GSI Helmholtzzentrum für Schwerionenforschung GmbH

FAIR Secondary Beams

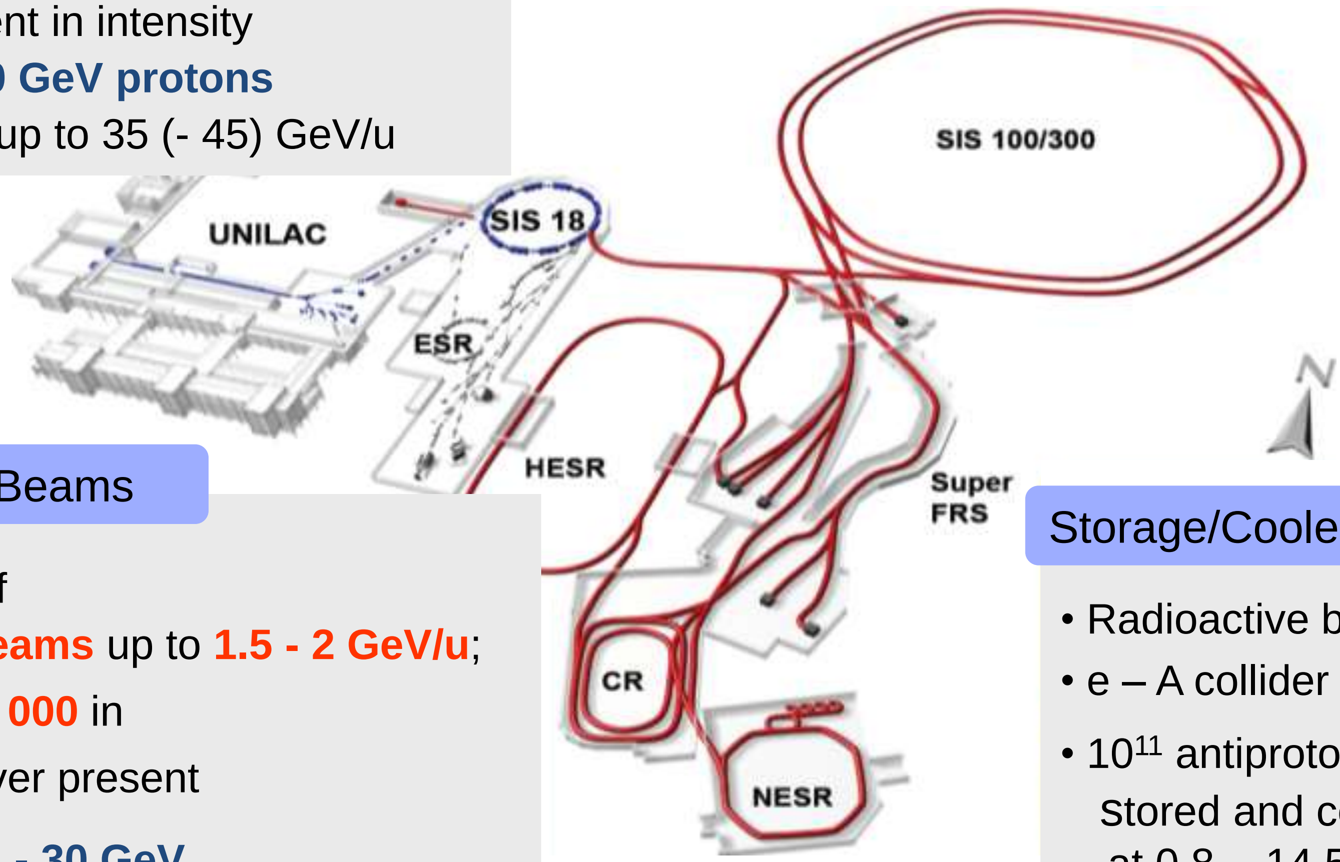
H. Simon

International Conference on Science and Technology for FAIR in Europe 2014, Oct 13th-17th in Worms

From GSI to FAIR: novel opportunities

Primary Beams

- 2-3 x10^{11}/s; 1.5-2 GeV/u; $^{238}U^{28+}$
- **Factor 100-1000**
  over present in intensity
- **2(4)x10^{13}/s 30 GeV protons**
- 10^{10}/s $^{238}U^{73+}$ up to 35 (- 45) GeV/u



Secondary Beams

- Broad range of
  radioactive beams up to **1.5 - 2 GeV/u**;
  up to factor **10 000** in
  intensity over present
- **Antiprotons 3 - 30 GeV**

Storage/Cooler Rings

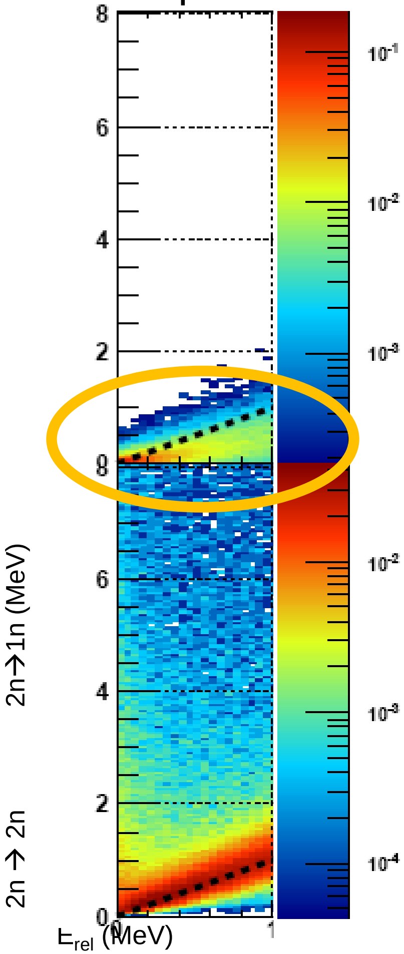
- Radioactive beams
- e – A collider
- 10^{11} antiprotons
  stored and cooled
  at 0.8 - 14.5 GeV

High intesities are of key importance!

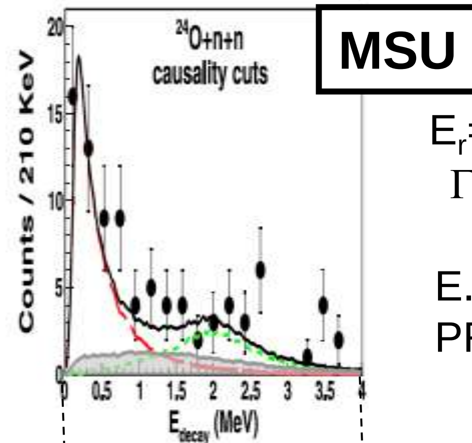
e.g. Current frontier: ^{26}O

^{24}F	^{25}F	^{26}F	^{27}F	^{28}F	^{29}F
0.34 s	50 ms	10.2 ms	4.9 ms	unbound	2.6 ms
^{23}O	^{24}O	^{25}O	^{26}O		
82 ms	61 ms	unbound	unbound		

Low energy response

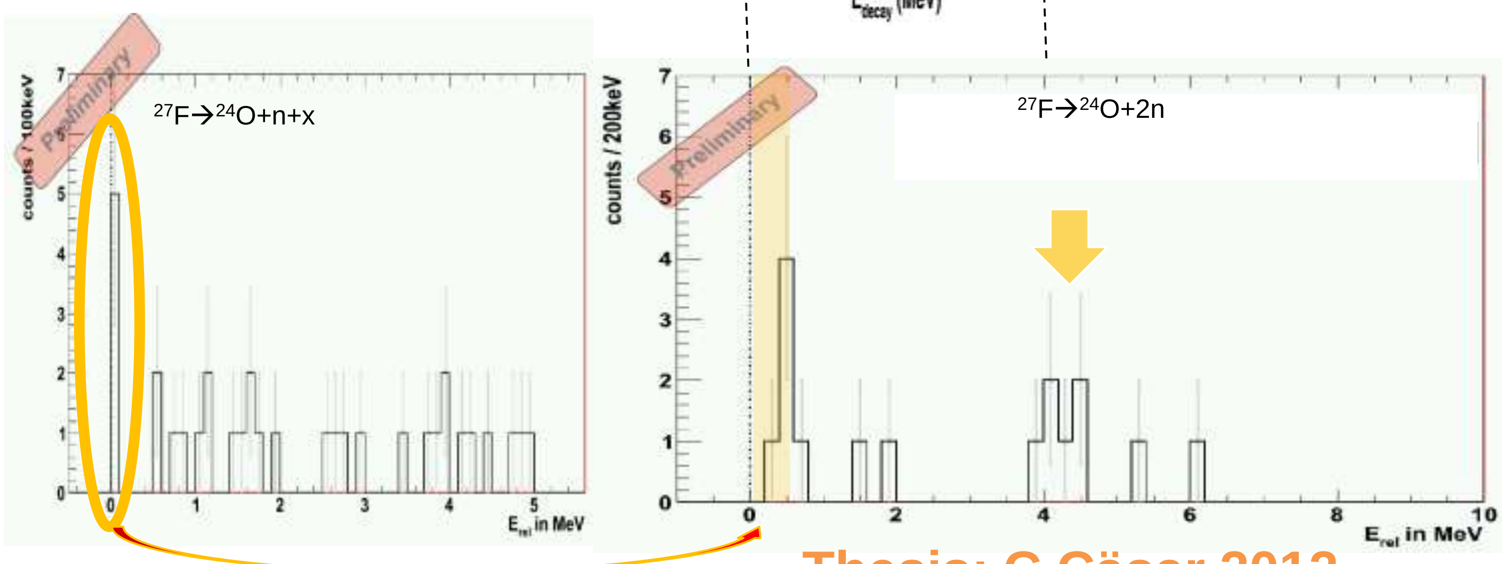


1) Beam intensity
   $3 \cdot 10^{10}$ ^{40}Ar/spill
   ➔ ~ 0.1 ^{27}F/s
2) Multi neutron detection and acceptance.



E_r=150$^{+50}_{-150}$keV
Γ= 5 keV

E. Lunderberg et al. PRL108(2012) 142503



Thesis: C.Cäsar 2012 TUDa/GSI

Layout of the Super-FRS (Full Version)

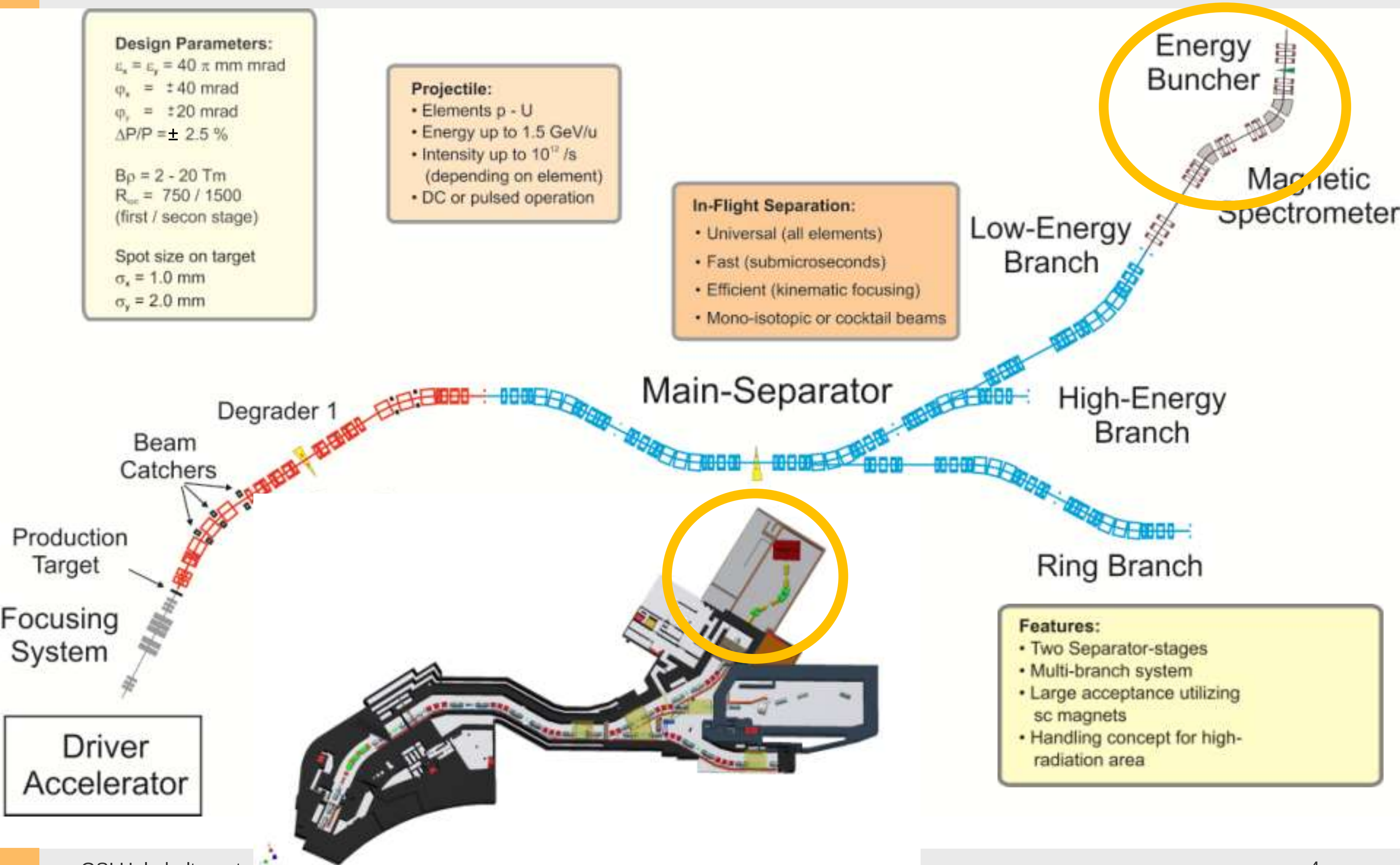
Design Parameters:
$\varepsilon_x = \varepsilon_y = 40\,\pi$ mm mrad
φ_x = ±40 mrad
φ_y = ±20 mrad
$\Delta P/P$ = ± 2.5 %

$B\rho$ = 2 - 20 Tm
R_{res} = 750 / 1500
(first / secon stage)

Spot size on target
σ_x = 1.0 mm
σ_y = 2.0 mm

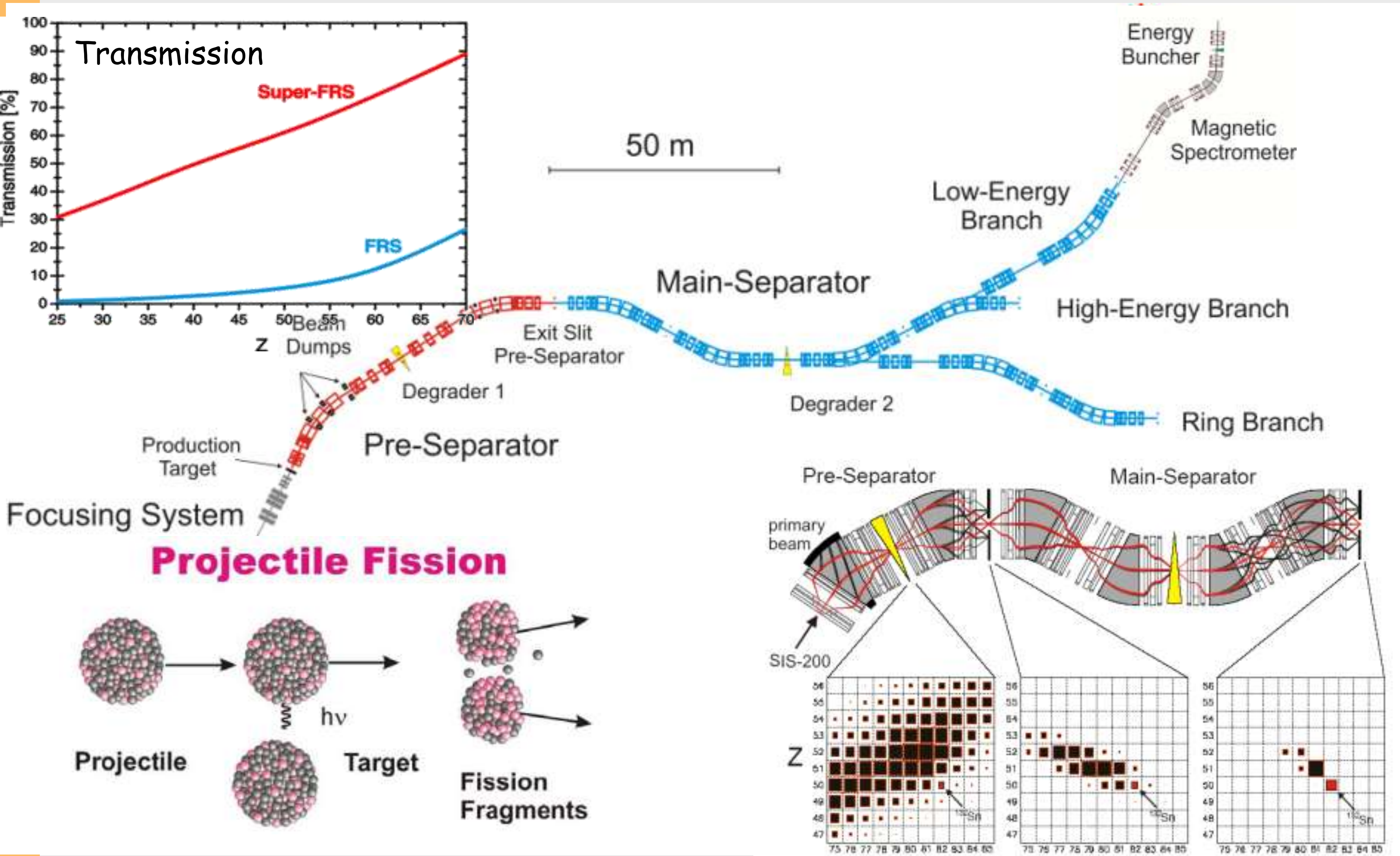
Projectile:
- Elements p - U
- Energy up to 1.5 GeV/u
- Intensity up to 10^{12} /s (depending on element)
- DC or pulsed operation

In-Flight Separation:
- Universal (all elements)
- Fast (submicroseconds)
- Efficient (kinematic focusing)
- Mono-isotopic or cocktail beams

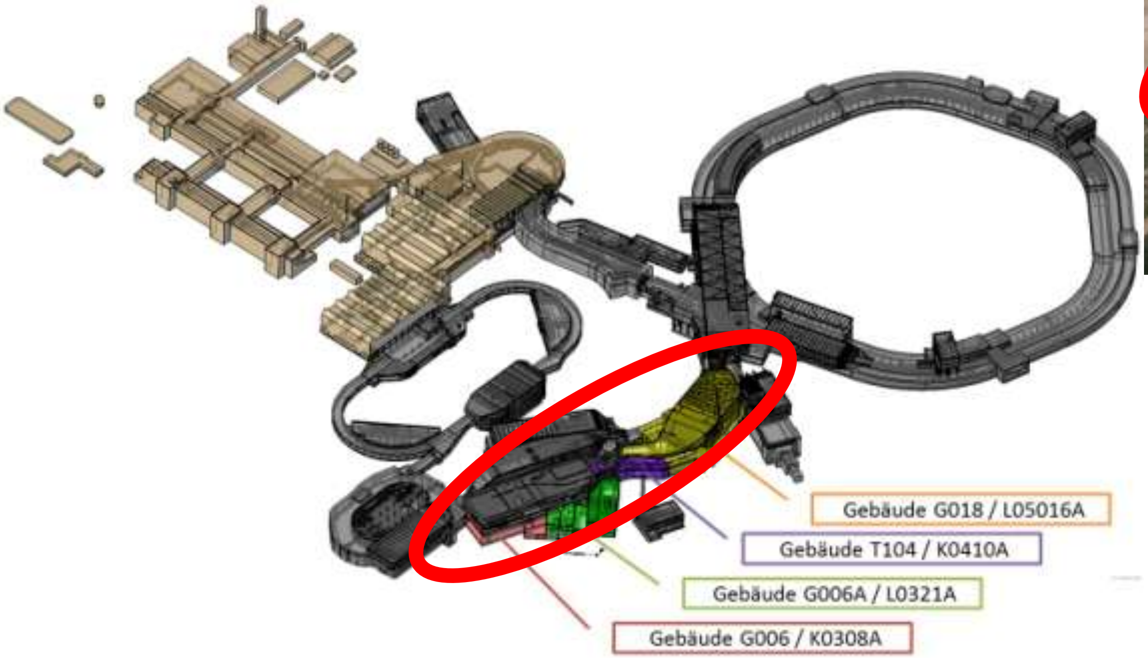


Features:
- Two Separator-stages
- Multi-branch system
- Large acceptance utilizing sc magnets
- Handling concept for high-radiation area

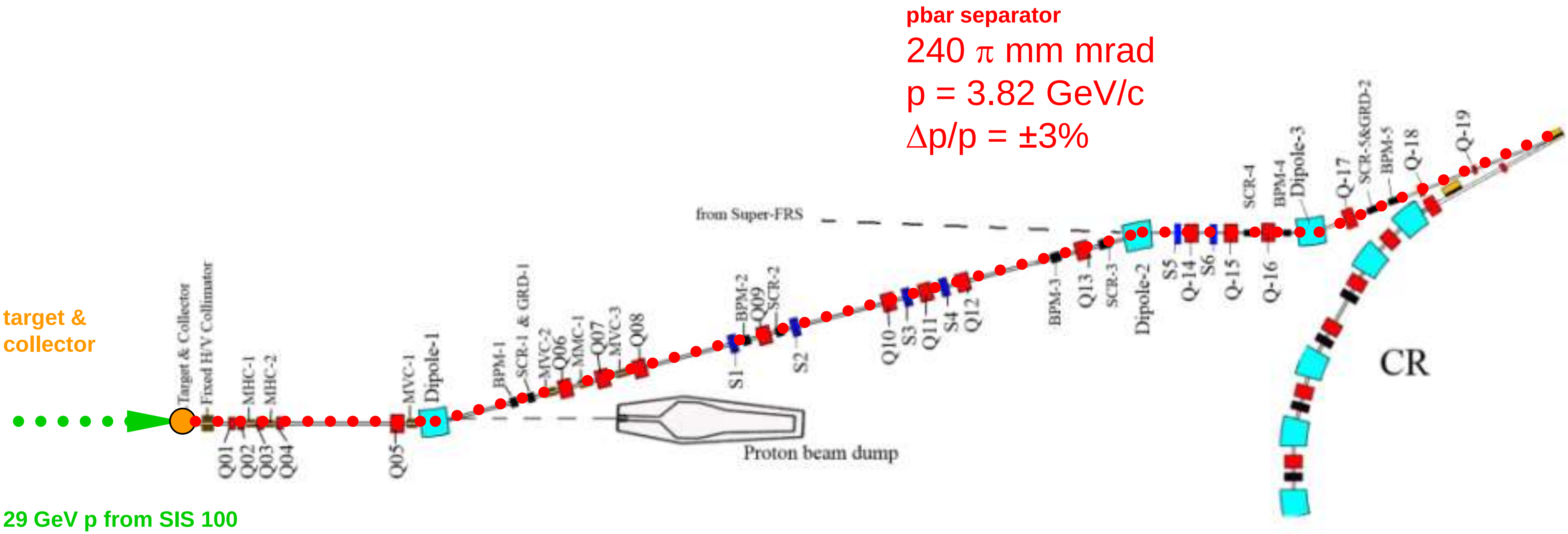
Superconducting FRagment Separator



Stepping stone towards the facility



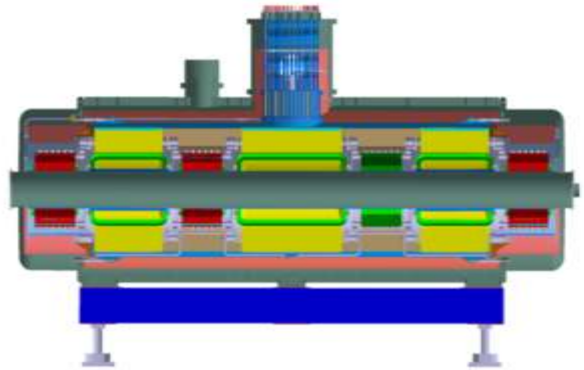
The pbar separator



See Talk by Klaus Knie on Friday

Super-FRS

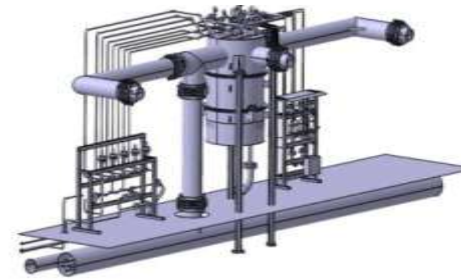
SC Multiplets

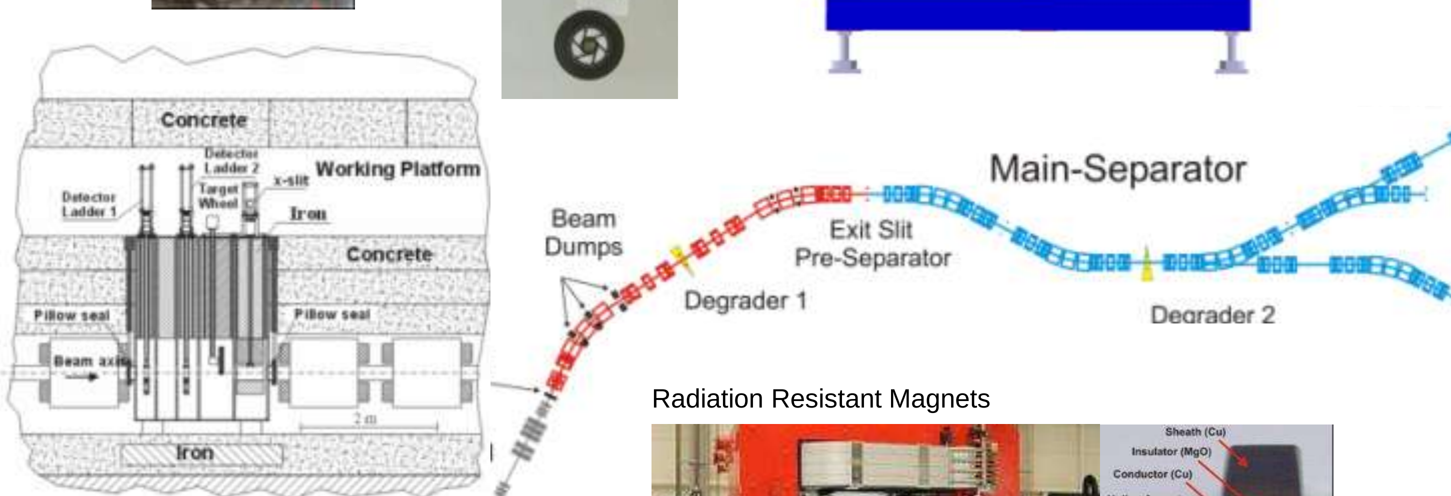


Remote Handling

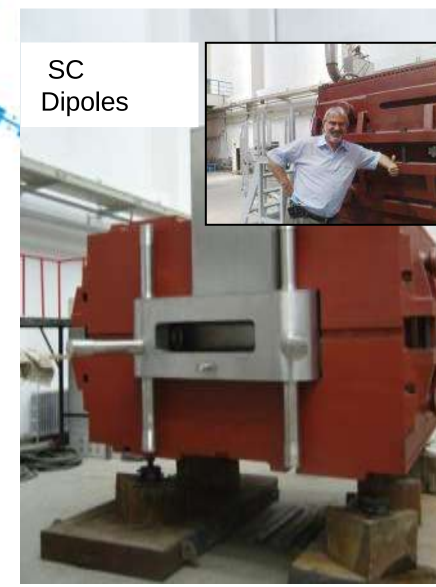
Target

Local Cryogenics

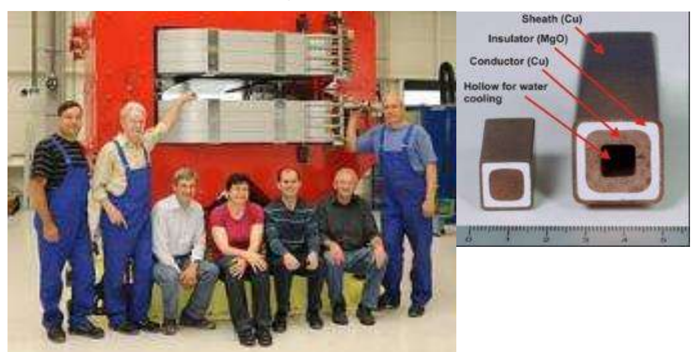




SC Dipoles



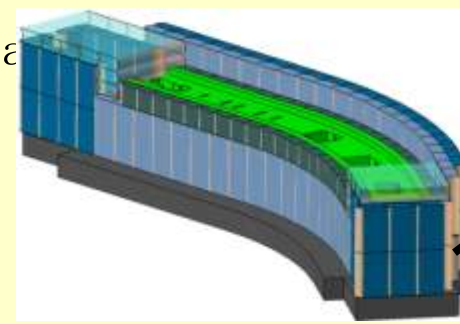
Radiation Resistant Magnets

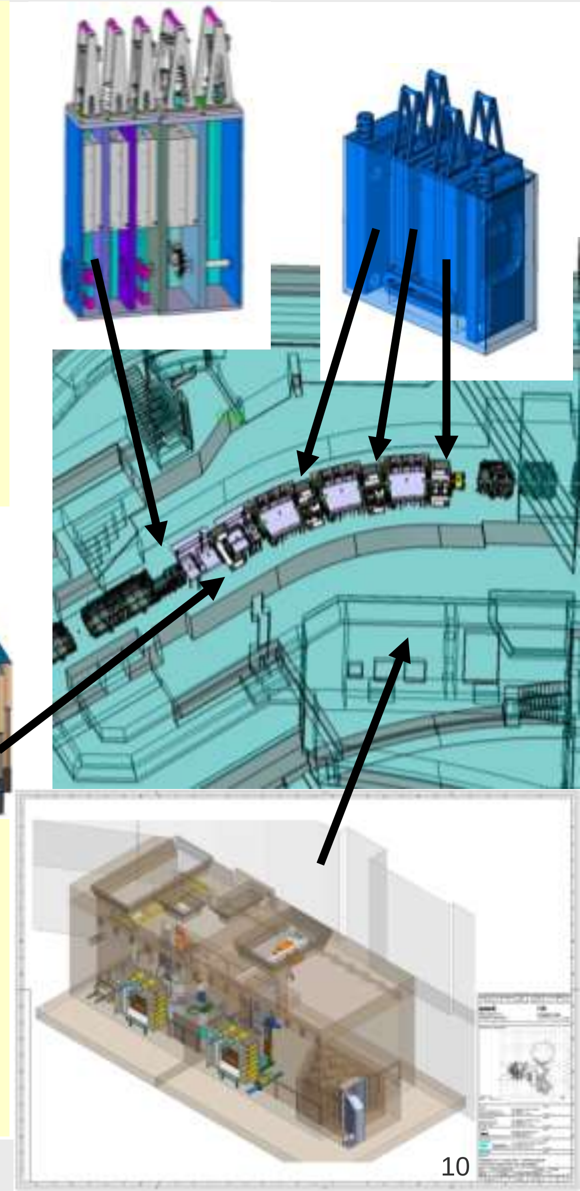


Super-FRS Target Area

Major Installation

- Target chamber & plug inserts
  - German in-kind in collaboration with KVI-CART
- Target wheel & plug inserts
  - German in-kind in collaboration with KVI-CART
- Beam catcher
  - Indian in-kind
  - chamber and plug inserts for slow and fast extracted bea





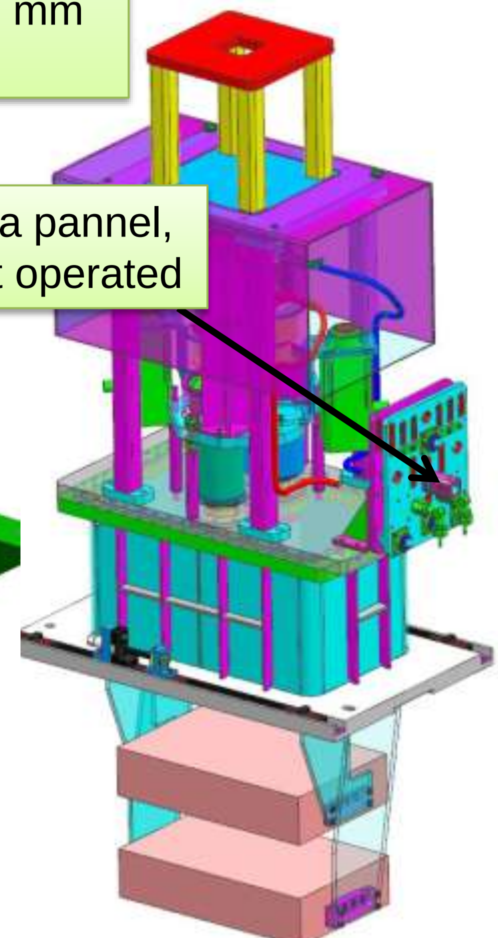
Major Infrastructure

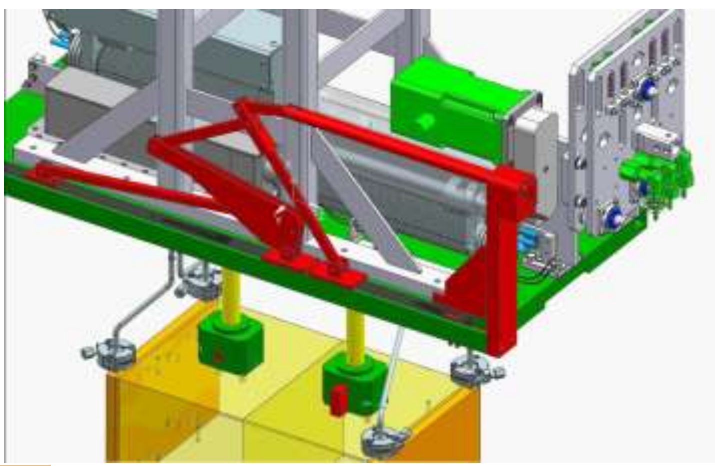
- Hot Cell Complex
  - German in-kind
  - So far planning by nuclear engineering company
- Shielding flask
  - Finnish in-kind
- Iron shielding (approximately 6.000 ton)

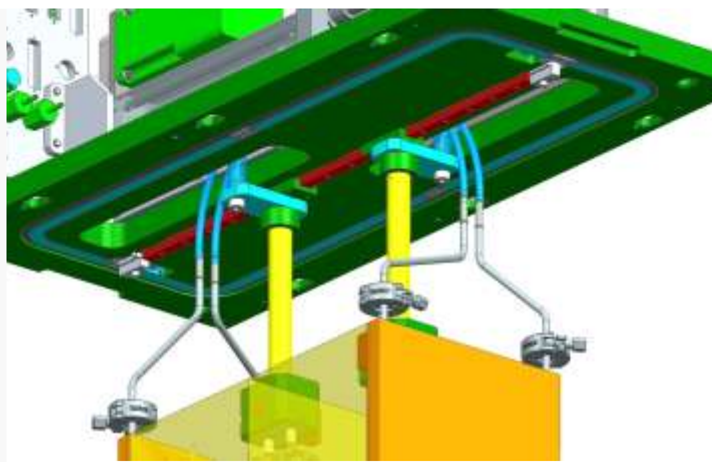
x/y Slit-systems

- Overall 18 slit pairs required
- Remote handling foreseen
- ✓ Specification established
- ✓ Collaboration contract with KVI-CART
- ✓ Kick-off done 01/2014
- ✓ PDR done 08/2014,
  - Pre-design existing
  - thermal simulation / cooling issues considered
- ➢ Pre-Series slit-system expected Q3/2015

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



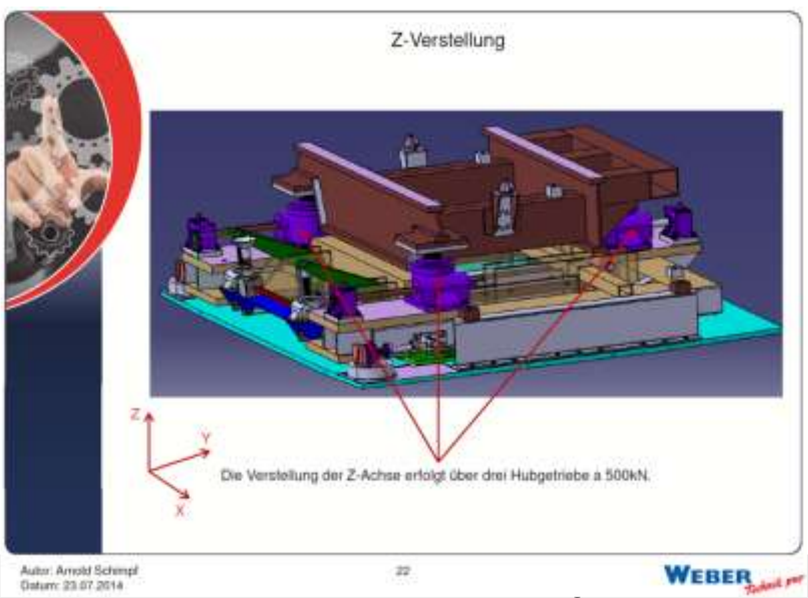


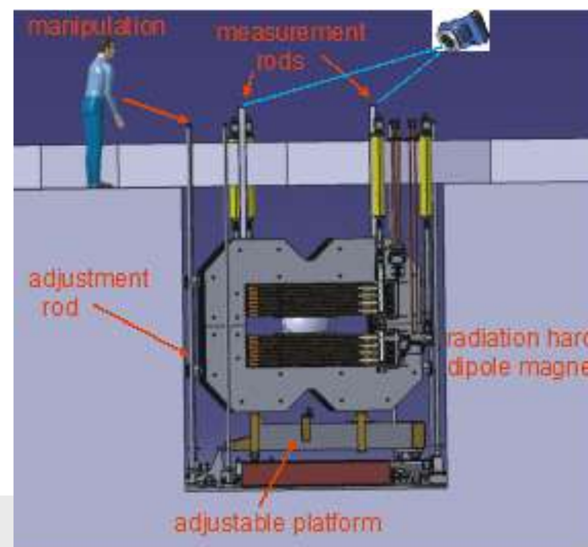


Radiation Resistant Magnets (at the Target Area of Super-FRS)

- Normal conducting magnets using MIC cable
- 3 dipole units, 3 quadrupoles, 2 sextupoles
- Prototype dipole built (95 ton) and tested by BINP
- Handling tests at GSI in 08/2014
- Remote alignment under revision
- Remote connectors under revision
- Specification in preparation,
- Tendering via FAIR Q1-Q2/2015

Prototype dipole at GSI testing-hall





Handling Test Dipole

(Mobile crane in dedicated hall “Testinghalle”)

{2}

Handling Test Dipole

(... yoke juggling …)

{2}

Handling Test Dipole

(Reassemble the magnet)

Mechanical guides are not sufficient dimensioned

Intervisibility was required

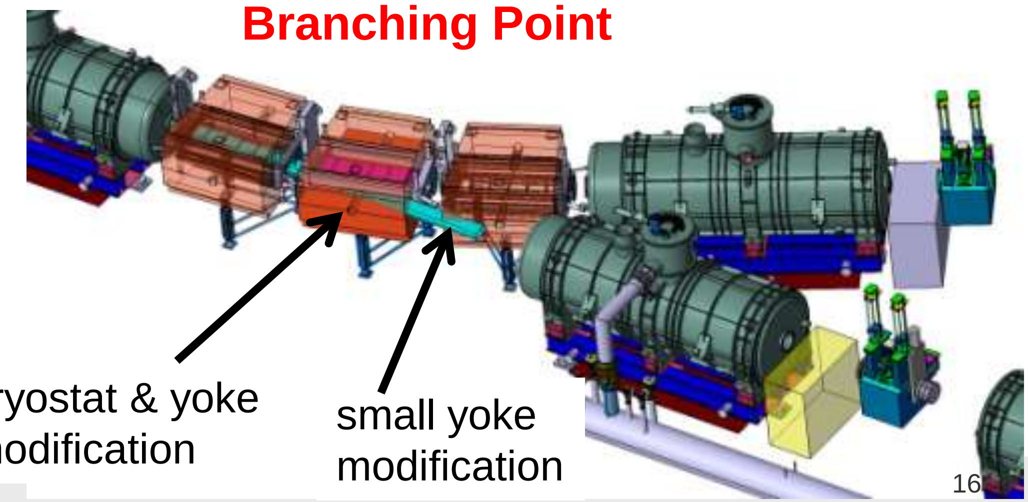
➔Small revisions necessary after full size test .

SC Dipole Magnets

- 3 dipole units 11°
- 21 dipole units 9.75°
  - ➢ 3 times modified cryostat
- Iron dominated/warm iron
- SC coil
- Aperture ±190mm x ±70mm
- Weight: 50 to 60 ton
- Prototype built and tested (FAIR China Group)

Status:

- ✓ Collaboration agreement with CEA/Saclay on:
  - ➢ Detailed design & Technical follow-up
  - ➢ Participation at CERN testing
- ✓ Technical Kick-off 1/2014
- ✓ IMP Visit 4/2014 (CEA & GSI)
- ✓ PDR done 7/2014 (including external advisor)
- FDR planned for 11/2014 (without special dipoles)
- Tender by FAIR starting 12/2014
- First of Series ready for testing: Q3/2016
- Series production & testing: Q4/2016 – Q1/2019

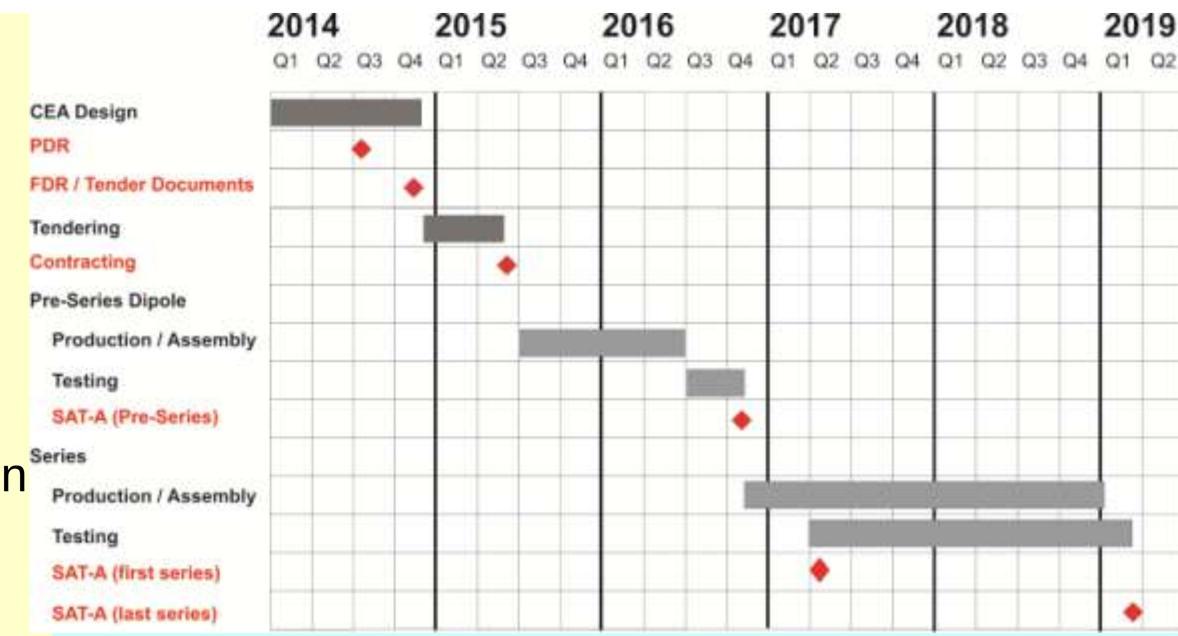


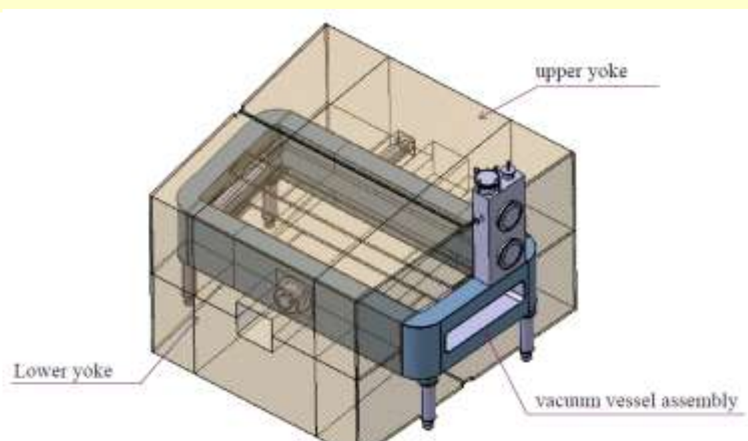
Collaboration with CEA/Saclay
Overall Status

- Focus on short dipole

Project includes:

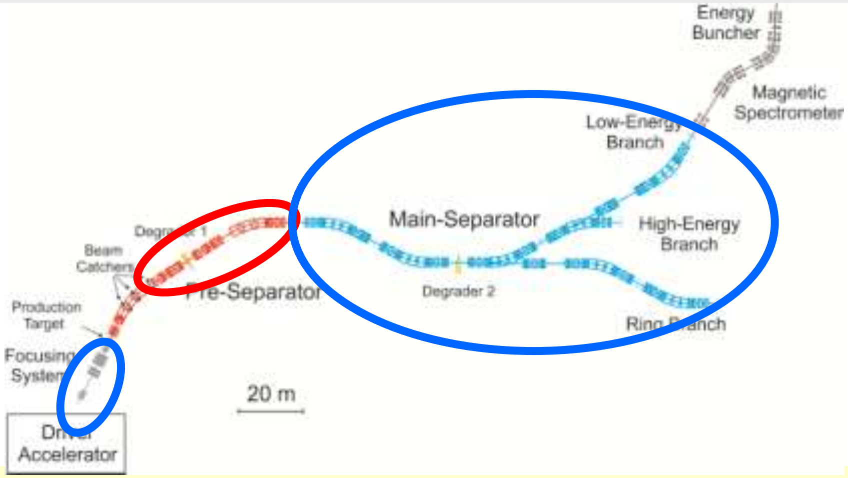
- ➢ Magnetic design
- ➢ Cryogenic Design
- ➢ Quench Analysis
- ➢ Mechanical Design (including cool down, magnetic forces)
- ➢ Protection & Quench Detection
- ➢ Instrumentation
- ➢ Interfaces with GSI/FAIR (cryogenics, PC, DMU, ...)





- Procurement Strategy under discussion (FAIR/GSI/CEA)
  - ➢ 3 lots (yoke, cold mass, integration)
  - ➢ branching units as option
  - ✓ pre-ordering of wire (running)
  - ✓ 'pre-bidder conference' (running, 8 companies applied)
- Time Schedule updated

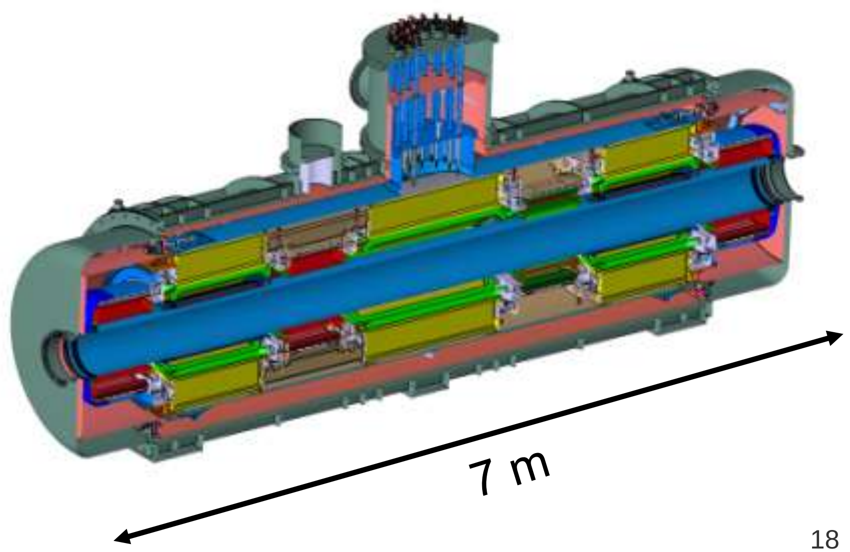
SC Multiplets



- 25 long multiplets (MS)
- 8 short multiplets (PS)
- Quadrupol triplet / QS configuration
- up to 3 sextupoles and 1 steerer
- Octupole coils in short quadrupoles

- iron dominated, cold iron (≈40 tons)
- common helium bath
- warm beam pipe (38 cm inner diameter)
- per magnet 1 pair of current leads
- max. current <300A for all magnets

- **Tender Status:**
- ✓ Tender opened Q3/2013
- ✓ Bidder submitted quotes Q4/2013
- ✓ 1st round negotiation finished Q1/2014
- ✓ 2nd round negotiation finished Q2/2014
- 3rd round negotiation still running
- ➢ signing of contract expected for Q4/ 2014
- ➢ FAT of first short multiplet Q2/2016
- ➢ FAT of first long multiplet Q3-Q4/2016
- ➢ Series production: Q4/2016 – Q1/2020



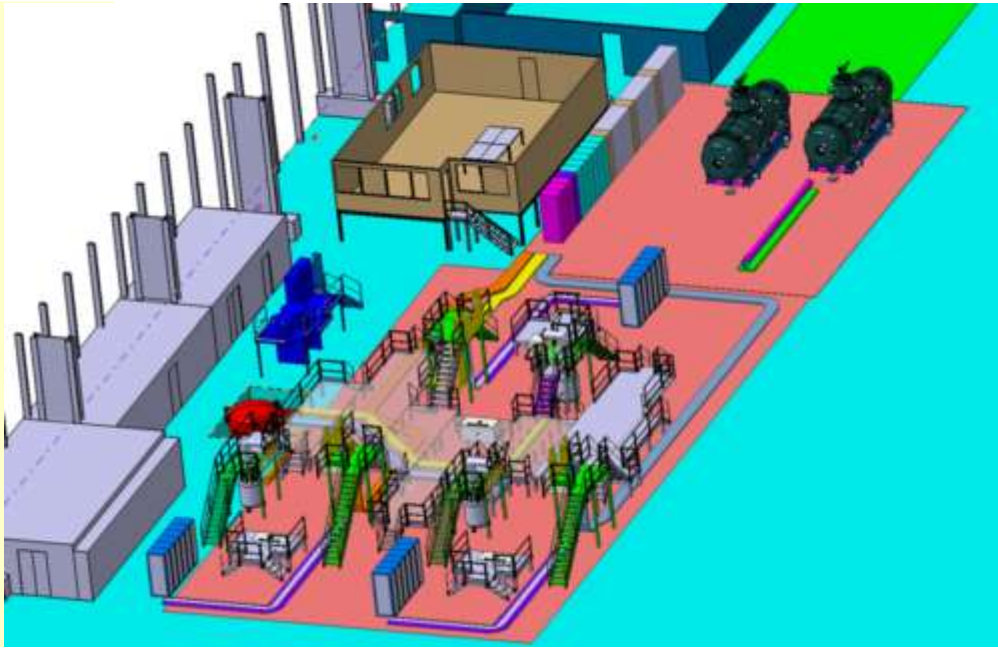
Multiplet tendering: Comparison of Timelines

	FAT short multiplet (month after project start)	FAT long multiplet (month after project start)	Release of SP (month after project start)	FAT 1st series (month after project start)	FAT last series (month after project start)
Project Plan	19	23	27	31	62
Bidder 1	20	22	26	33	68,5
Bidder 2	22	25	27	36	73
Bidder 3	24	27	28	34	56

- Overall time for production of 33 multiplets ≈5.5 years
- Start in Q4/2014,
  - 1st multiplet at CERN: Q2 /2016
  - WP runs at least until **Q1/2020**
- Series Production Rate approximately ≈1 unit/month;
  - Bidder 3 produces too fast (<2 years, requires 4 test benches at CERN)

Magnet Testing & Mapping @ CERN

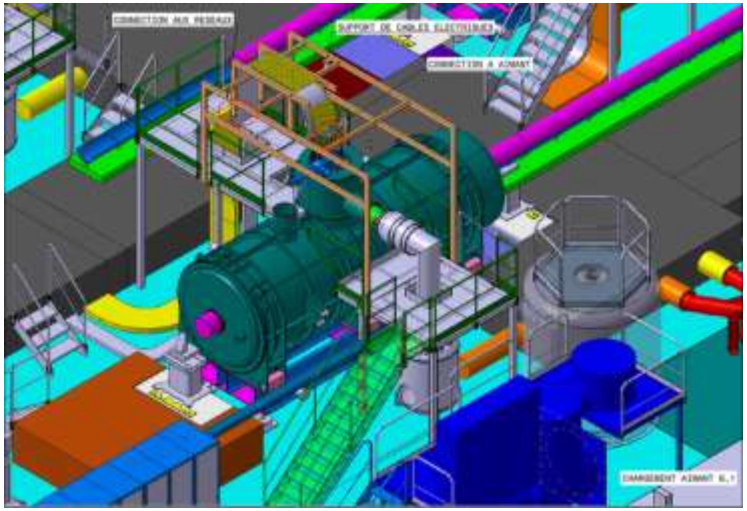
- ✓ GSI-CERN Agreement K1727/DG & Addendum #2 (signed)
- Scope (separator magnets):
  - ✓ 24 Dipoles (PS & MS),
  - ✓ 31 Multipletts (+ 2 spare)
- Place: CERN building 180
- 3 universal test benches, basically:
  - 1 setting-up & cool-down
  - 1 measuring
  - 1 warm-up & disassemble

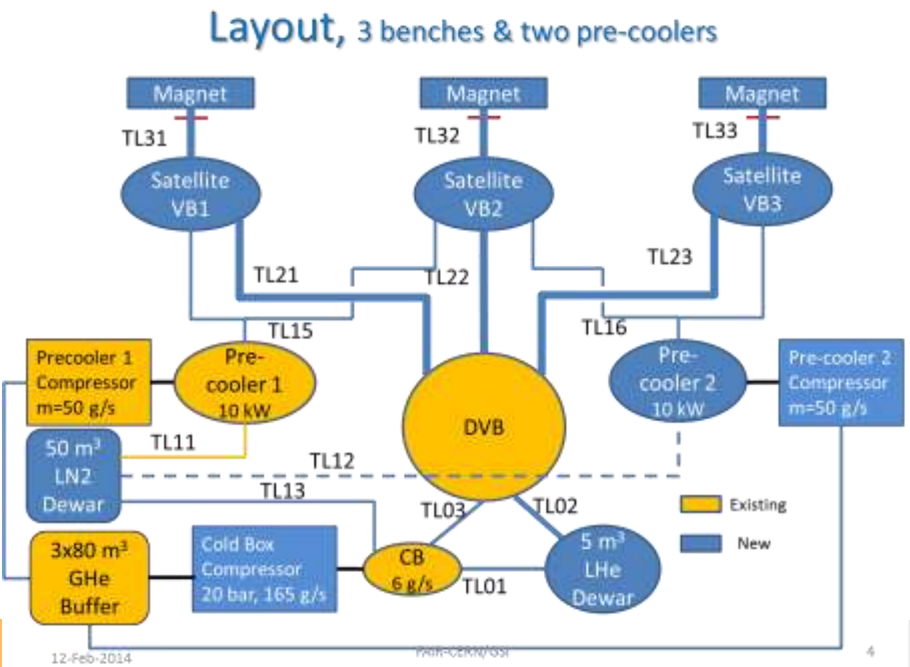


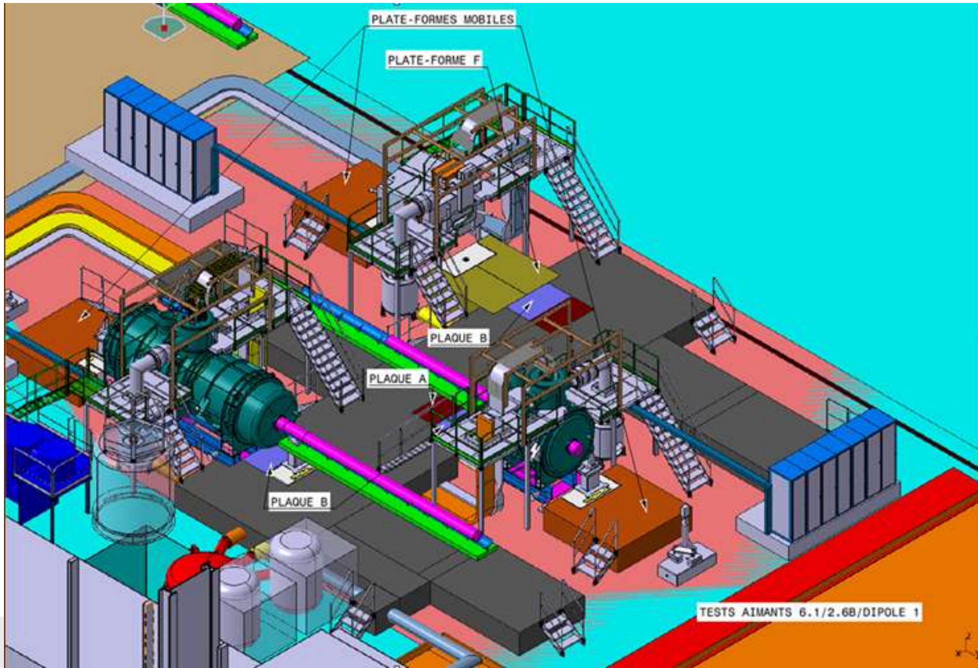
- Ready for testing: Q1/2016
- Time estimate (single multiplet): 44 days
  - Installation, connection, cool-down: 15 days
  - Cold test (powering, magnetic field): 15 days
  - Warm-up, disassembly: 14 days
- overall series measurement time: ≈ 3-3.5 years

Magnet Testing Area @ CERN

- ✓ Existing equipment
  - magnet-measurement station, crane
  - Cryo: Ghe Buffer, distribution box
    pre-cooler (10kW) + compressor
- ✓ New required equipment (mainly cryo-parts):
  - 2nd pre-cooler (10kW) + compressor
  - 3 satellite valve-boxes & cryogenic lines
  - LN2 & LHe tank



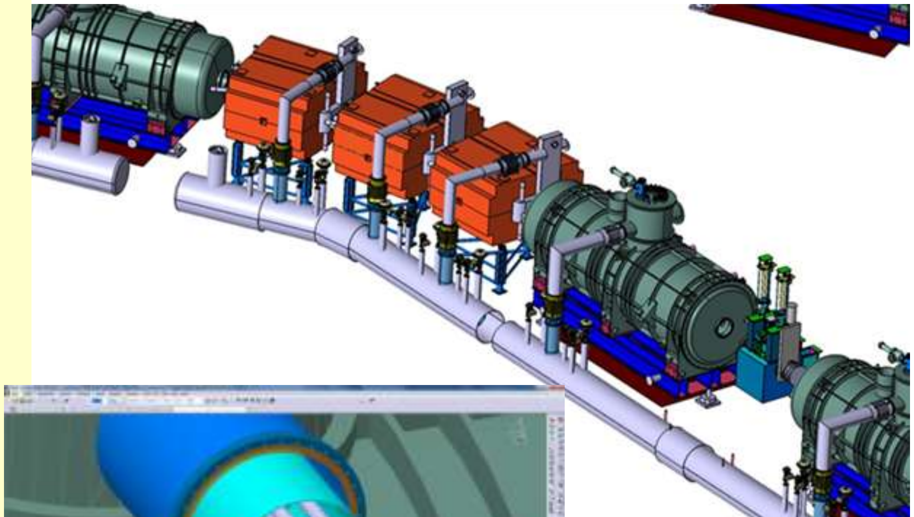


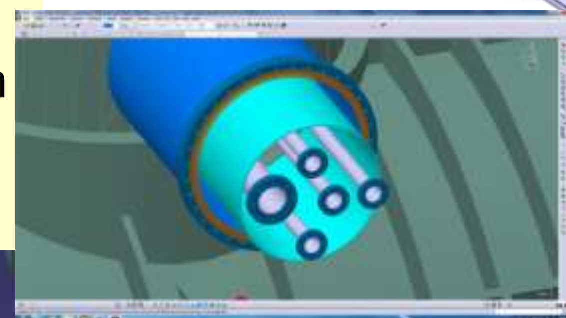


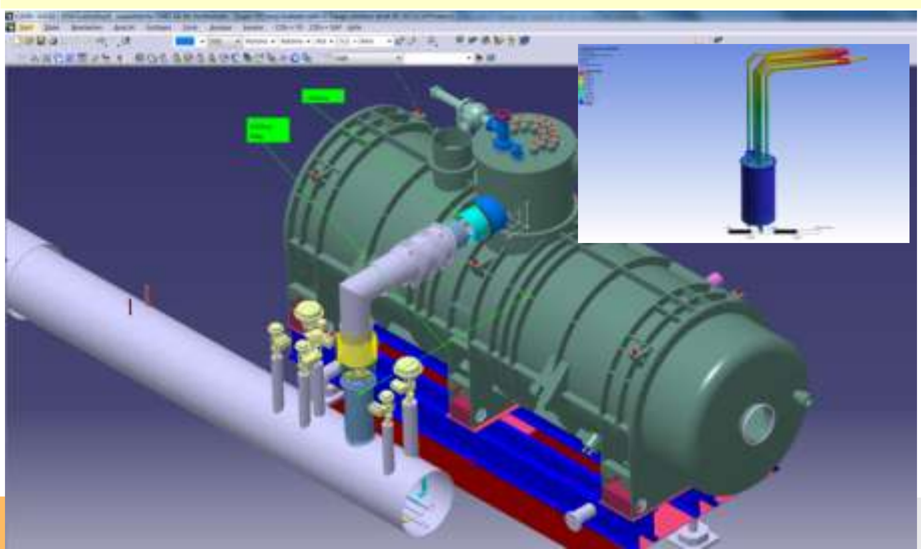
Super-FRS Local Cryogenics

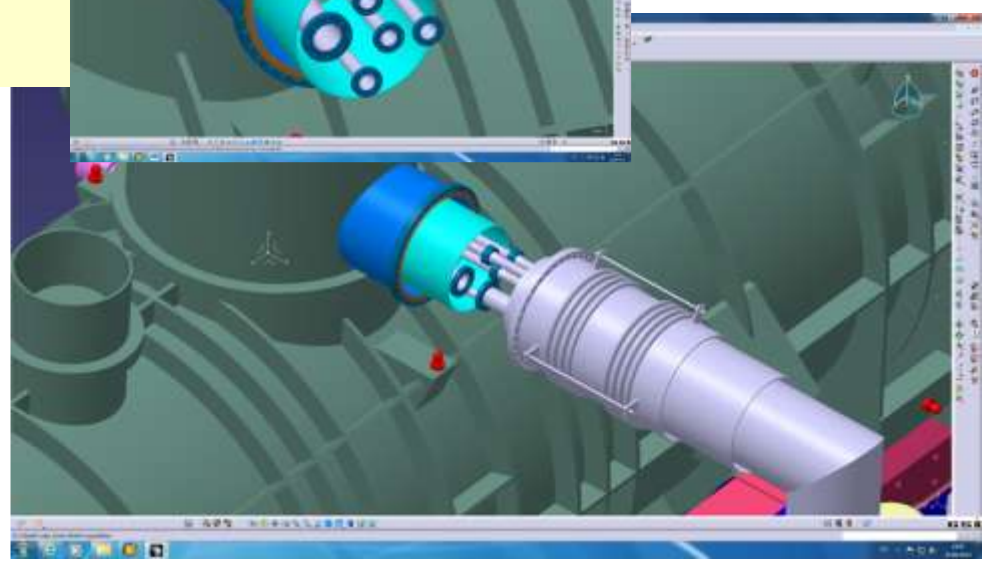
- Flow scheme / Cooldown processes
  - Total cold mass (PS + MS): ≈1.100 ton
  - Cryogenic operation modes
- Revision of feedboxes
- Updates of cryogenic interfaces
- Emergency cases
  - Normal quench → 70% of energy deposited in quench protection system
  - Worst case → full energy in He

  ➔ safety valves/burst disc dimensions





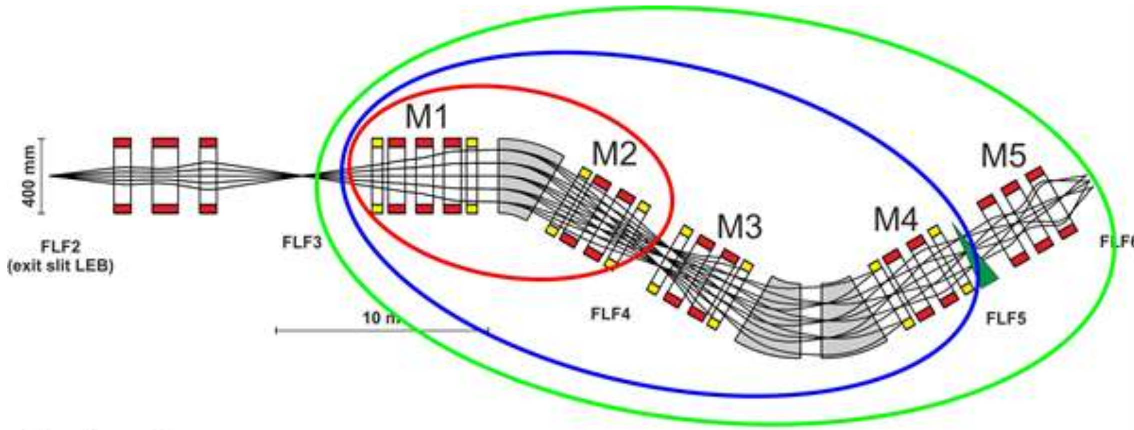




Magnets for Energy Buncher

- Magnets are Indian in-kind,
- Revised parameters defined
- VECC colleague at GSI to finalize magnetic design
- 3 dipole units with 30° deflection angle
  - superferric, warm iron, SC coils
  - challenging: required field quality
  - new design: weight ≈70 ton (old design 115 ton)
- Multiplet: individual magnets as in the separator
- Magnet testing technically possible at CERN

Maximum field	1.6 T
Minimum field	0.15 T
Bending angle	30^0
Radius of curvature	4.375 m
Effective length	2.29 m
Good field aperture - elliptical	± 25 cm (horizontal) ± 7 cm (vertical)
Vertical pole gap	± 8.5 cm
Integrated Field quality ΔB/B	$\pm 1.5\times10^{-4}$
Pole face rotation	0^0
No. of magnets	3



Configuration:
M1: St, Q800, Q800, Q800, Sext
M2, M3, M4: St, Q800, Q800, Sext
M5: Q800, Q800, Q800

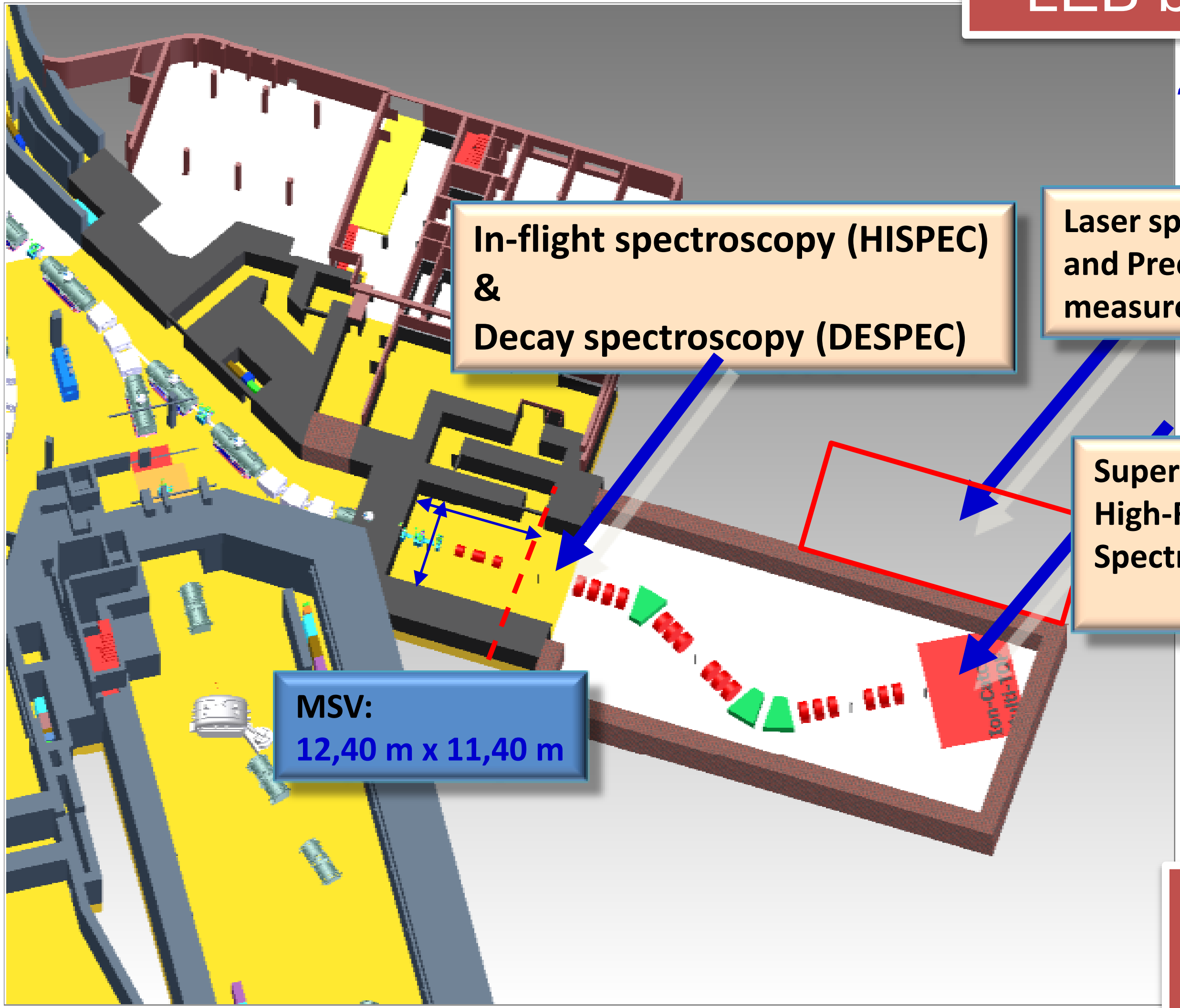
Option 1: M1 and M2
Option 2: Option 1 and M3 and M4
Option 3: Option 2 and M5

DIPOLE MAGNET FOR ENERGY BUNCHER - 2014

Low Energy Branch – involvement of physics community

LEB building not in MSV!

2 feasibility studies by architect office ion42

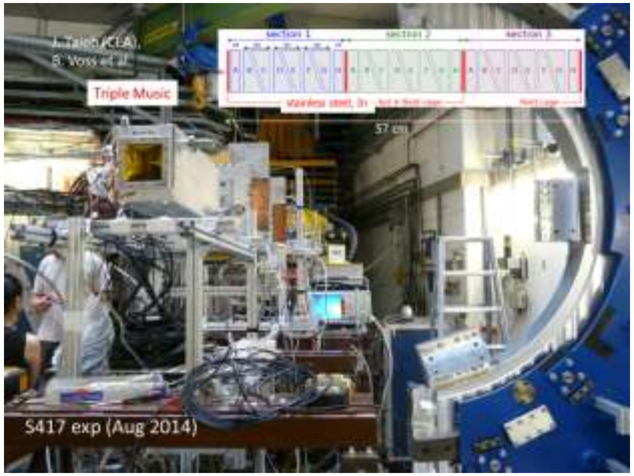


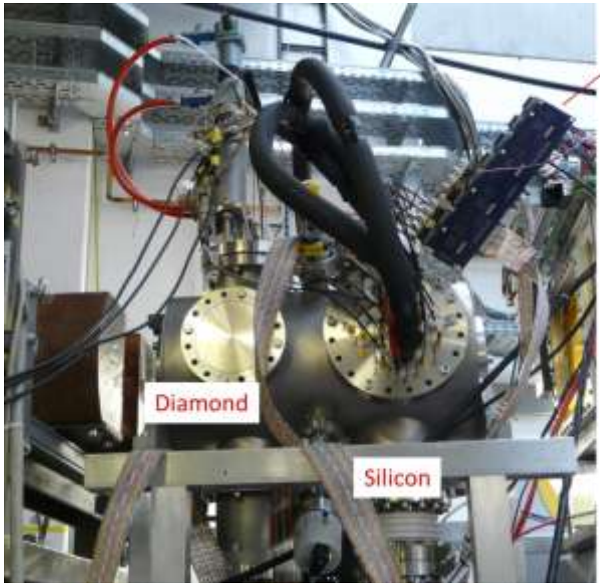
See Talk by Nasser today

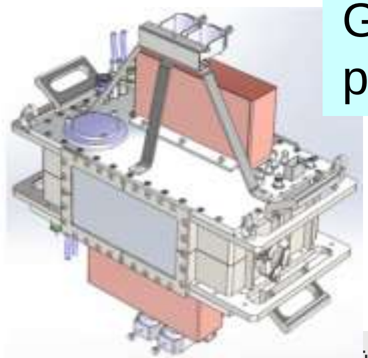
LEB task force very active!

Beam Diagnostics

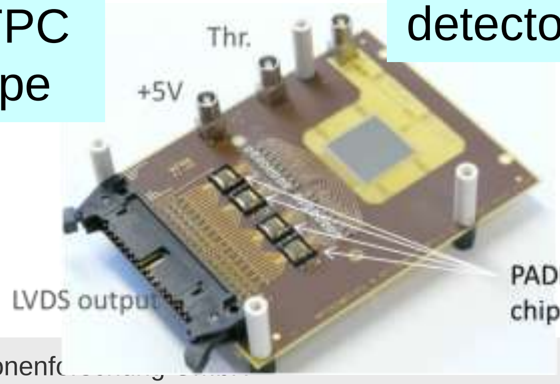
- Full isotope identification (x, y, x', y', DE and TOF)
- Operation modes: fast- and slow-extracted beams
- Special devices (slits, degrader, secondary target, ...)
- Controls → machine safety
- DAQ (in-kind GSI / Sweden)
- Various detector systems
  - GEM-TPC (Finnish in-kind) Test @ GSI 10/2014
  - SEM-GRID & ladder system (Finnish in-kind) "
  - Silicon detectors (EoI Russia) Test @ GSI 08/2014
  - Diamond detectors (EoI Finland) "
  - MUSIC detectors (EoI Finland) Test @ GSI 10/2014
- Various test beam-times at FRS/Cave C





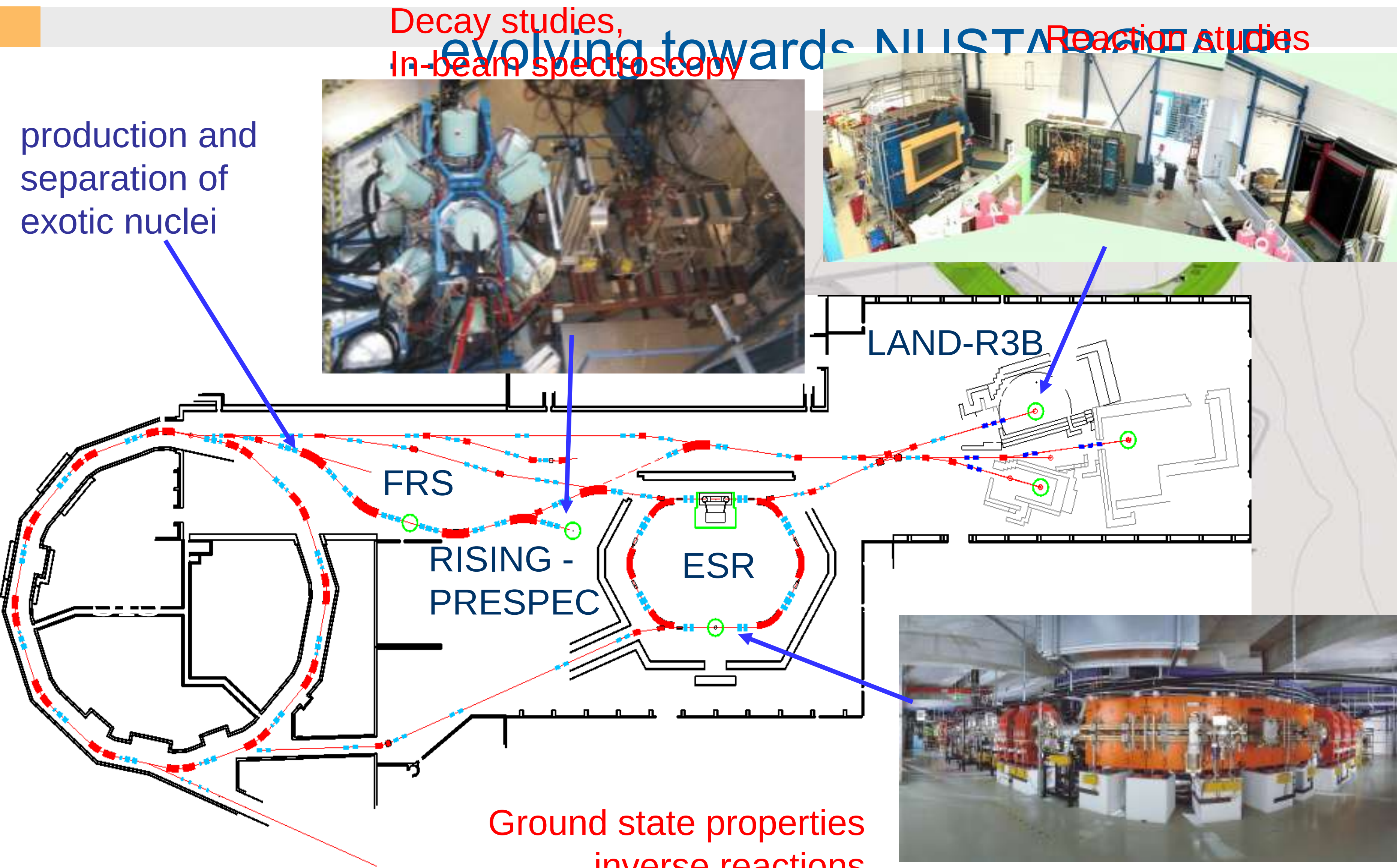


GEM TPC prototype

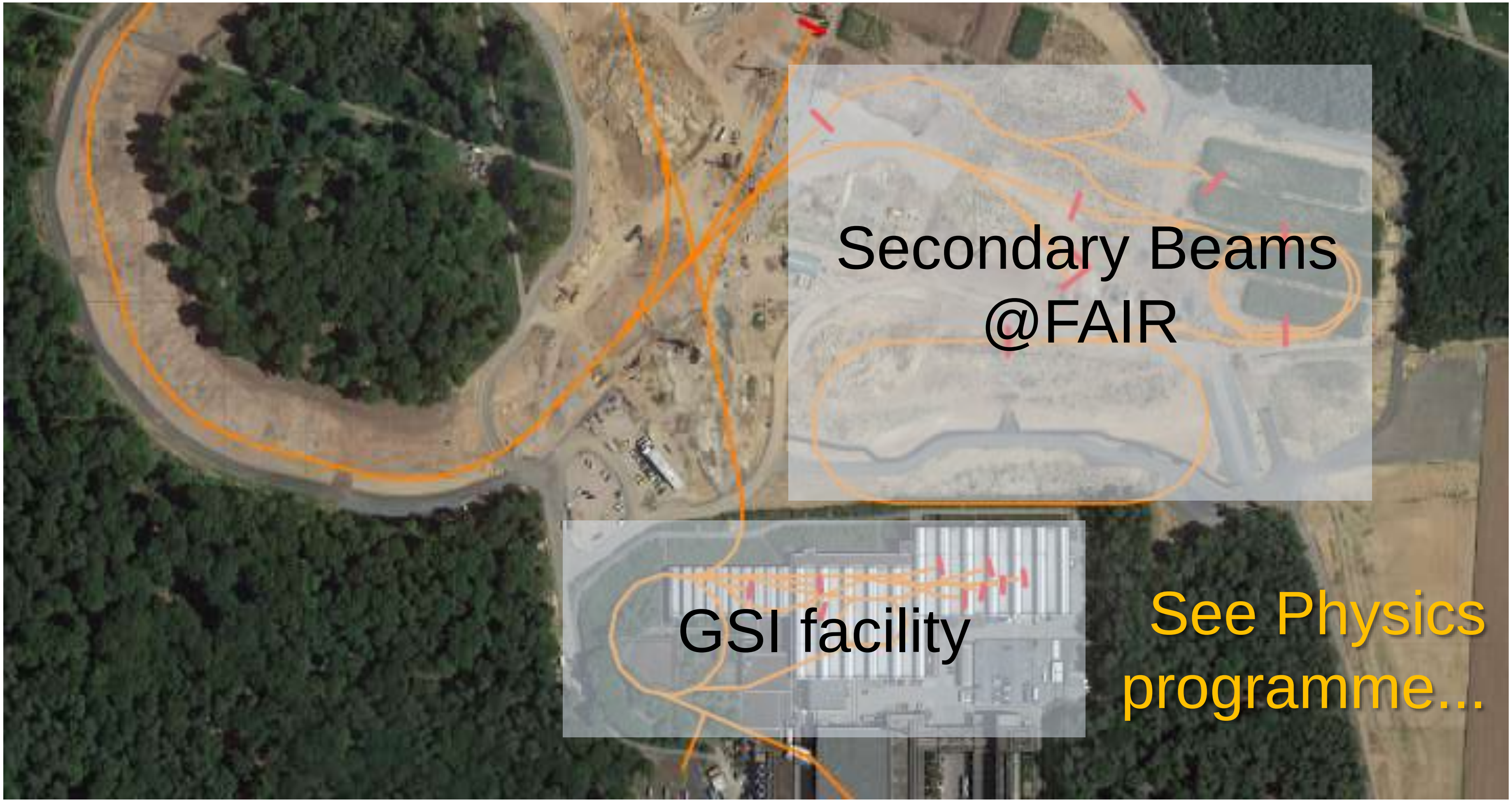


Diamond strip detector

Existing research opportunities at GSI



Areal view of the combined facility



Summary

- ➢ The secondary beam production facilities @FAIR are progressing!
  - – main components are defined and mostly in purchasing process.

- ➢ The facilities @SIS are needed as:
  - – test bench,
  - – for commissioning runs,
  - – and viable experiments with already existing novel instrumentation. (2017+)

- ➢ FAIRs intensities and opportunities are of key importance to maintain international competitiveness.