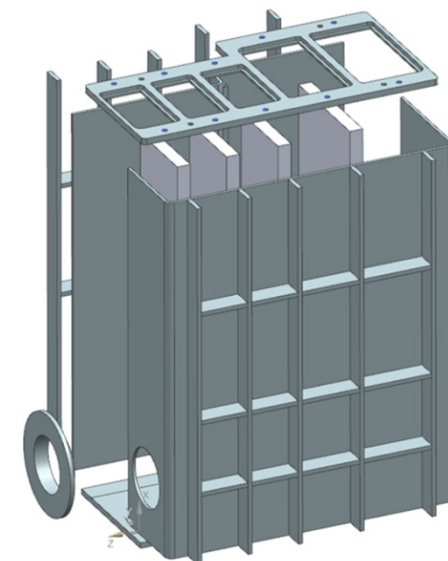
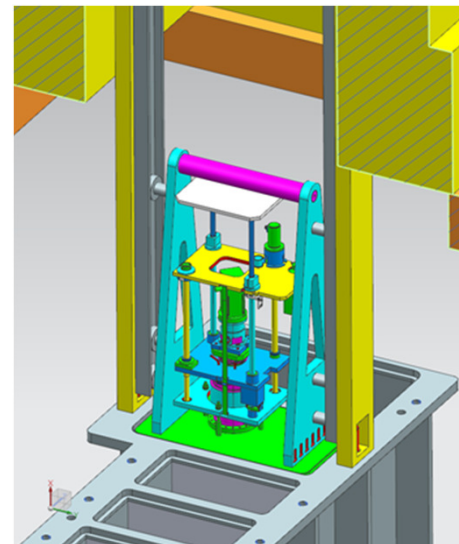
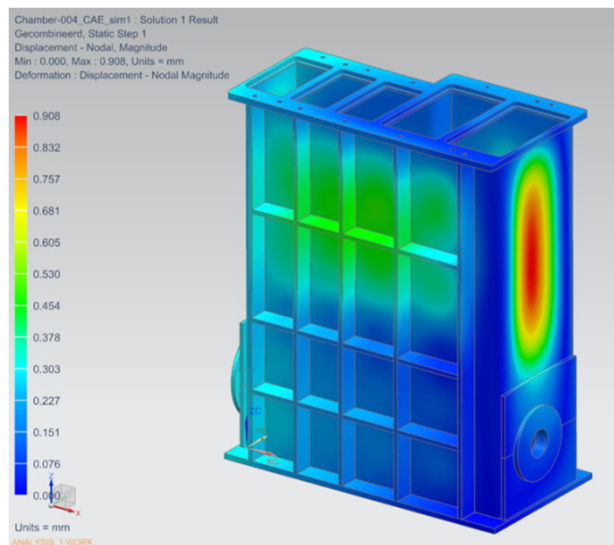
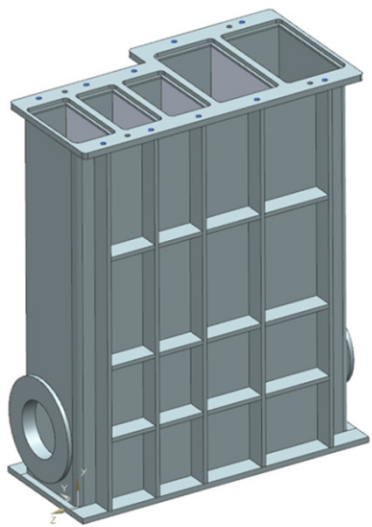


Heat Loads & Cool-down (Summary MSV):

Cold Mass: 1.302 ton
 LHe: 43.610 l
 4.5 K Load : 1.472 W
 50 to 80 K Load : 12.969 W
 Sum Liquefaction : 7.99 g/s

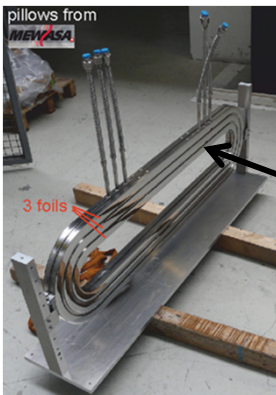
Target Area III (Target Chamber & Plug Systems)

- ✓ German in-kind → collaboration with KVI-CART (umbrella MoU exists)
- ✓ Specification released
- Two-part R&D contract
 - a) Design (under approval, KVI started already working), includes:
 - chamber and plug design, plug vernier adjustment
 - remote handling concept study of these components
 - alignment support (adapt available concept)
 - (infrared) diagnostic of beam spot on target
 - b) Manufacturing

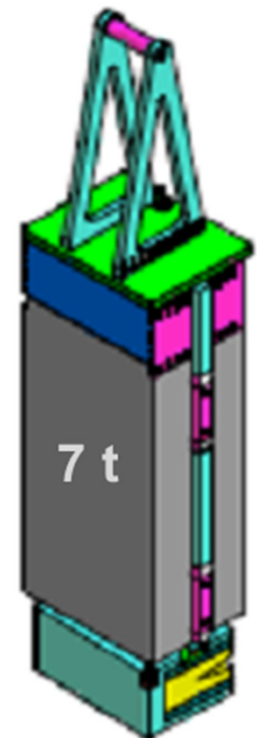
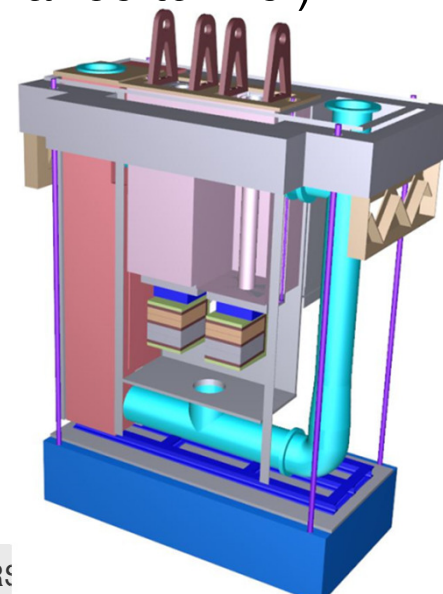
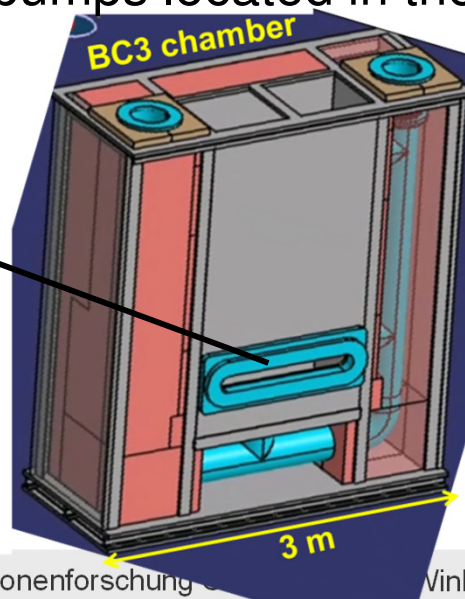


Target Area IV (Beam Catcher)

- ✓ Indian in-kind → Technical Design by **CMERI Durgapur**
- ✓ Interactive work process:
 - ✓ definition report agreed
 - preparation of specification
- ✓ Thermal calculation ongoing (FEM/LS-DYNA)
 - includes water cooling, copper heat sink
 - consider metal / graphite catcher
- ✓ Draft design of chamber available
 - includes plug guidance
 - pumping duct (pumps located in the maintenance tunnel)

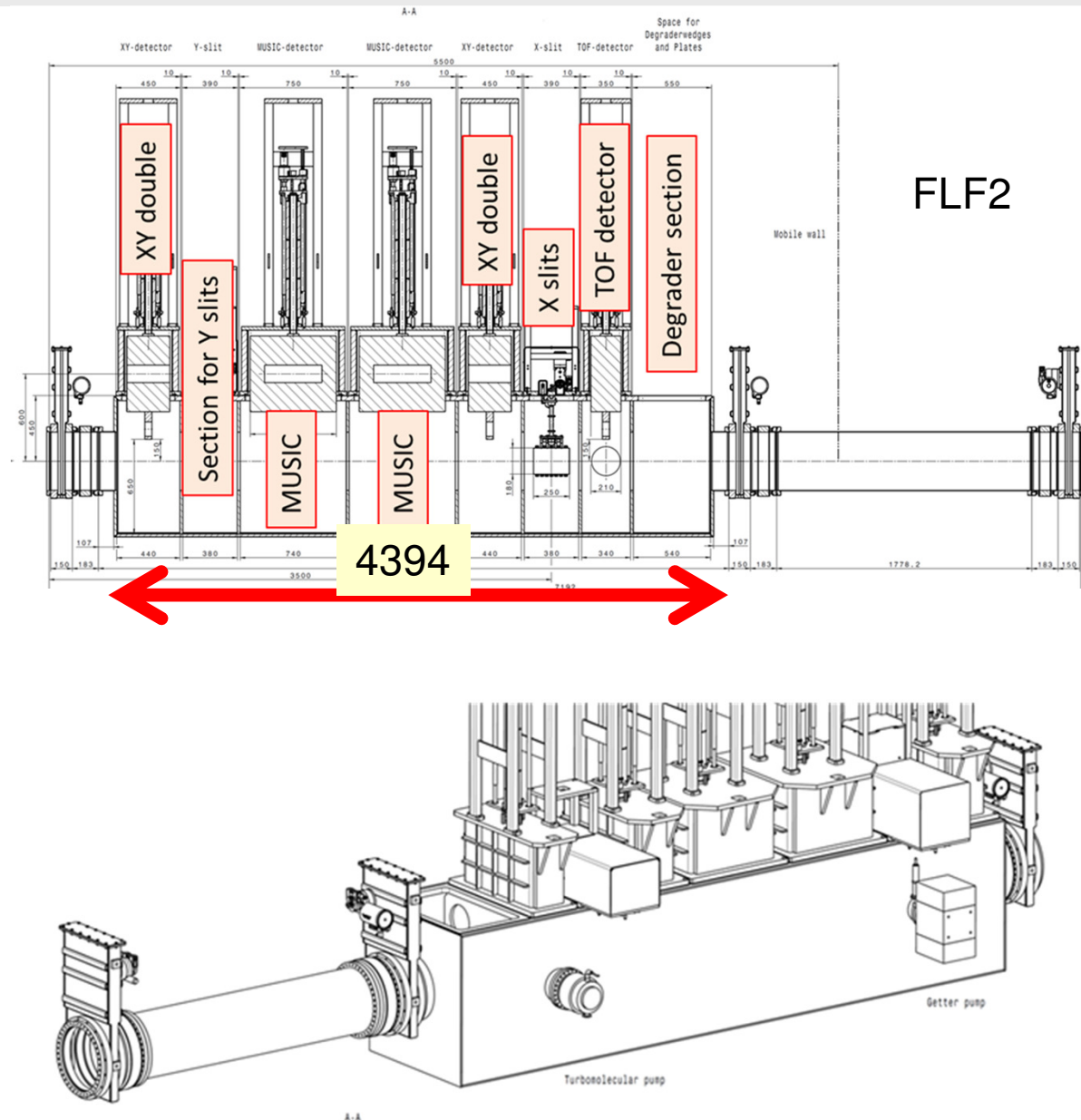


Inflatable pillow seal
with 1200 mm width



Beam Instrumentation II (Focal Plane Chambers)

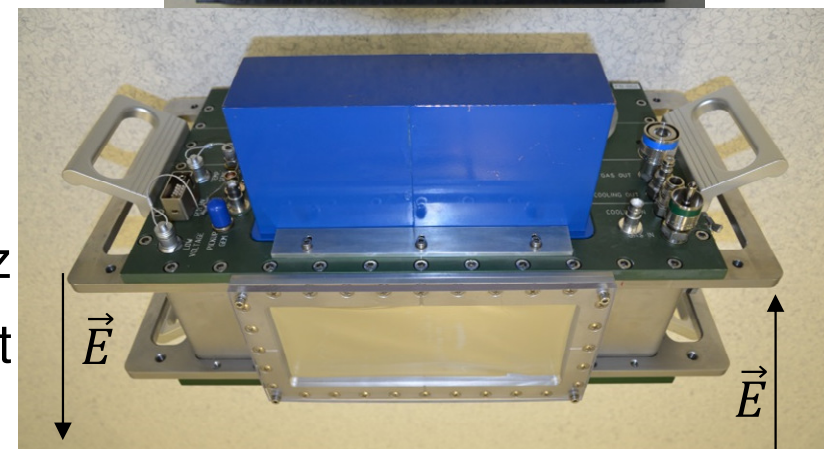
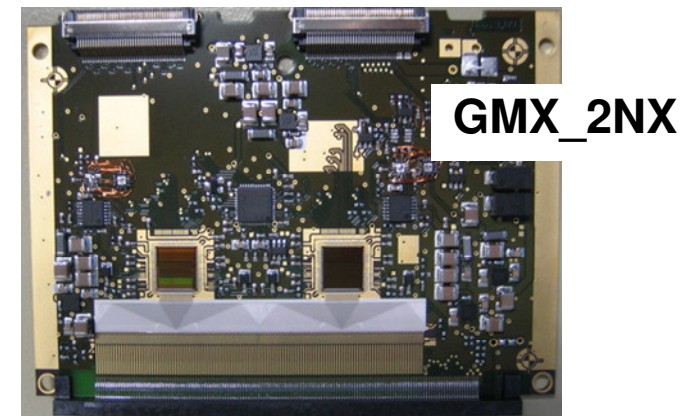
- Russian in-kind (BINP)
- Overall 21 chambers
- Chambers cross section defined
 - 720 x 1130 mm²
 - 970 x 1130 mm² (slits)
 - 970 x 1280 mm² (degrader)
- Chambers length
 - from ≈800 mm to ≈ 4.400 mm
- ✓ Standardize flanges for inserts
- ✓ Pumping ports and vacuum instrumentation considered
- ✓ FEM simulation on chamber stability including insert load
- ✓ DMU collision checks
- ✓ Remote handling capability (robotic @ Pre-Separator)



Beam Instrumentation III (GEM-TPC development)



- Finnish in-kind (HIP), RBDL, CUB
- Various prototypes built and tested
- Review Meeting 07/2015 (external advisor)
 - separate requirements: profile mode (PS) from event by-event tracking mode (MS)
- **New GEMEX+ board (== NYXOR + GMX_2NX)**
 - based on XYTER chip v. 2
 - being designed and tested at RBEE / RBDL
 - will be ready for beam test 2016
- **Two new Twin GEM-TPC prototypes**
 - detector with two field cages in one housing box being constructed to stand up to few MHz
 - Twin GEM-TPC will be ready for beam time at JYFL in 04/2016 and GSI 06/2016

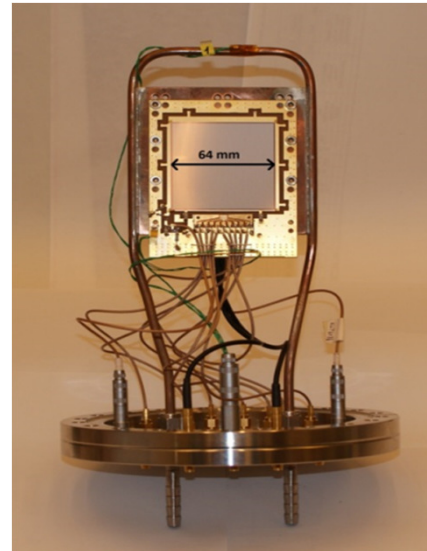
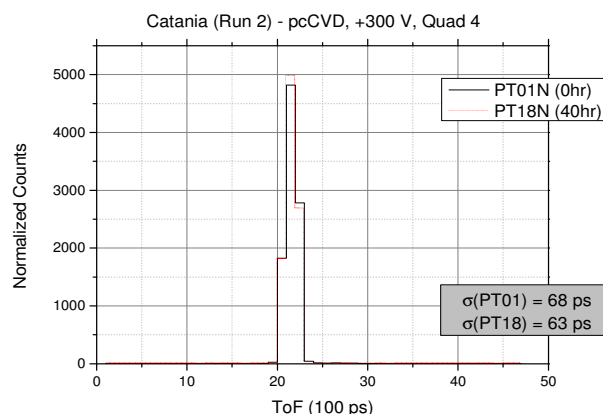
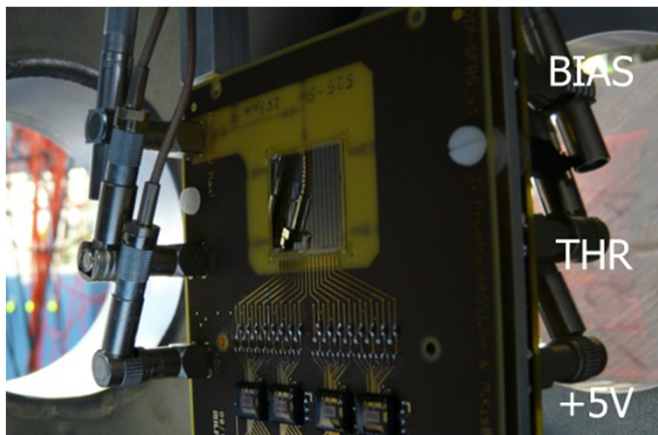


Twin design

Beam Instrumentation IV

(TOF detector development)

- Russian in-kind (IOFFE StP), RBDL
- Required Resolution $\sigma \approx 20...25$ ps
- Technology
 - silicon based
 - diamond based



- Silicon large area (64x64x0.3 mm³) SSSD
- vacuum test (cooled)
- Res. down to 15 ps (ToF measured with smaller detectors of different topologies)

- pcCVD-DD, 20x20x0.3 mm³, 16-strip design, (1x18) mm², 0.15 mm gap, C = 4.3 pF/strip, 50/100 nm Cr/Au by photolithography
- Sub 50 ps ToF resolution (PADI+VFTX), over a path length of 30 m, no Time-over-Threshold correction
- pcCVD-DD, 10x10x0.3 mm³, no degradation of signal at the end of long-term irradiation measurement

Beam Instrumentation V (Slit Systems)

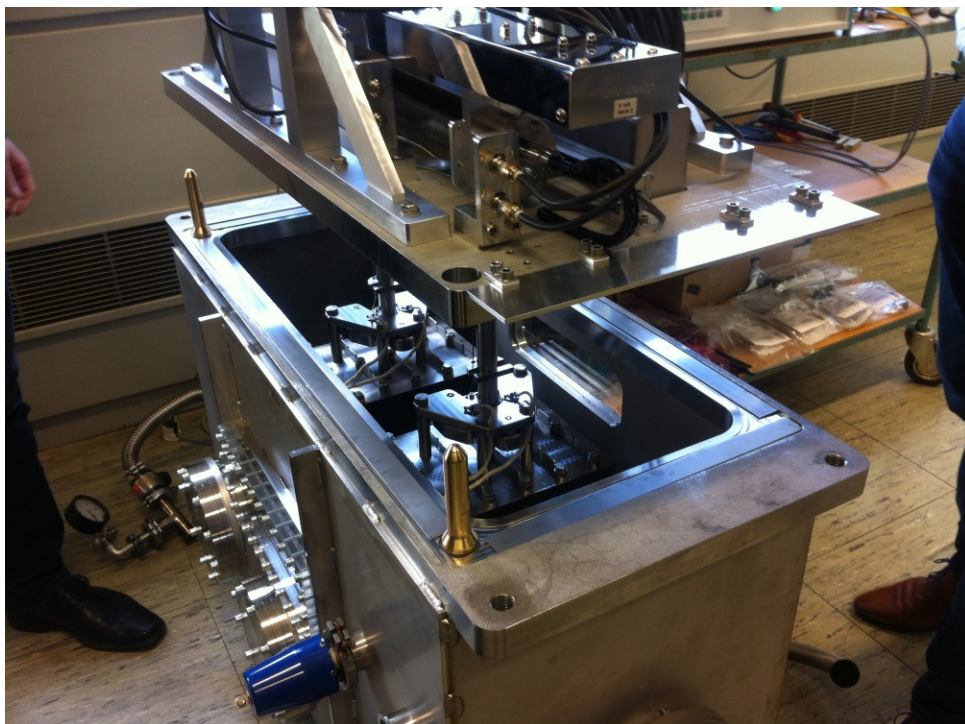


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x/y Slit-systems

- Overall 18 slit pairs required
- Remote handling foreseen
- German in-kind, R&D contract with KVI-CART
- ✓ PDR done
- ✓ Pre-Series x-slit system assembled at KVI
 - Design Verification / FAT running 04/16



Media pannel,
robot operated
to be added

x-slit system:
block size: 200mm x 200 mm
y-slit system:
Block size: 400mm x 90 mm
Material: DENSIMET®

- Civil Construction
 - execution planning resuming
 - includes LEB/Energy Buncher cave
 - includes the review of the target area shielding design
- SC Magnets and Testing (most time critical items):
 - multiplets: contract awarded, design running
 - dipoles: TCC missing, CDR and DS ready to be released, tendering in preparation; design of branching units still tbd
- Development and procurement of various components under way
 - in particular contract for target chamber and plug inserts ready for signing