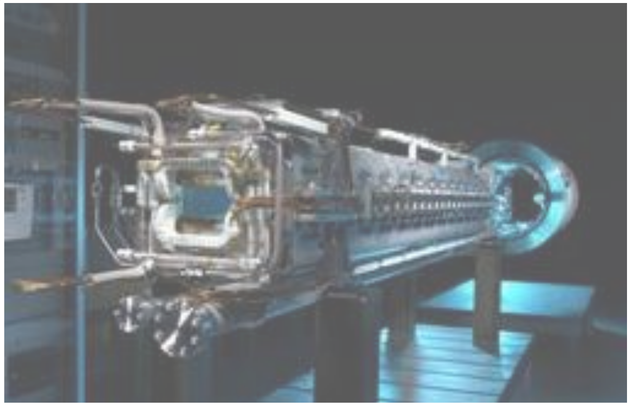
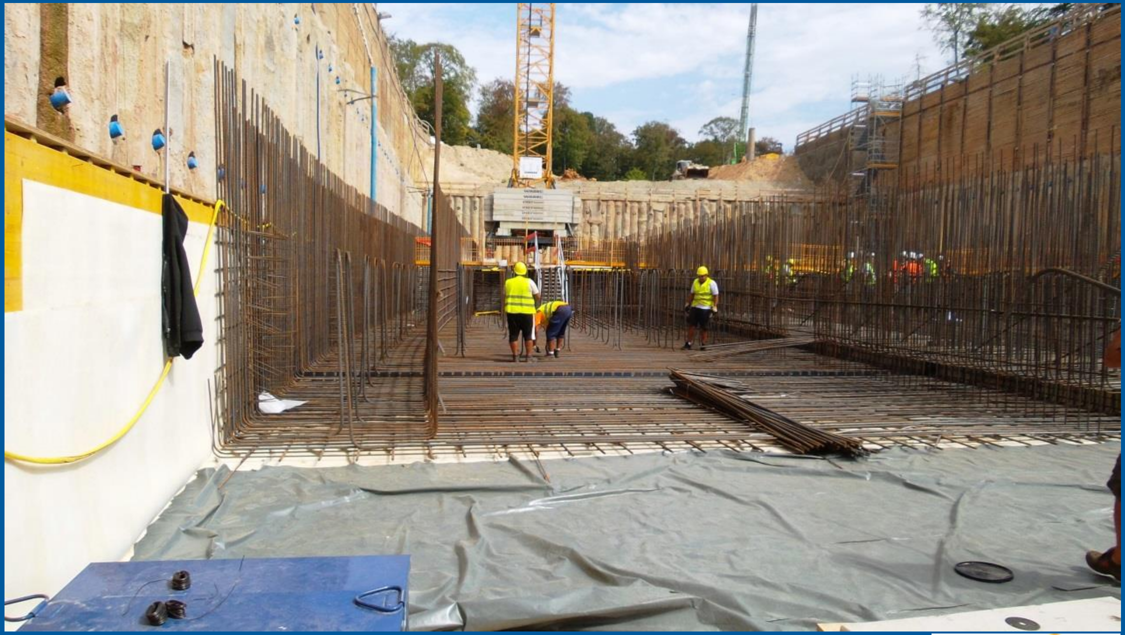




Status of the Super-FRS project at FAIR

H. Simon, M. Winkler,
GSI Darmstadt

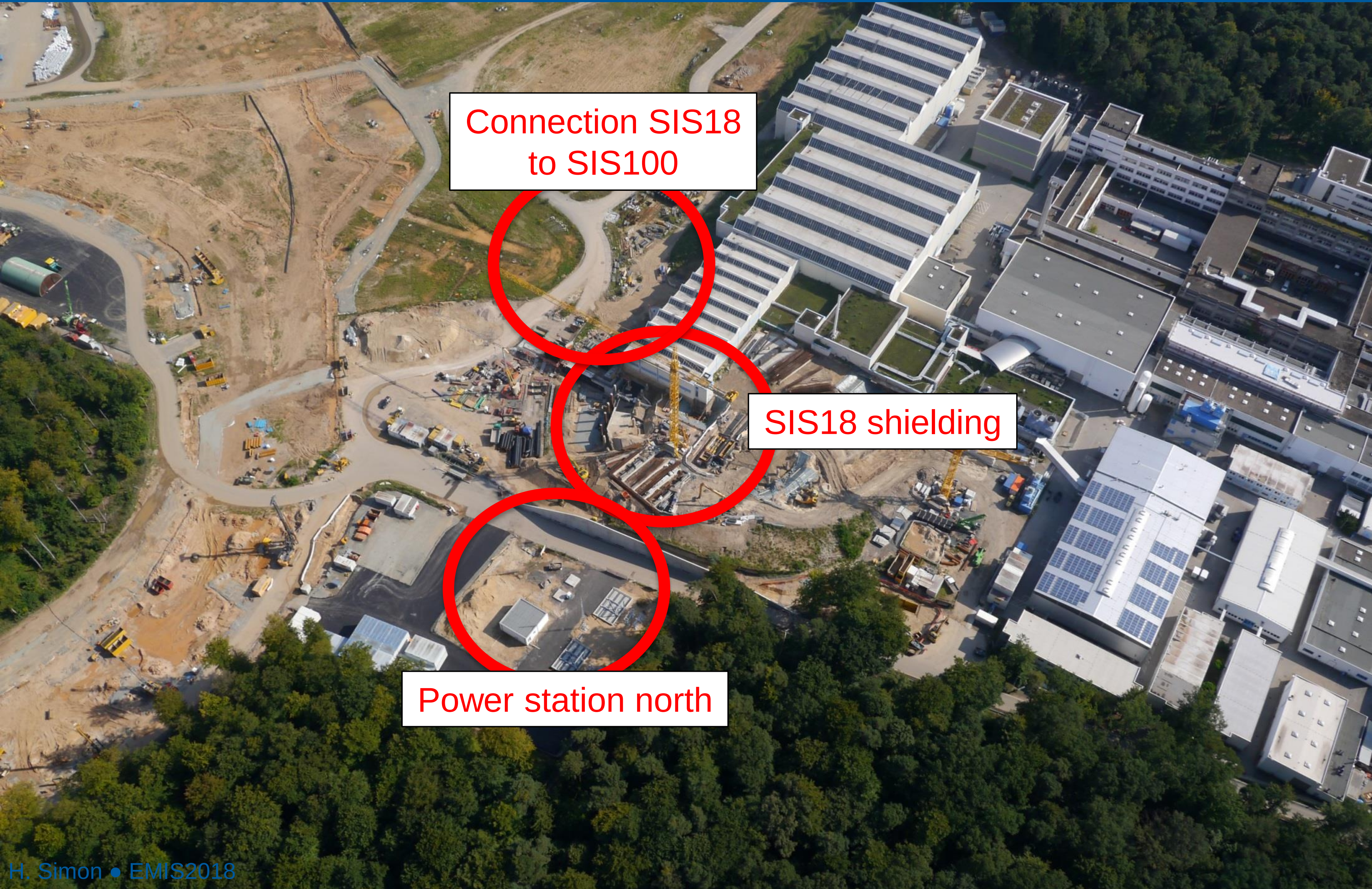


Finland France Germany India Poland Romania Russia Slovenia Sweden UK

FAIR Groundbreaking

(photo: G. Otto, GSI)

FAIR construction

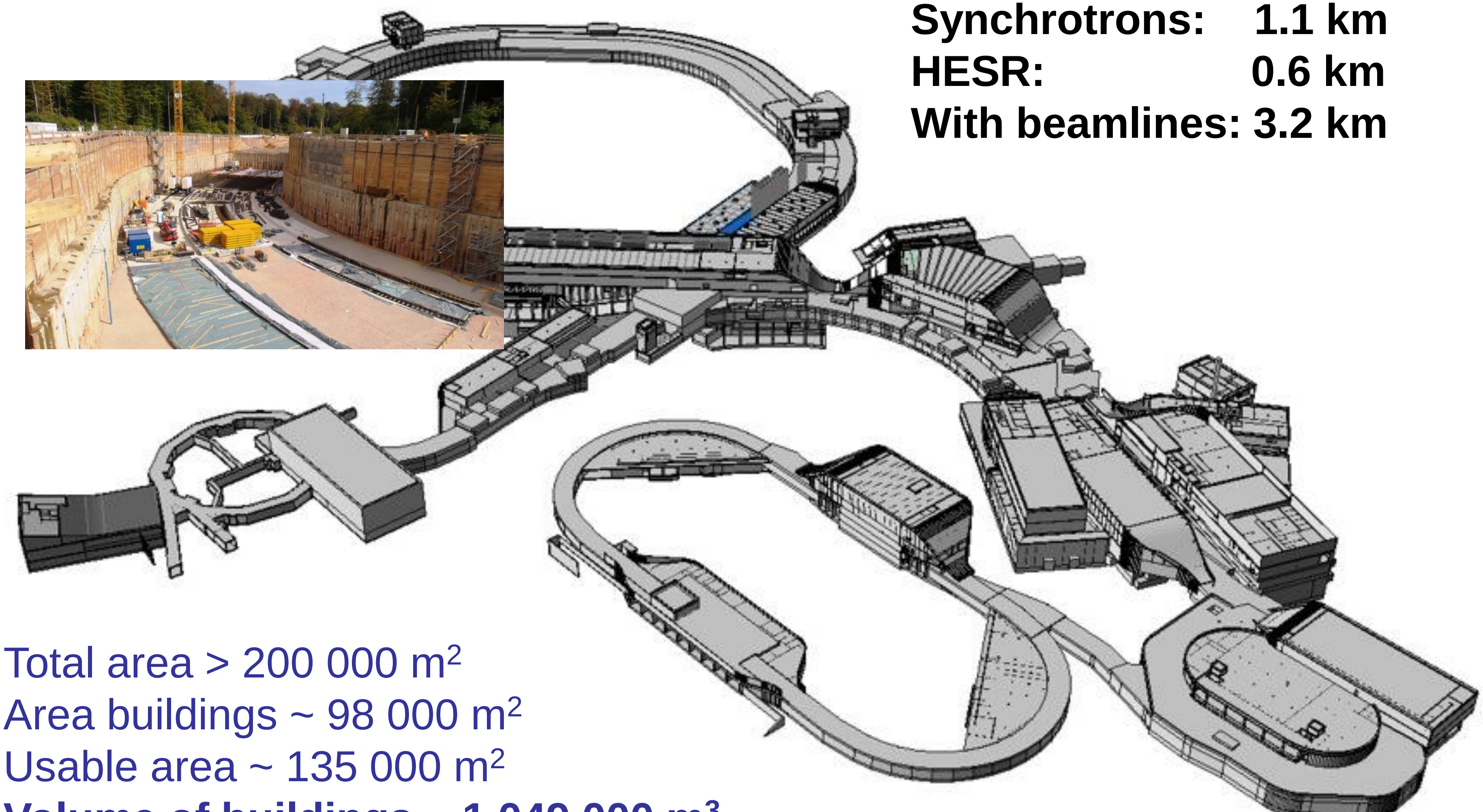


Connection SIS18 to SIS100

(photo: G. Otto, GSI)

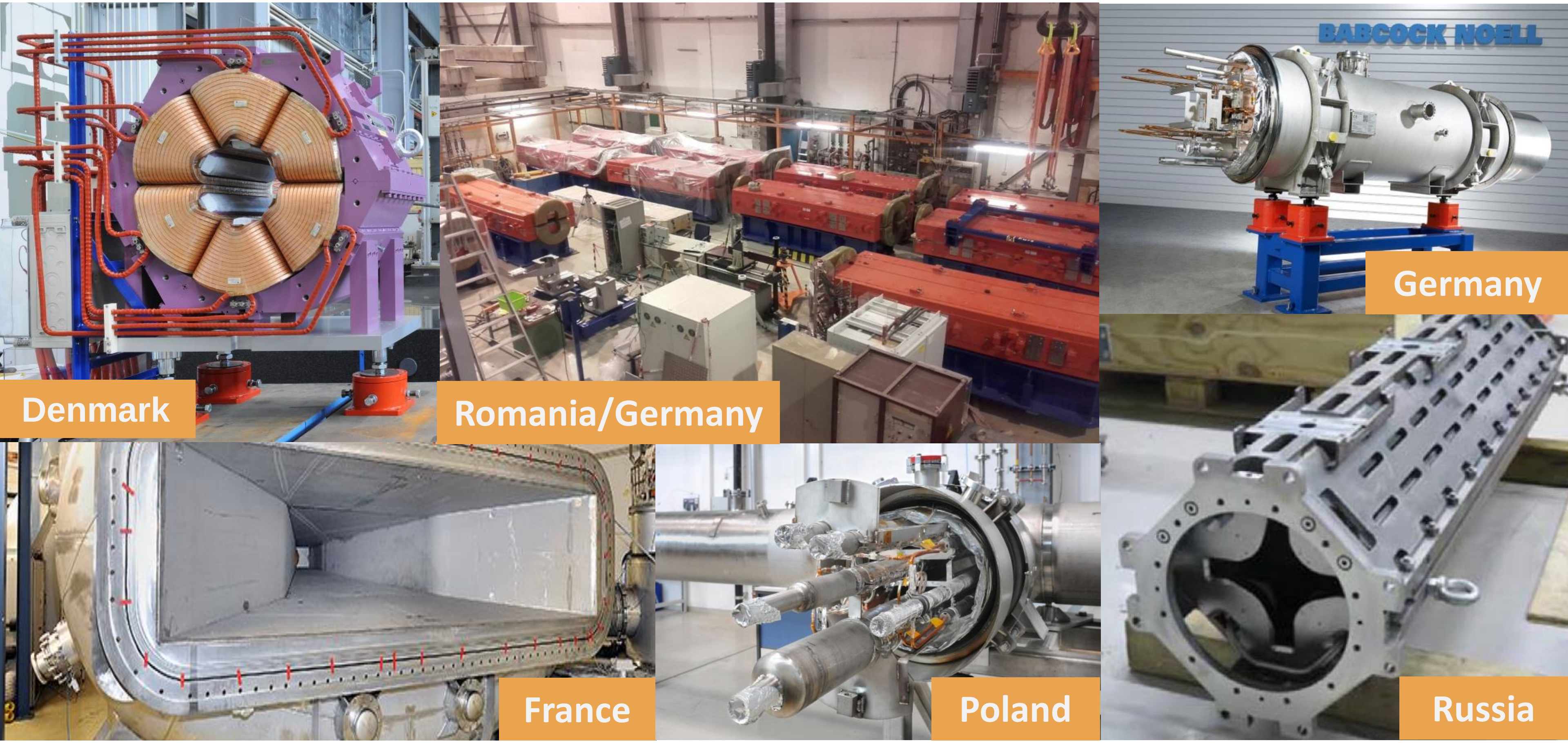
Civil construction: buildings

Synchrotrons: 1.1 km
HESR: 0.6 km
With beamlines: 3.2 km



Total area > 200 000 m^2
Area buildings ~ 98 000 m^2
Usable area ~ 135 000 m^2
Volume of buildings ~ 1 049 000 m^3
Substructure:~ 1500 pillars, up to 65 m deep

Procurement of FAIR accelerator components is progressing well ...



- Accelerator and detector contributions from many different partner institutions

NUclear **S**tructure, **A**strophysics and **R**eactions

FAIR

What are the limits for existence of nuclei?

Where are the proton and neutron drip lines situated?

Where does the nuclear chart end?

How does the nuclear force depend on varying proton-to-neutron ratios?

What is the isospin dependence of the spin-orbit force?

How does shell structure change far away from stability?

How to explain collective phenomena from individual motion?

What are the phases, relevant degrees of freedom, and symmetries of the nuclear many-body system?

How are complex nuclei built from their basic constituents?

What is the effective nucleon-nucleon interaction?

How does QCD constrain its parameters?

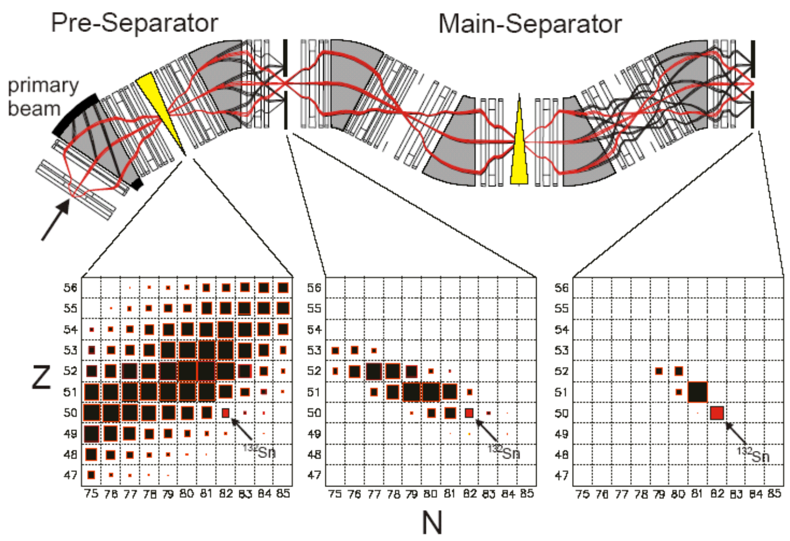
Which are the nuclei relevant for astrophysical processes and what are their properties?

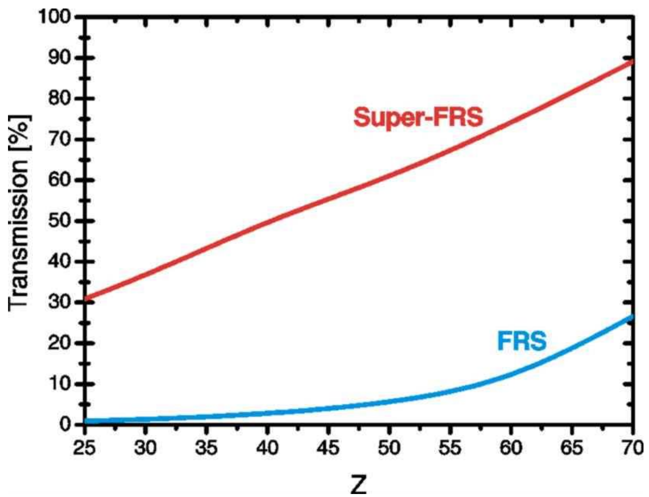
What is the origin of the heavy elements?

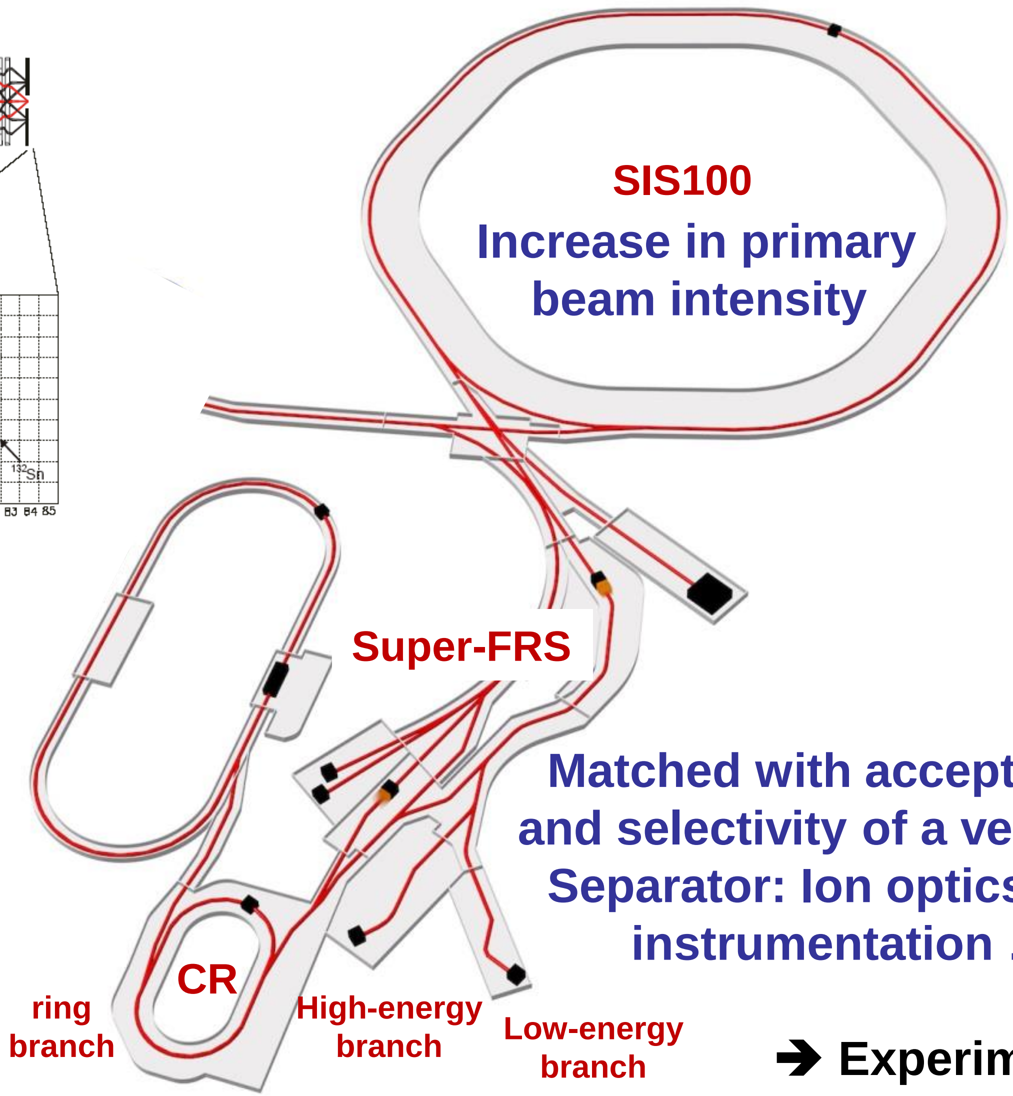
Need for intense secondary beams

➔ Super-FRS

Main Objectives



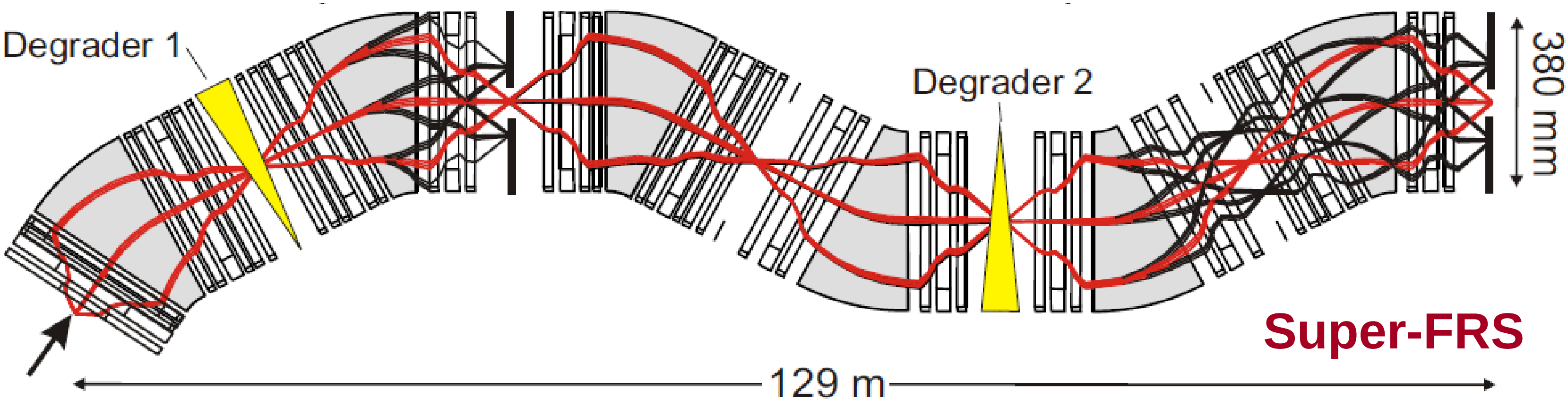


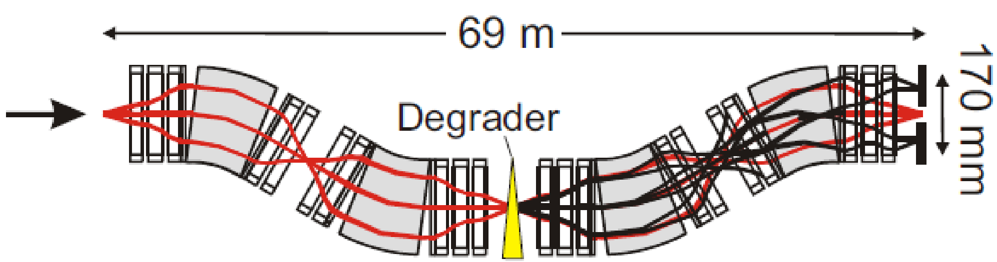


Matched with acceptance and selectivity of a versatile Separator: Ion optics and instrumentation …

➔ Experiments

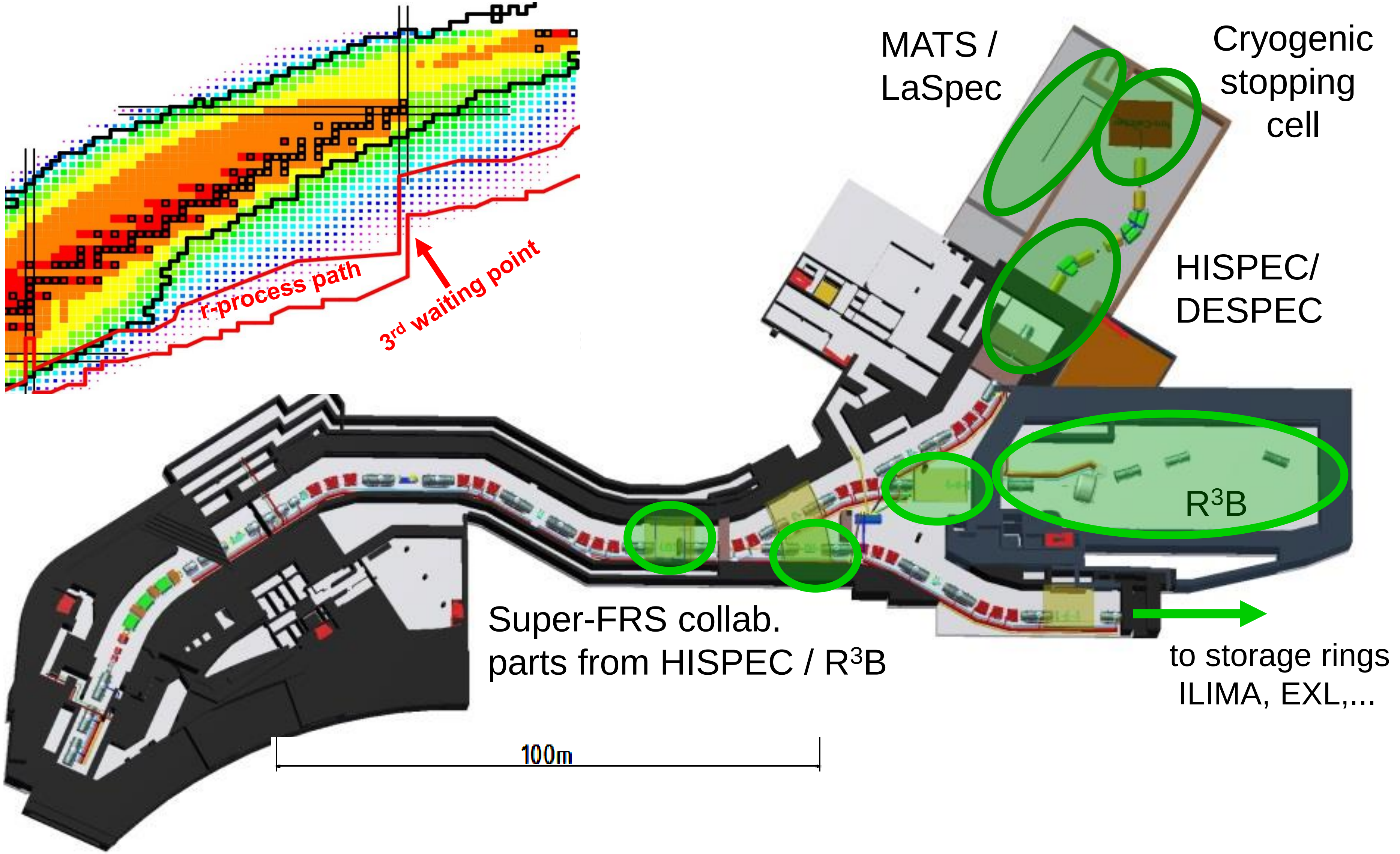
GSI FRS → FAIR Super-FRS





	$B\rho_{max}$	$\Delta p/p$	$\Delta\Phi_x$, $\Delta\Phi_y$	resolving power	gain factor ^{19}C	^{132}Sn
FRS	18 Tm	1.0 %	±13, ±13 mrad	1500	1	1
Super-FRS	**20 Tm**	**2.5 %**	**±40, ±20 mrad**	**1500**	5	10
				including primary rate	1000	7500

Location of experiments



NUSTAR – The project 1.2

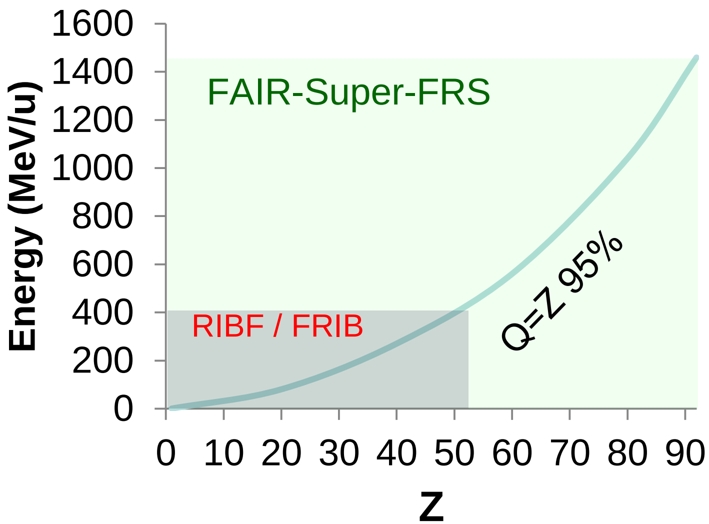
	Super-FRS	RIB production, separation, and identification
PSP	**Experiment**	**Description**
1.2.2	**HISPEC/ DESPEC**	In-beam γ-spectroscopy at low and intermediate energy, n-decay, high-resolution γ-, β-, α-, p-, **spectroscopy**
1.2.3	**MATS**	In-trap **mass measurements** and decay studies
1.2.4	**LaSpec**	**Laser spectroscopy**
1.2.5	**R^3B**	Kinematically complete **reactions** with relativistic radioactive beams
1.2.6	**ILIMA**	Large-scale **scans of mass and lifetimes** of nuclei in ground and isomeric states
1.2.10	**Super-FRS Exp**	**High-resolution spectrometer** experiments
1.2.11	**SHE**	Synthesis and **study of super-heavy elements**
1.2.8	**ELISe(*)**	Elastic, inelastic, and quasi-free e^--A **scattering**
1.2.9	**EXL(*)**	**Light-ion scattering** reactions in inverse kinematics

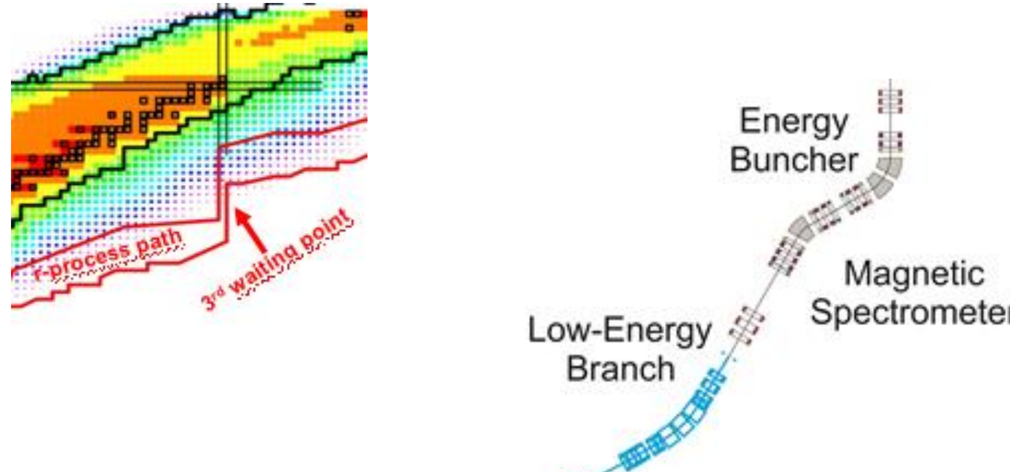
(*) NESR required – alternative/intermediate “operation” within MSV under discussion.
SHE physics case to be evaluated.

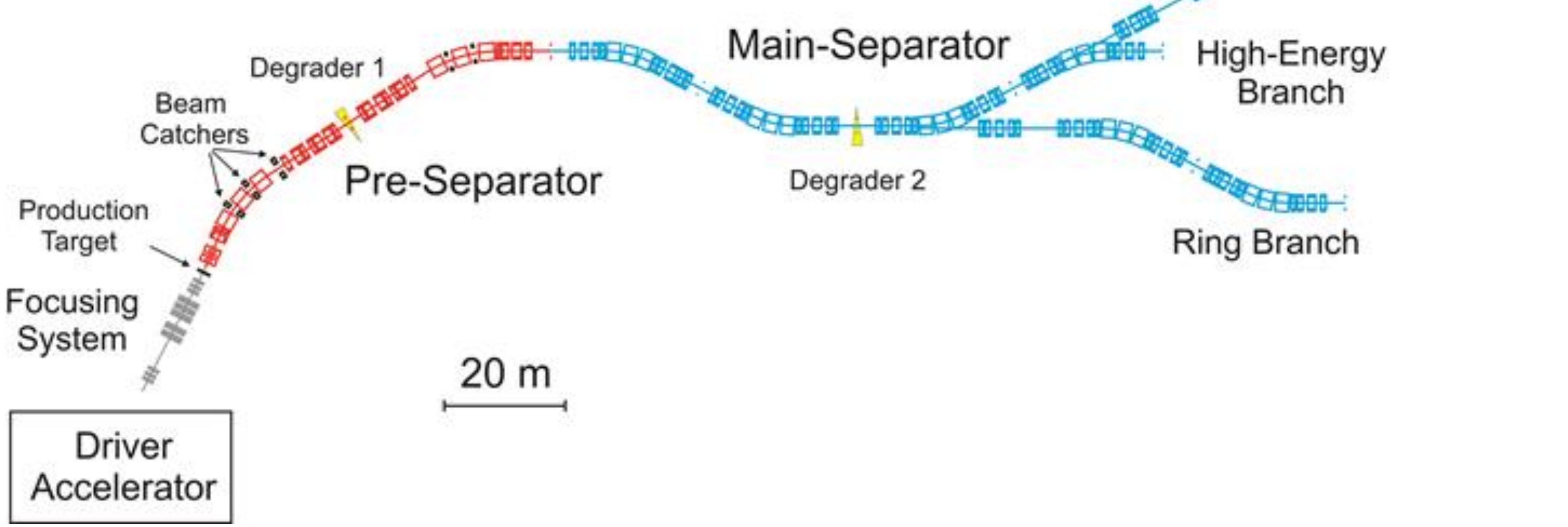
Definition of NUSTAR experiment phases

- **Phase 0 (2019 …)**
  - R&D and experiments to be carried out with present facilities <u>and</u> FAIR/NUSTAR equipment
- **Phase 1 (2025 …)**
  - Core detectors and subsystems completed
  - First measurements with FAIR/Super-FRS beams
  - ➢ **Carry out experiments with highest visibility as part of the core program and within the FAIR Modularized Start Version (MSV)**
- **Phase 2**
  - FAIR evolving towards full power
  - Completion of experiments within MSV
  - ➢ **Essentially the full program of MSV can be performed**
- **Phase 3**
  - Moderate projects, which have been initiated on the way (outside MSV) can be included (e.g. experiments related to return line for rings)
- **Phase 4**
  - Major new investments and upgrades for all experiments

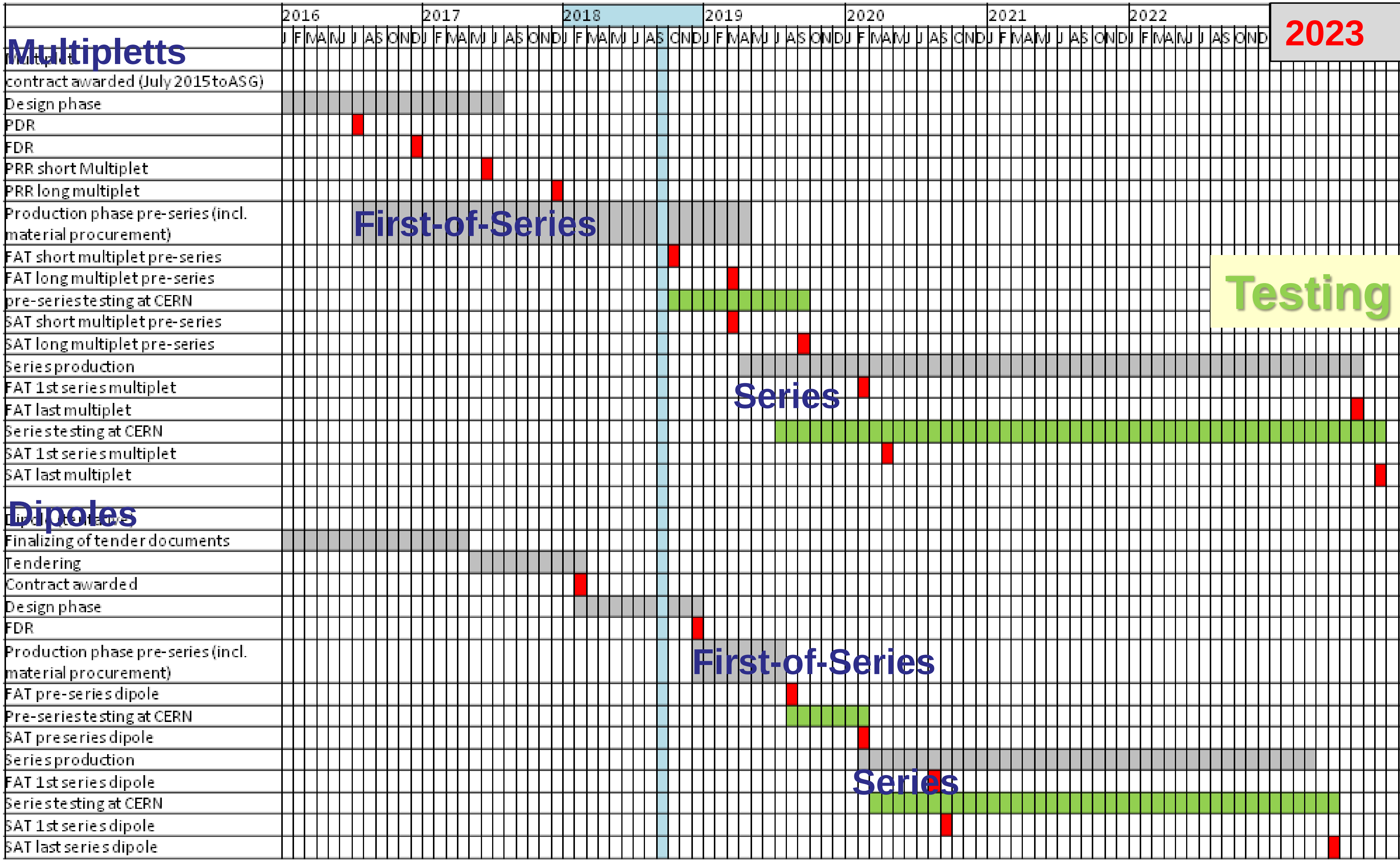
Schematic Layout







Schedule is governed by magnet production



Sc Magnet testing @ CERN

K. Sugita et al.

- Collaboration between CERN and GSI
  - CERN Build. 180: Infrastructures, renovation
- Cold (4K) testing of the SC dipoles and multiplets
  - 3 test benches,
  - incl. magnetic field measurements
- Addendum to collaboration agreement
  - Covering operation phase 5.5 years
  - ✓ **Signed January 2018**
- Facility commissioning ongoing
  - FoS multiplet expected for 10/18

Sc Magnet testing facility

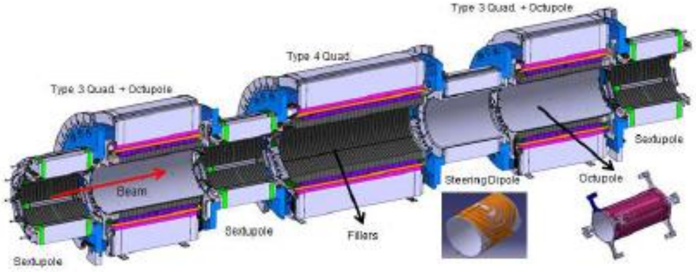
(Bât. 180)

Sc Multiplets, Overview

H. Müller,
E.J. Cho et al.

Scope:

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

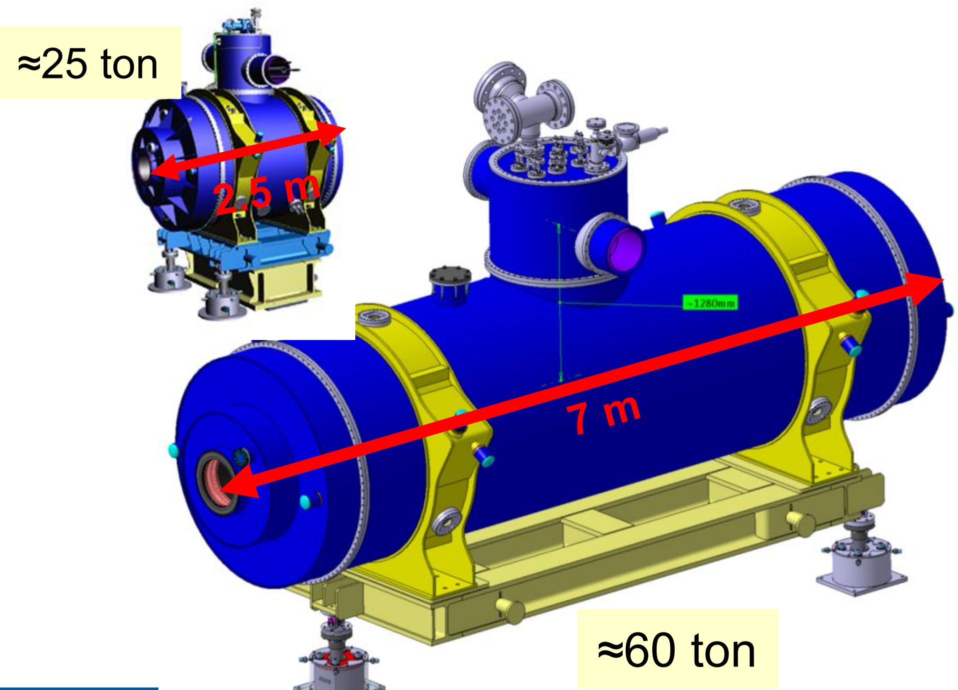


Main characteristics:

- iron dominated, cold iron (up to 37 tons)
- common helium bath
- warm beam pipe (38 cm inner diameter)
- individual powering, max. current <300A

Schedule FoS SC multiplets

- ✓ Contract closed 07/2015 (ASG, Genova)
- ✓ Design phase for SM and LM done
  - ✓ FDR 12/16
  - ✓ PRR SM 07/17
  - ✓ PRR LM 12/17
- **Construction phase for FoS running**
  - ➢ **FAT FoS SM 09/18**
  - ➢ **shipment CERN 10/18,**
    SAT FoS SM 03/19



FOS short Multiplett production

- All coils produced (quadrupol, sextupol)
  - ➢ vacuum impregnated
  - ➢ electrical integrity tests
- Laminations punched (sub-provider)
- Yoke assembly tool manufactured
- Yoke assembled (short quad, sextupole)
- CL prototype qualified (20 bar, M&W)

➢ CL for FoS SM manufactured

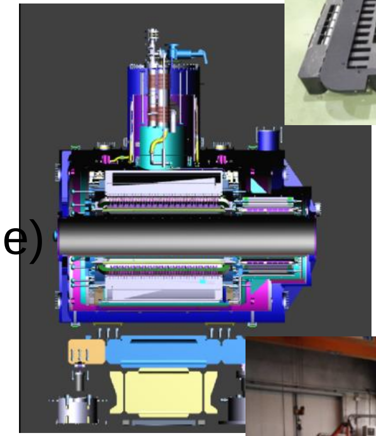
➢ Thermal shield manufactured

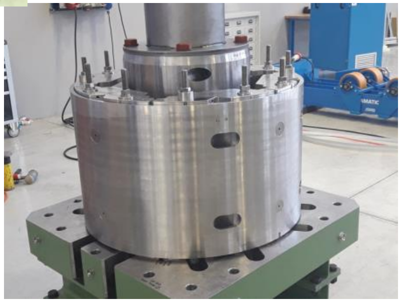
➢ LHe vessel manufactured

➢ Vacuum vessel manufactured

➢ Assembly bench manufactured (subprovider)

➢ **Final assembly ongoing**







Sc Dipole Magnets

H. Müller,
E.J. Cho et al.

Scope

- 3 units 11°, 18 units 9.75° + support
- Warm iron, SC coil
- Aperture ±190mm x ±70mm
- Weight: 50 to 60 ton

Collaboration with CEA, Saclay:

✓ TCC signed , includes:

- ➢ Detailed design, CDR, Spec, 3D Model
- ➢ Technical follow-up

Tender Status :

✓ Announcement published April 2017

✓ Qualifying submission closed mid May 2017

✓ Offers received by mid July 2017

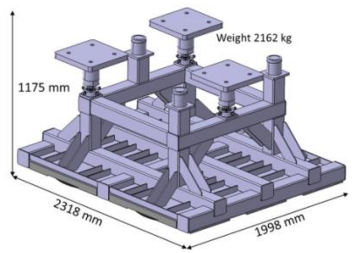
✓ 1st round negotiation closed mid November 2017

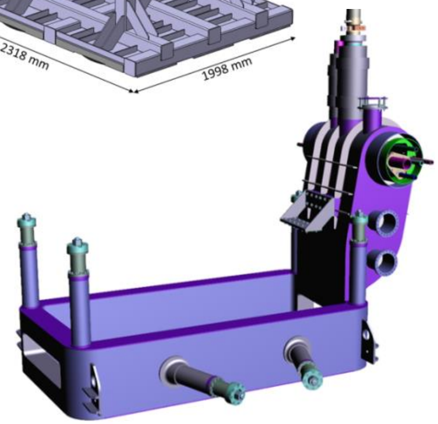
✓ 2nd round negotiation closed Jan. 22, 2018

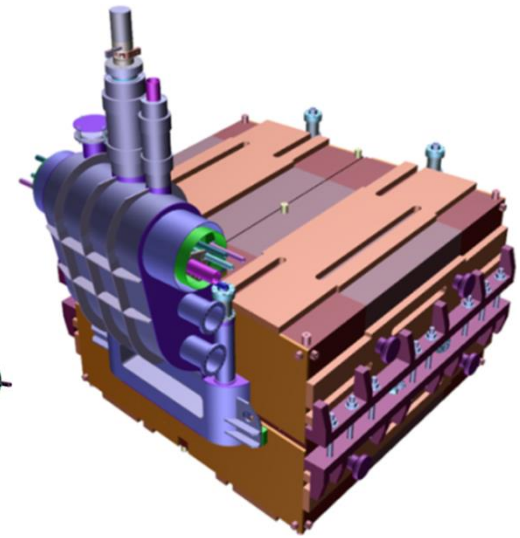
✓ **Contract award Feb. 8, 2018**

✓ **Kick-off: March, 1, 2018**

- **FDR expected Q3/2018**
- **FAT of FoS expected Q2/2019**







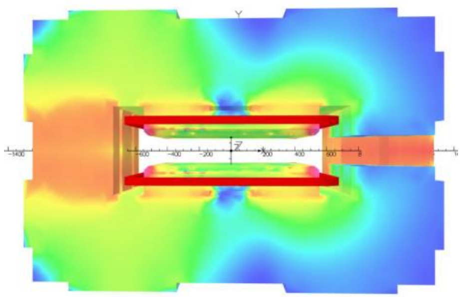
manufacturing plant
ELYTT, Bilbao Spain

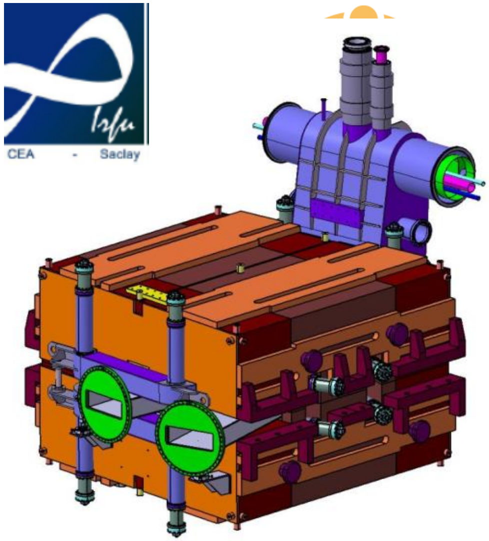
Branching Dipole Magnets

H. Müller,
E.J. Cho et al.

Schedule (R&D work):

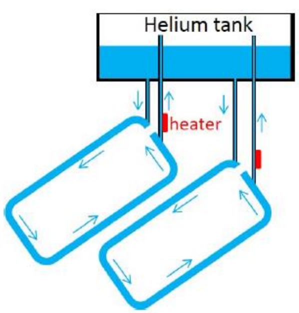
- ✓ Collaboration agreement with CEA/Saclay
  - ➢ Detailed design, CDR, Spec, 3D Model
- ✓ Kick-off meeting 06/2017
- ✓ PDR 12/2017
- ✓ **FDR 09/2018**
- **Final Report, Detailed Specs 10/2018**
- ➢ **FAIR tender directly after**

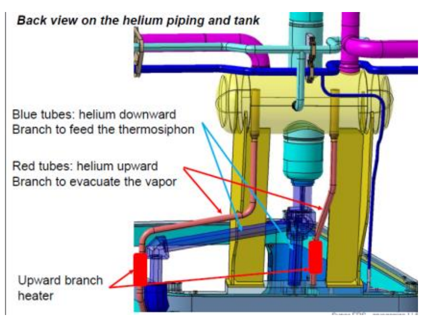


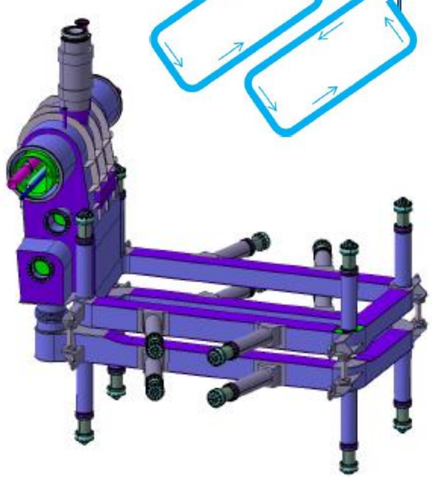


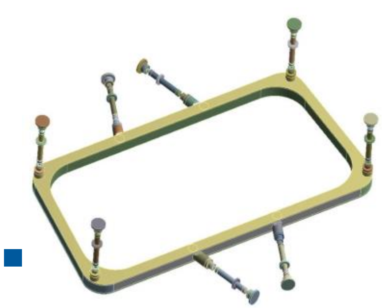
PDR/FDR status

- Geometry (yoke, coil, cryostat)
  - ➢ ∫Bdl achieved, I adopted
  - ➢ magnetic field quality, chamfers included
- Assembly Scenario
- Thermal behavior after cool -down
  2 active thermosiphon loops foreseen
  - ➢ use heaters to force flow direction
  - ➢ design modification done
  - ➢ thermal budget simulated
  - ➢ thermosiphon experimental mock-up
- Magnetic interference
  - ➢ Fringe field evaluated
  - ➢ Interference study started





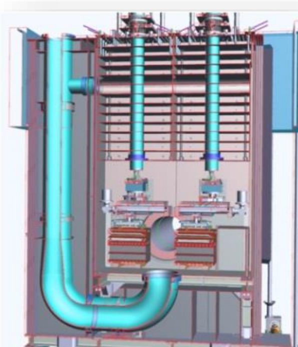


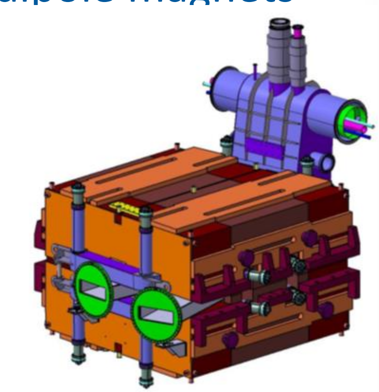


Many systems in progress

Super- FRS

- Production of First-of-Series sc multiplets running
- CERN magnet testing facility ready for operation
- sc standard dipole contract signed (Elytt Bilbao, Spain), CDR done
- sc branched dipole design phse running with (CEA Saclay, France), CDR done
- Quench detection prototype board developed
- Detectors (MUSIC) contract is signed
- FAT of First-of Series y-slits successfully passed
- CDR beam catchers successfully passed
- Handling of target area components (shielding plug concept) verified
- Agreement with BINP to build radiation resistant dipole magnets





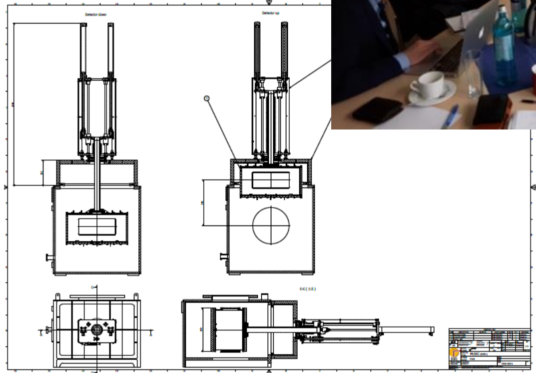
Beam Instrumentation
(e.g. ΔE and ToF)

C. Nociforo
B. Voss,
O. Kiselev, et al.

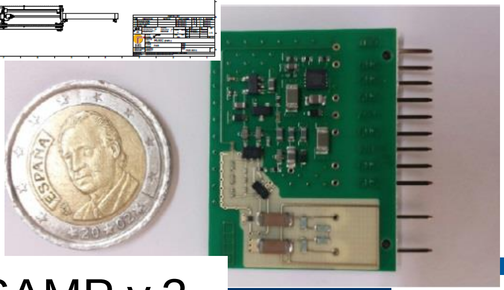
FAIR

- MUSIC (energy-loss, Finnish in-kind)
  - ✓ Specification approved Q1/2017
  - ✓ **1st IKC for Super-FRS signed !**
    - ➢ Field cage subcontracted to GSI
  - ✓ Kick-off meeting done
    - ➢ schematic design presented
    - ➢ schedule for design phase and FoS development agreed (ready Q3/19 → beam test if possible)
  - ○ PreAmps by CEA Bruyeres
    - ➢ successfully tested at beam time in 2016
    - ➢ contract waiting for signature (CEA)

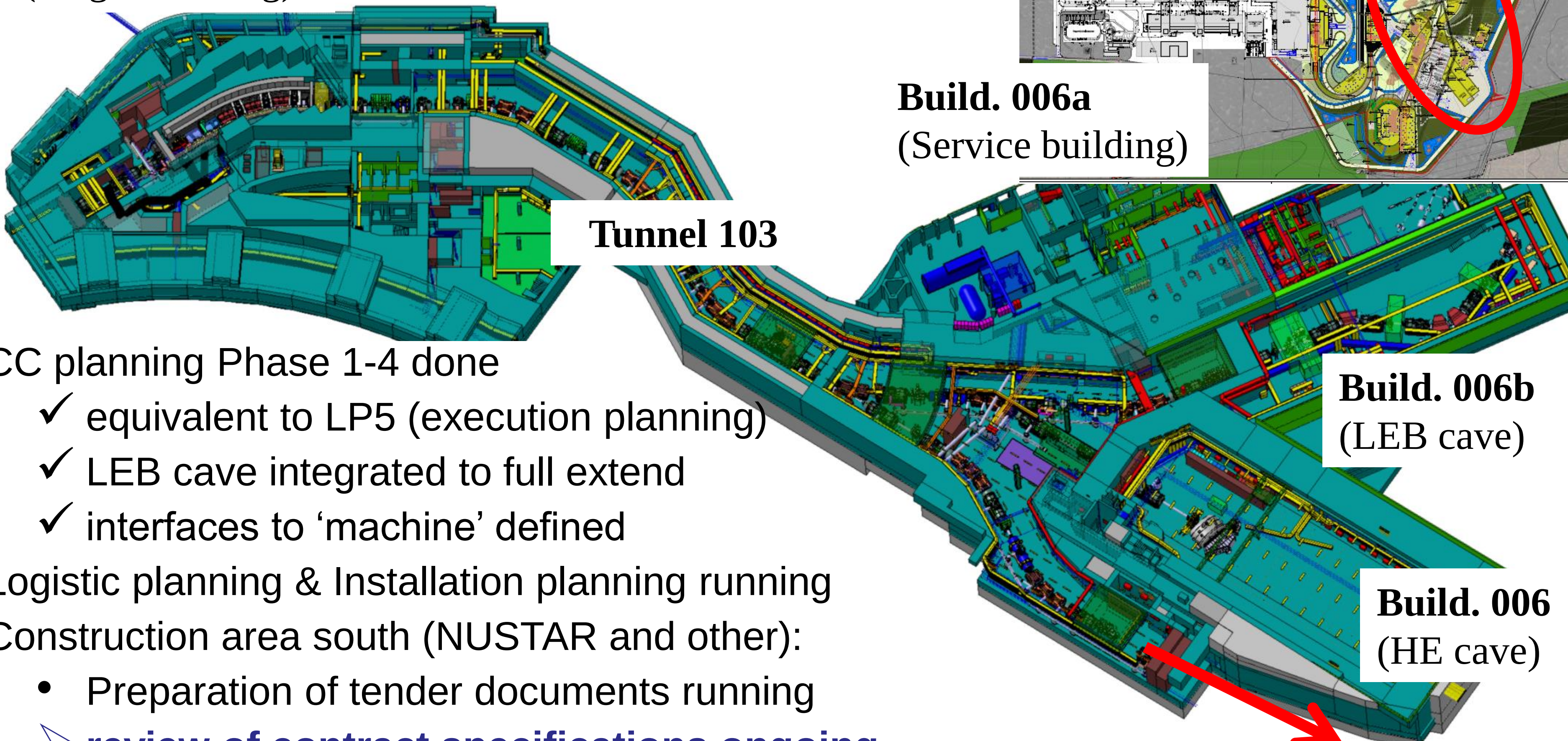
UNIVERSITY OF JYVÄSKYLÄ
JYVÄSKYLÄN YLIOPISTO



- Time-of-Flight (Russian in-kind, IOFFE StP)
  - ✓ Specification approved Q3/2016
  - ✓ IKC drafted Q3/2017
  - ➢ Responses from IOFFE 02/17 & 08/18, many proposed changes, still under negotiation
  - • R&D on diamond and silicon ongoing


MUSAMP v.2

Civil Construction
(Overview)



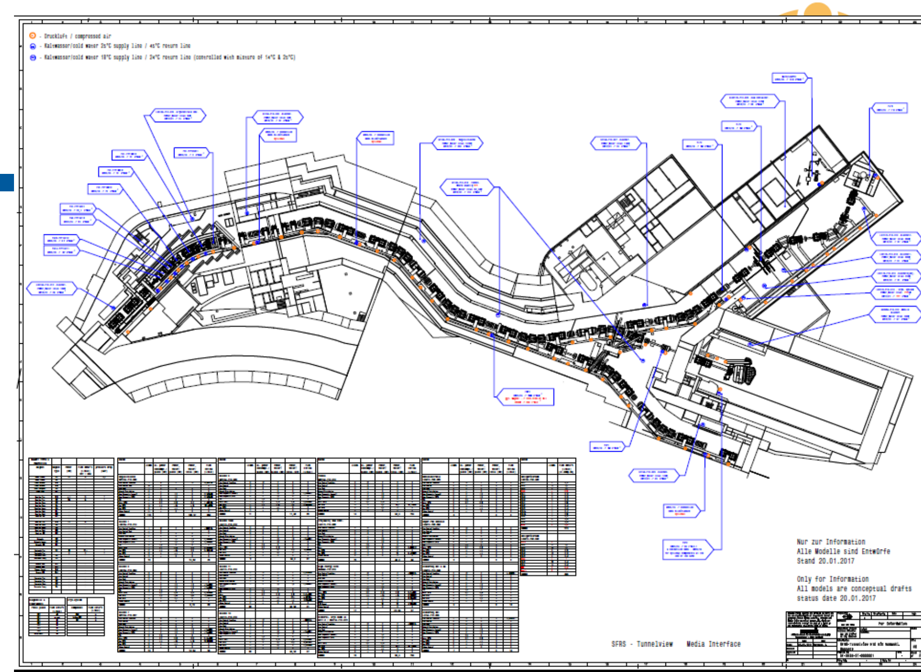
CC planning Phase 1-4 done
- ✓ equivalent to LP5 (execution planning)
- ✓ LEB cave integrated to full extend
- ✓ interfaces to ‘machine’ defined

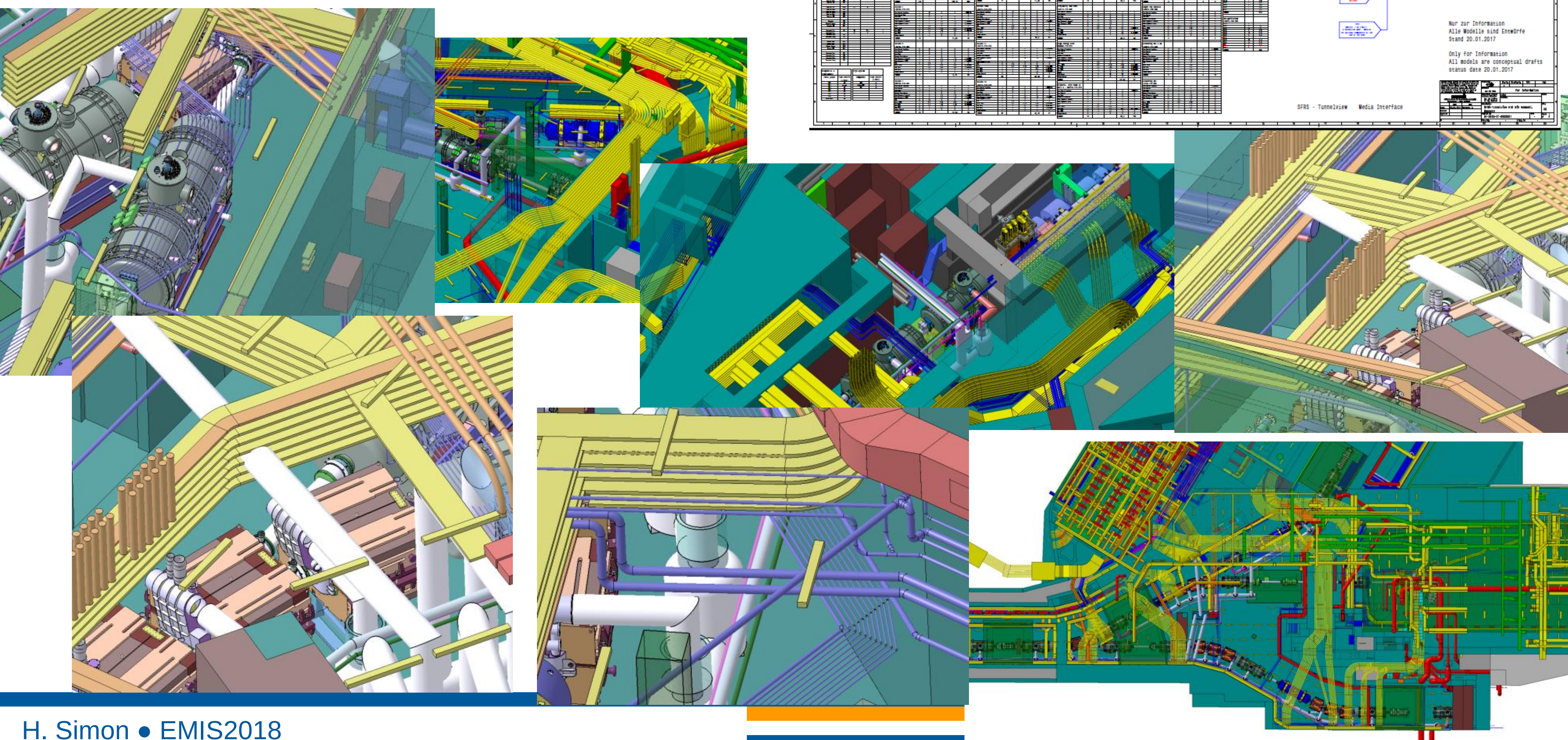
Logistic planning & Installation planning running

Construction area south (NUSTAR and other):
- Preparation of tender documents running
- ➢ **review of contract specifications ongoing**
- ✓ **partly tender already running (e.g. conveyor tech.)**

Civil Construction
(Building services)

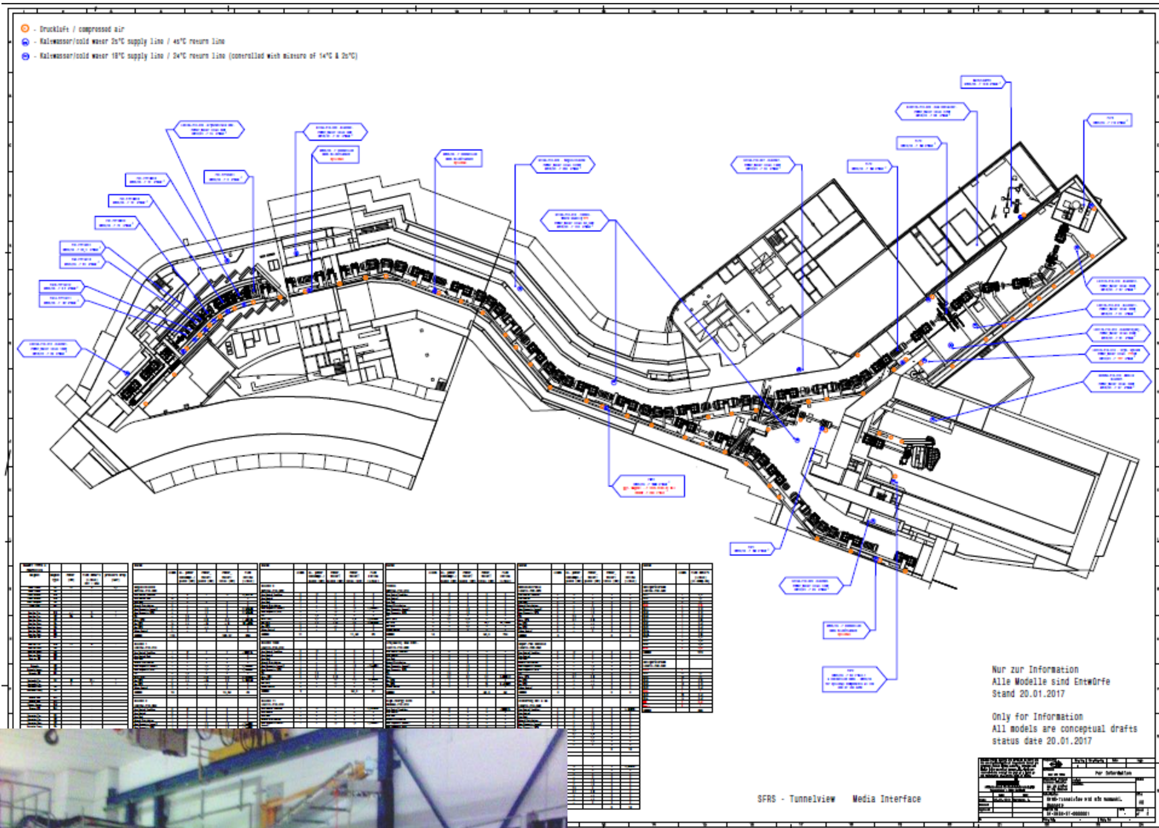
- ✓ Complex technical building infrastructure!
  - ➢ Cable data base updated 09/17
  - ➢ Power & ventilation demands finalized
  - ➢ Collision checks done

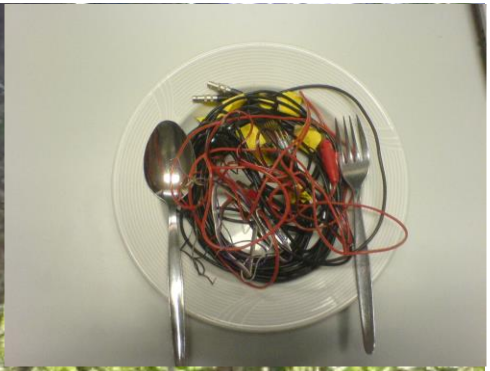




Cable cost become sizeable (hundreths of km)!

Inconvenient cable path length.





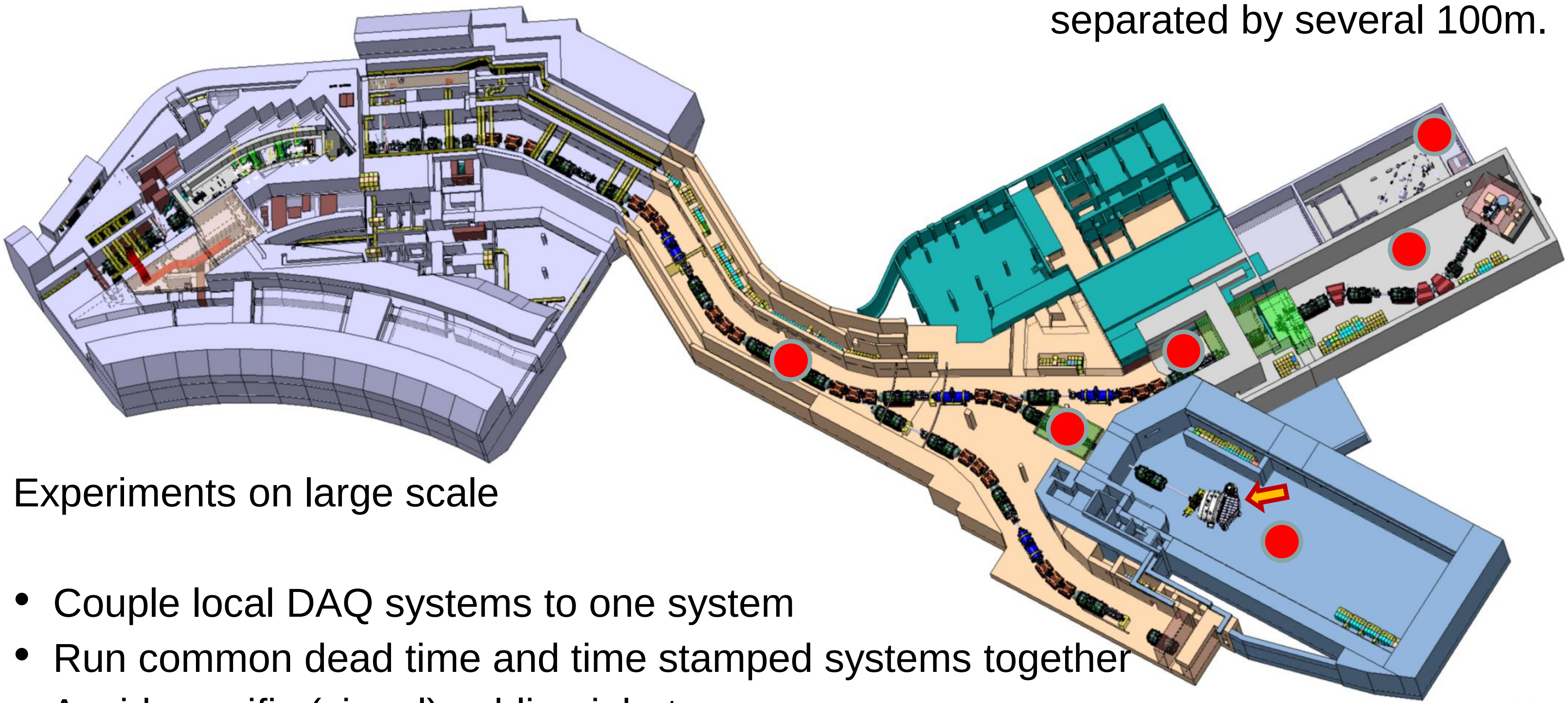
Avoid Cabling to single Central DAQ System➔

Distributed System

Super-FRS and experiments @ FAIR

NUSTAR DAQ TDR accepted 2018 by ECE
https://edms.cern.ch/document/2024803/1

Experiment Areas („Caves“) separated by several 100m.



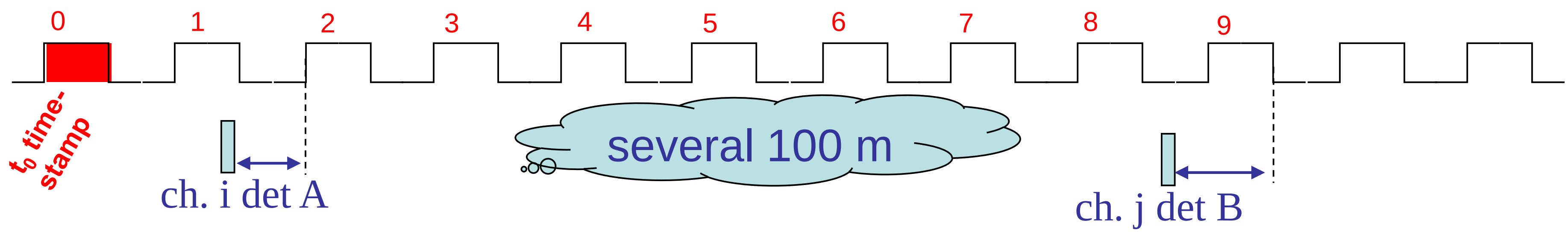
Experiments on large scale

- Couple local DAQ systems to one system
- Run common dead time and time stamped systems together
- Avoid specific (signal) cabling inbetween caves

➔Collector Ring

White Rabbit time distribution

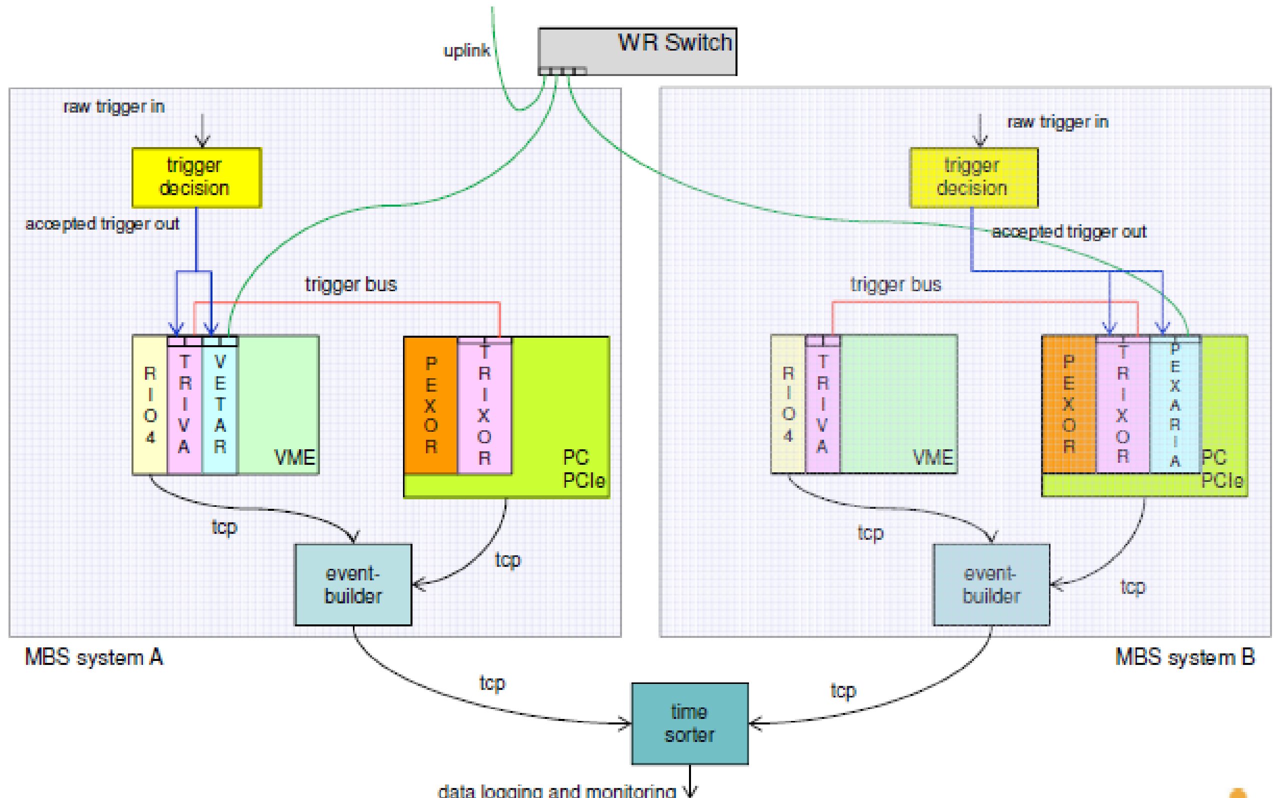
timestamps and reference clocks for ToF meas.



Precision clock Distribution

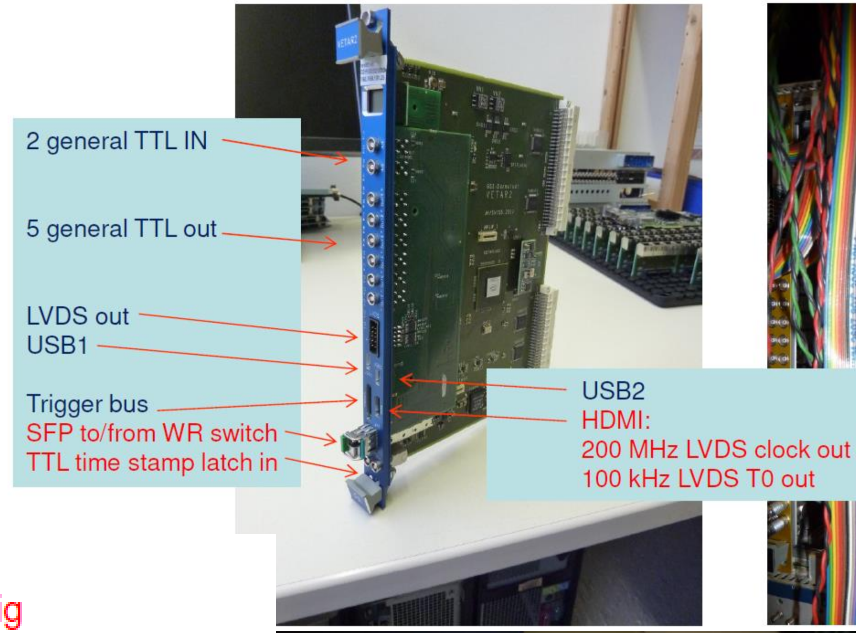
and

event stamping
(Example MBS, N.Kurz)



White Rabbit time distribution timestamps and reference clocks.

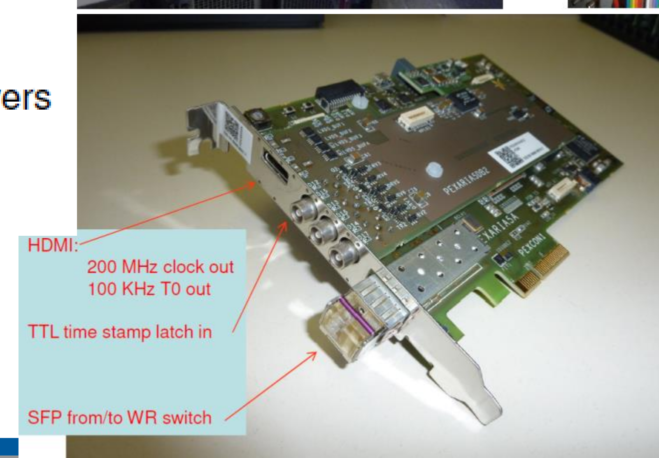
R³B @ Cave-C (phase-0)



White Rabbit core team:

D. Beck, M. Kreider, C. Prados, S. Rauch,(W. Terpstra,)M. Zweig

EE:	Jan Hoffmann:	Design of White Rabbit Timing Receivers
	Joern Adamczewski-Musch:	Linux device drivers
	Jochen Fruehauf:	VFTX, MBS TOF setups
	Nik Kurz	System Integration (MBS)

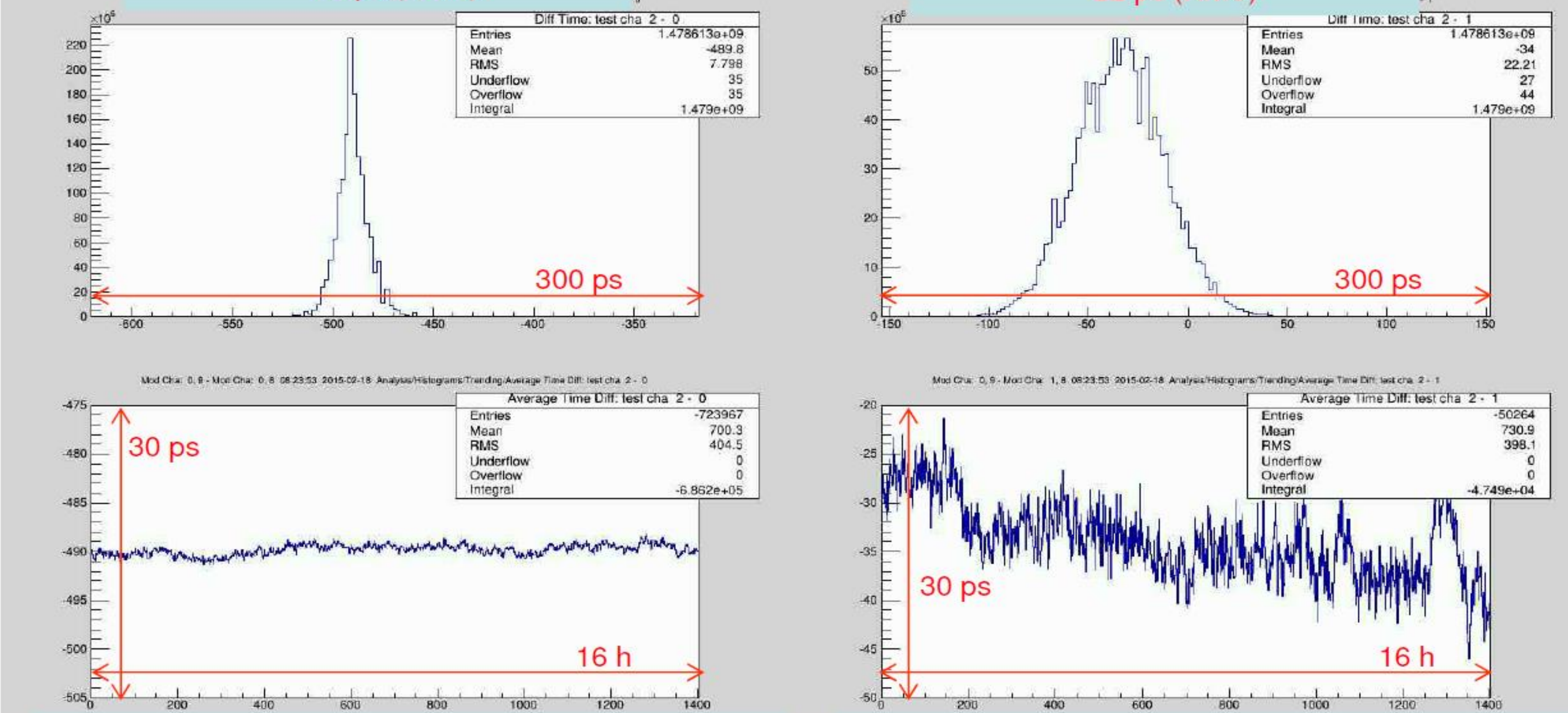


Open Hardware open firmware

System Check:
WR timestamps/clock & FPGA TDC (VFTX)

time difference between 2 channels fed in identical VFTX: 7.8 ps (RMS)

time difference between 2 channels fed in different VFTX: 22 ps (RMS)



trending of average time differences between 2 channels fed in identical VFTX (each entry is average of 1000000 TOF measurements

trending of average time differences between 2 channels fed in different VFTX (each entry is average of 1000000 TOF measurements

Firmware for measurements

FPGA TDCs with many applications

The 10-ps Wave Union TDC:
Improving FPGA TDC Resolution beyond Its Cell Delay
Jinyuan Wu and Zonghan Shi
IEEE Nuclear Science Symposium Conference Record, 2008. NSS '08.

In particular useful for our community

- COTS (limited ASIC developments – PADI preamp./disc.)
- Firmware can be ported to newly appearing hardware
- excellent resolution allows for ToT measurement with good A/QDC performance – Multihit capability !!!

Application:
Sci. Based ToF/ΔE system for RIBs

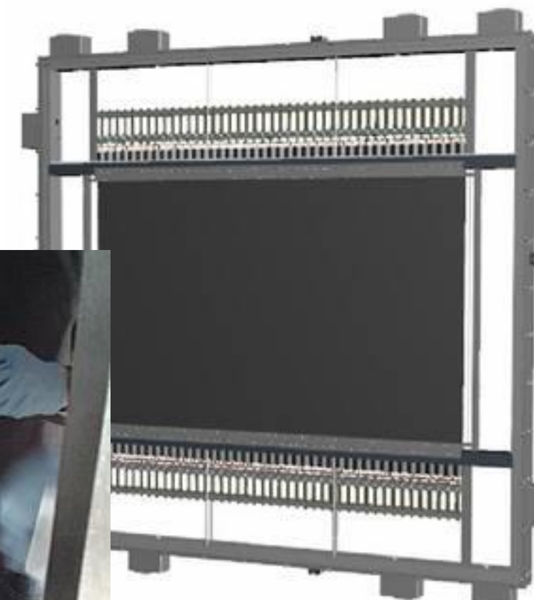
Performance:

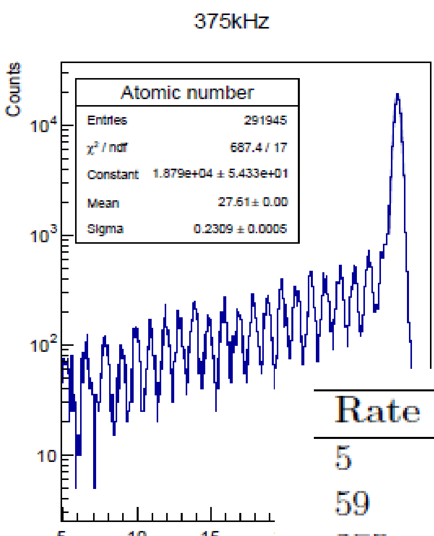
- Time resolution σ_t/t = 2E-4
  (⇔ σ_t =20 ps for 20 m flight path at 1 *A*GeV)
- Energy resolution σ_E /E = 1%
- High-counting rate capabilities (~1 MHz)
- Large dynamic range (up to Pb-U).
- FPGA based TDC readout (ΔE via ToT Techniques)

M.Heil et al.

- Size: 120 x 100 cm^2
- No light guide, PMT R8619 coupled directly to scintillator

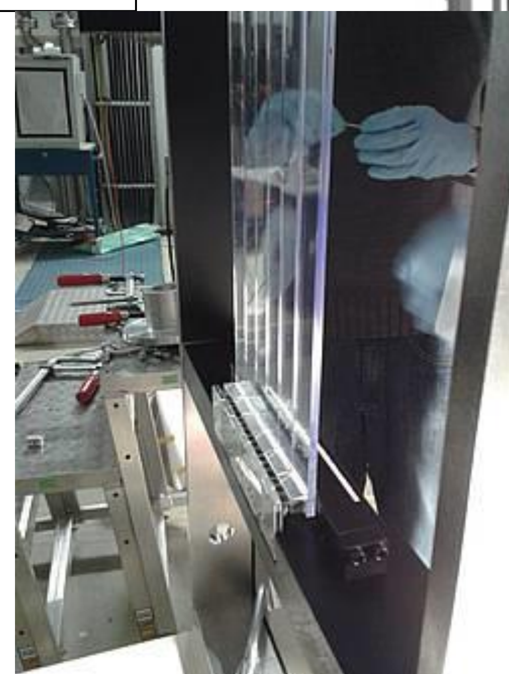
Detector layout





Excellent time and energy resolution at highest rates (multihit time meas.)

Rate / kHz	σ_t / ps	σ_t^{det} / ps
5	41	14
59	41	14
375	45	16
1000	64	23



Prototype studies R³B @ Cave-C 2014/2016

Summary

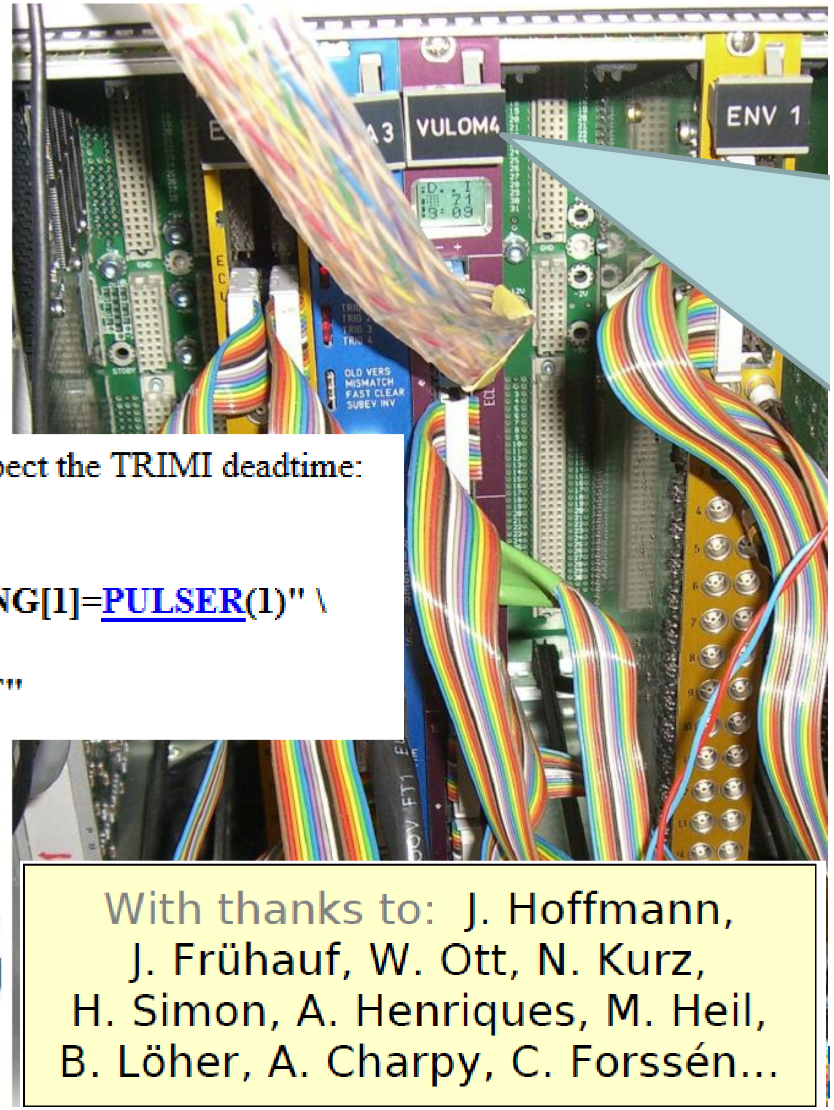
- Civil Construction of FAIR facility has started
- Project in full swing, major components in procurement phase
- SC Magnets & Testing (most time critical items):
  - Standard dipoles: contract awarded Feb 2018, design about to be finalized
  - Multiplets: design phase done; manufacturing of FoS SM: last steps
  - Testing@CERN: contract addendum signed, commissioning of cryo-facility running, FoS SM expected in 10/2018
- Development and procurement of various other components under way
- Civil Construction execution planning finalized; tender documentation in preparation, building services planning running
- Distributed Instrumentation for PID and related DAQ concept
  - FPGA TDC application for TOF and energy loss measurements

Thank you for you attention !

Ligthweigth implementation: time distribution, triggers, scalers, timestamps and reference clocks.

TRLOII/TRIMI

Incl. serial timestamps, no length compensation



Set the TRLO II to generate triggers and respect the TRIMI deadtime:

```
trloctrl --addr=2 --clear-setup \
  "period(1)=10us" "TRIG_PENDING[1]=PULSER(1)" \
  "DEADTIME_IN(1)=TRIMI_TDT"
```

http://fy.chalmers.se/~f96hajo/trloii/

Dedicated Firmware exploring full capability of FPGA module

Full Setup via config. fille!!!

Håkan T. Johansson,
Chalmers, Göteborg

Liverpool, November 2013

With thanks to: J. Hoffmann, J. Frühauf, W. Ott, N. Kurz, H. Simon, A. Henriques, M. Heil, B. Löher, A. Charpy, C. Forssén...

Trigger & Timestamp

Distribution
via „any“ cable
Open Firmware !
(http://fy.chalmers.se/~f96hajo/trloii)

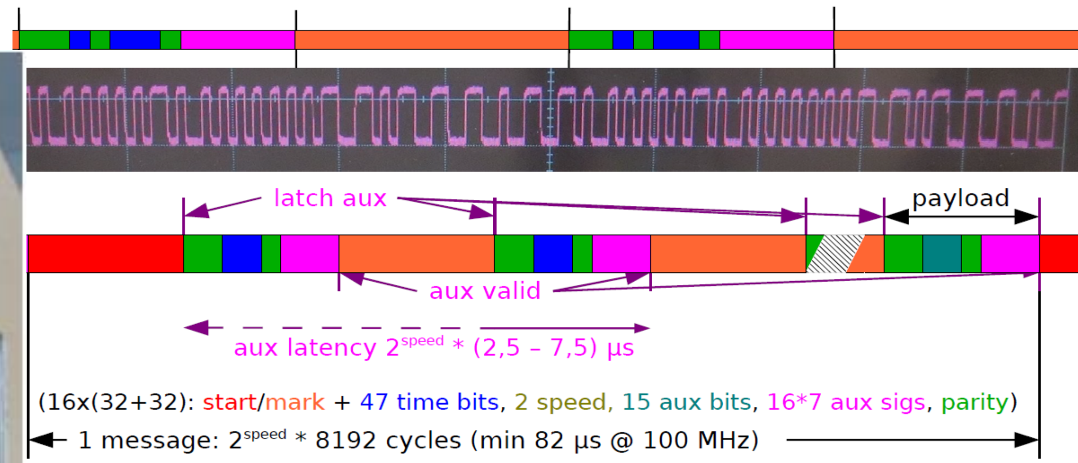
→FPGA friendly

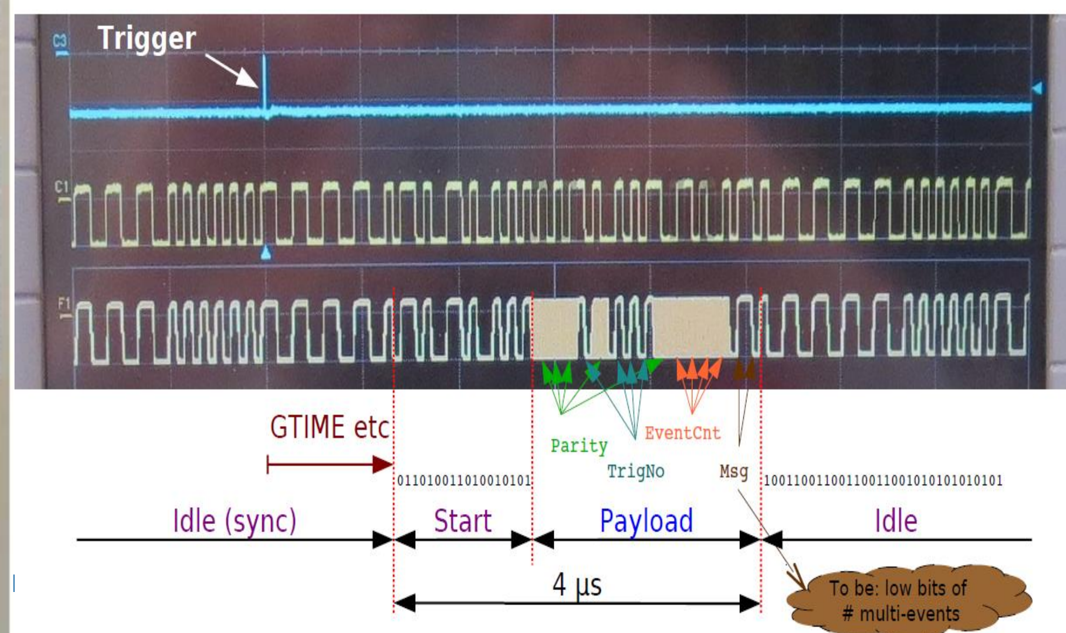
→Works e.g. in LUPO @ RIBF
(see RIKEN docu)

(implementation and testing in less than a week, NeuLAND @ RIBF campaign)

Serial timestamp protocol

- Continous bitstream (→ recv. freq./phase sync)
- Each payload has 7 aux signals and 4 bits of time, 5 parity
- Header pattern for sync, different before first payload





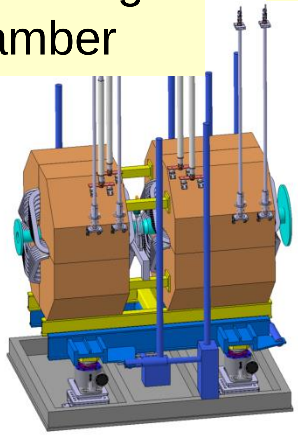
Magnets
(Radiation Resistant Magnets)

H. Leibrock,
T. Blatz, et al.

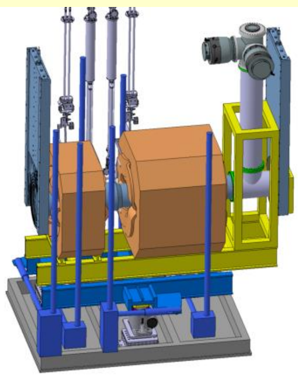
- 3 dipole, 3 quadrupole, and 2 sextupole
- Normal conducting magnets using MIC cable
- Remote connectors and alignment

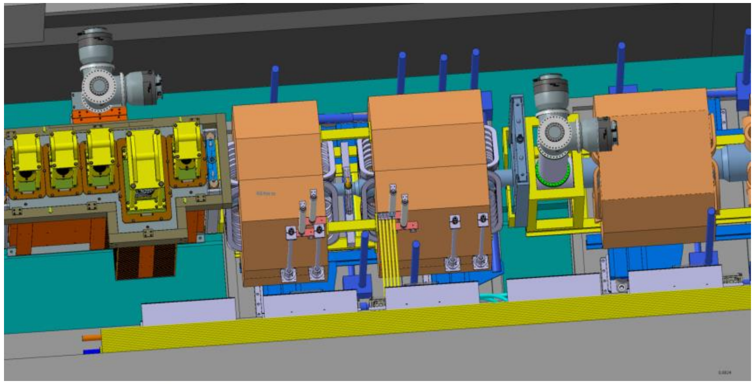
✓ Prototype dipole built and tested by BINP
✓ Dedicated support structure constructed
✓ Dipole: specification released
  - ➢ FAIR procurement
  - tender not yet started, discussion with RU
- Two further specification in preparation
  - ➢ DS for QQ
  - ➢ DS for QS, includes pump port

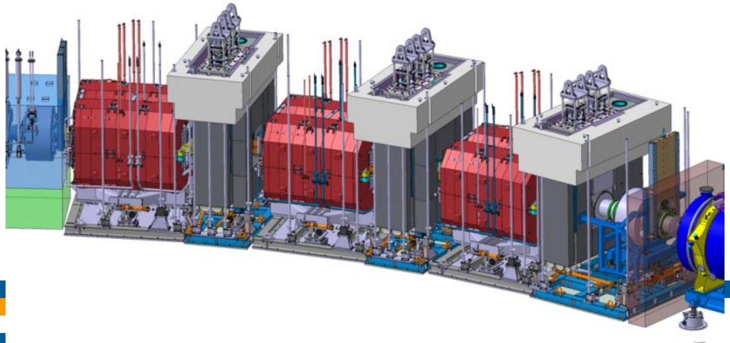
QQ after target chamber

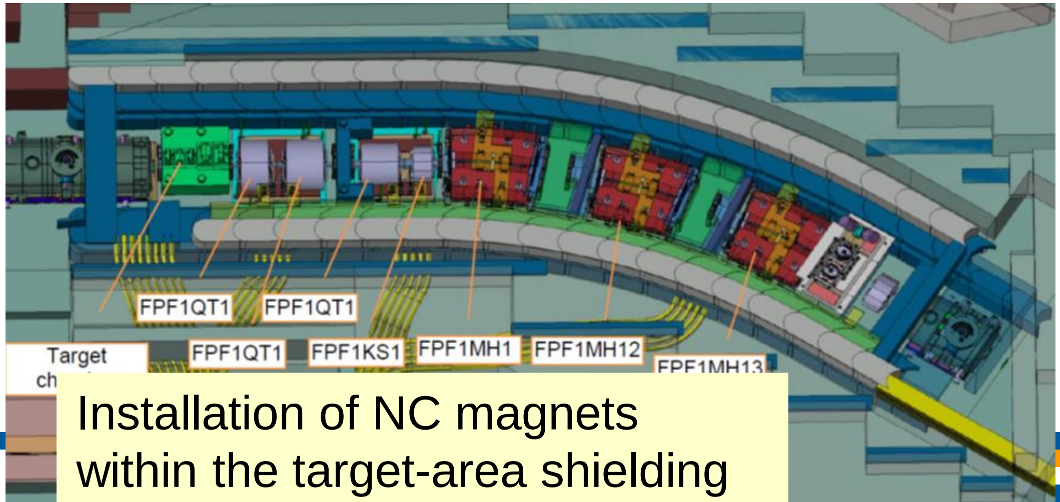


QS plus pump port









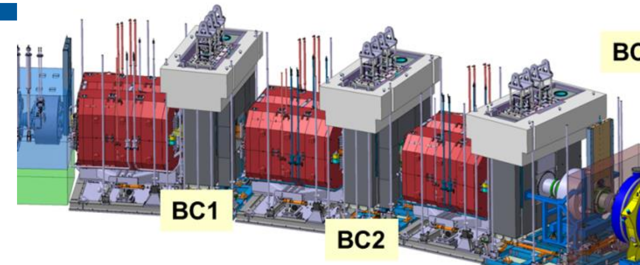
Installation of NC magnets within the target-area shielding

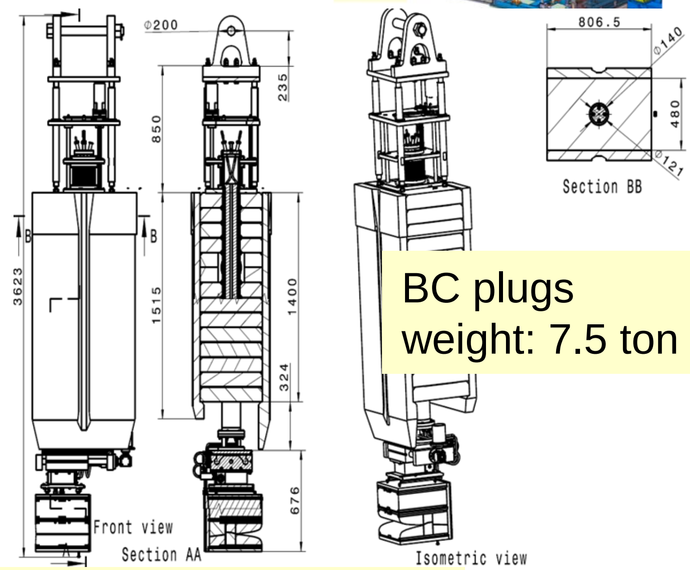
Target Area
(Beam Catcher Plugs)

CSIR - CMERI
सी एस आई आर - केन्द्रीय यांत्रिक अभियांत्रिकी अनुसंधान संस्थान
CSIR - Central Mechanical Engineering Research Institute

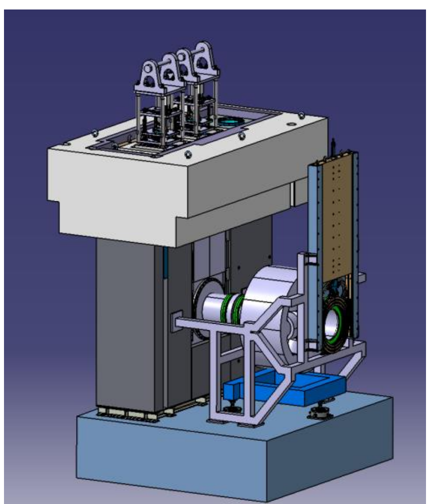
FAIR

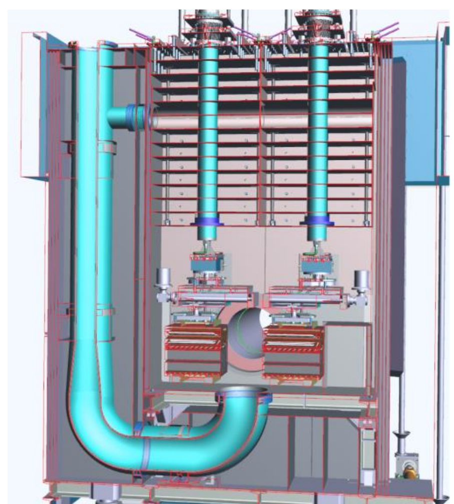
- 3 BC station equipped with two absorber each
- Indian in-kind, Collaborator: **CMERI Durgapur**
- Design running, based on definition report
  - ➢ absorber geometry optimized
  - ➢ use C/Cu (fast/slow extraction) → avoid Be
- ✓ CDR released 12/17
  - ➢ build a absorber mock-up verify RH capability
  - ➢ DS in preparation (Q2/2018)
  - ➢ in-contract preparation (Q4/2018)
- ▪ India started company qualifying phase (Q4/2018)



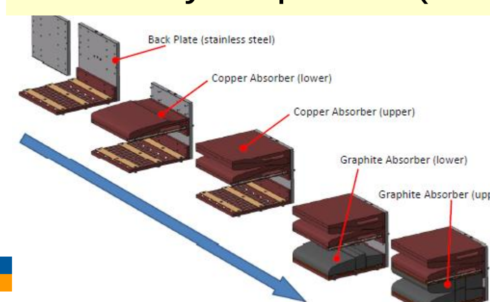


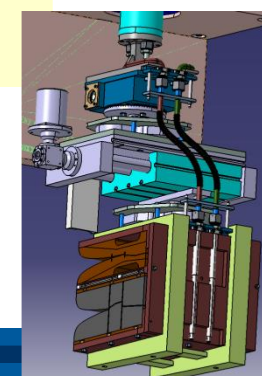
BC plugs weight: 7.5 ton





absorber and assembly sequence (RH)

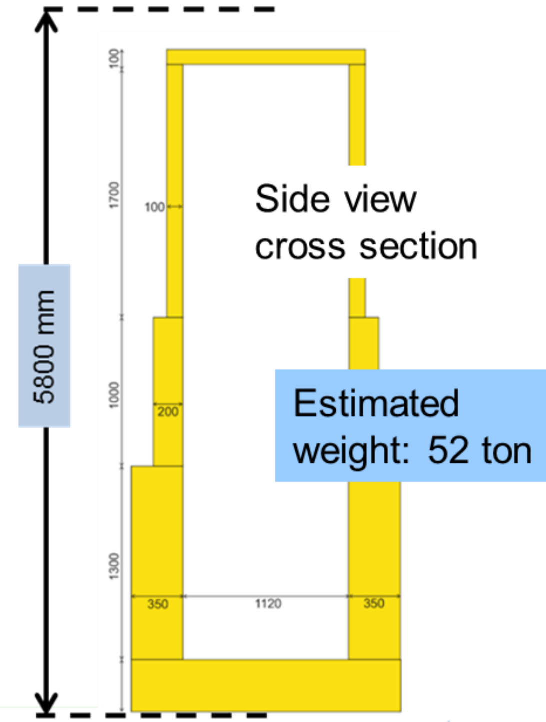




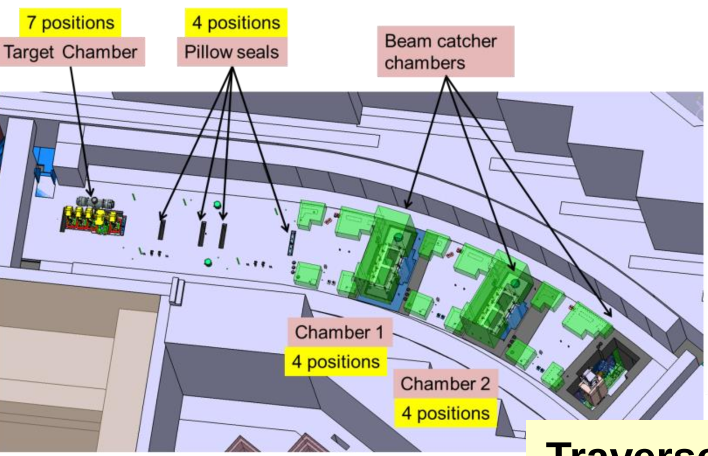
Target Area
(Shielding Flask)

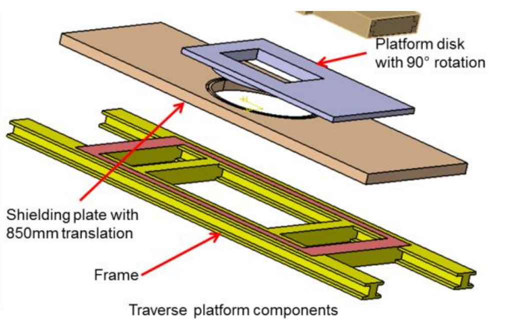
F. Amjad,
H. Weick et al.

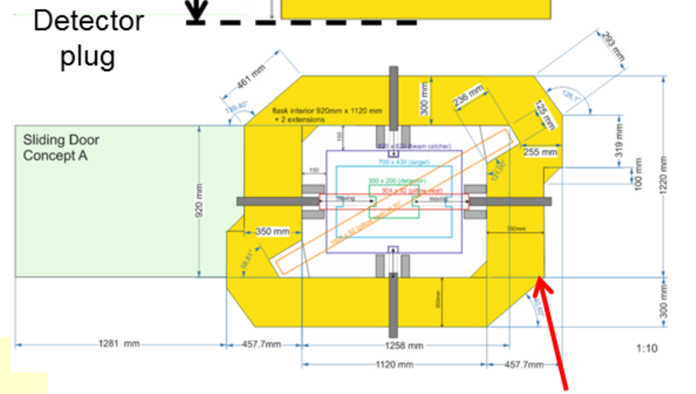
- ✓ Specification ready for approval
  - all dimensions finalized → interface HC finalized
  - internal crane with automatic gripper; load 9 ton
  - shielding: design goal is 10mSv/h on surface
  - includes traverse platform with shielding plate
    - ➢ allows for 90° rotation for position adjust
- MoU between Finland, KVI, PS, GSI in preparation
  - ➢ to be signed Q2/2018
- ✓ in-kind contract with Finland to be established



Estimated weight: 52 ton







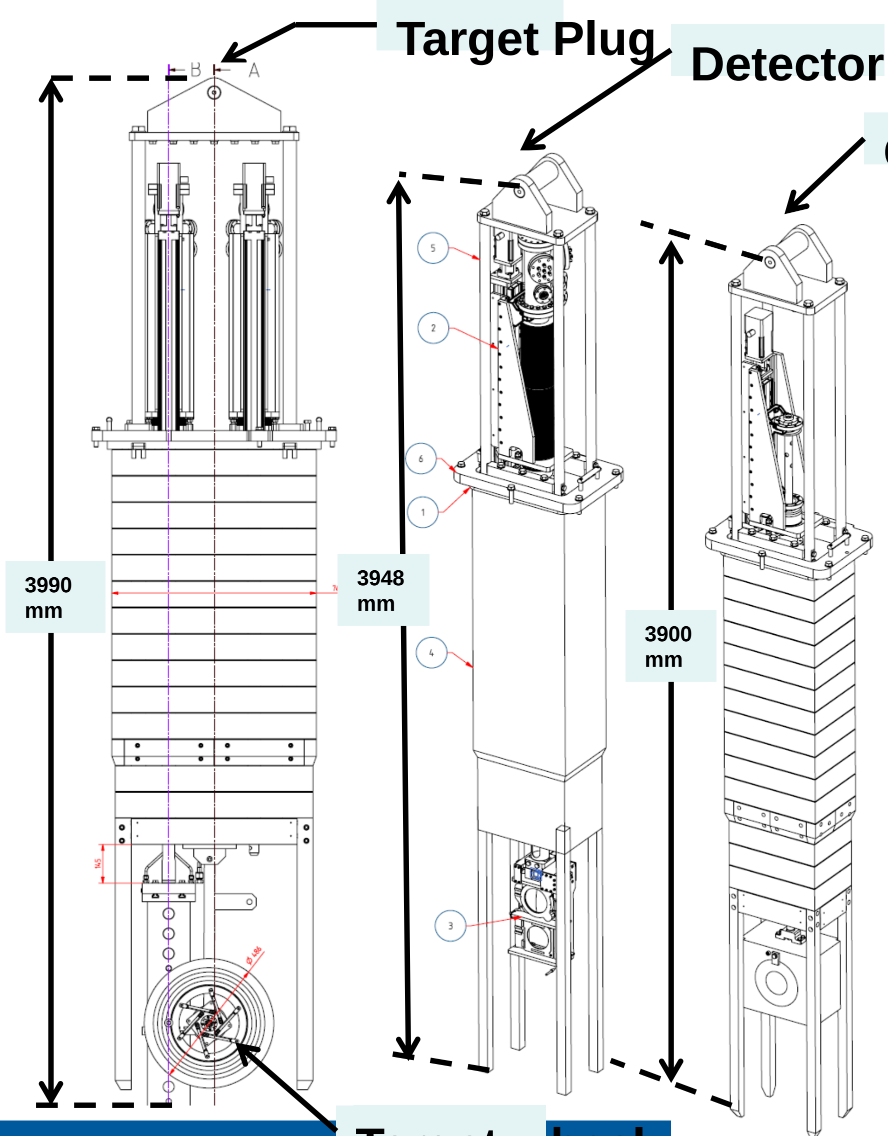
Top view cross section

Traverse platform:
dim: 8.700mm x 3.000mm x 300mm
weight: 19.5 ton

Target Area
(Plug System)

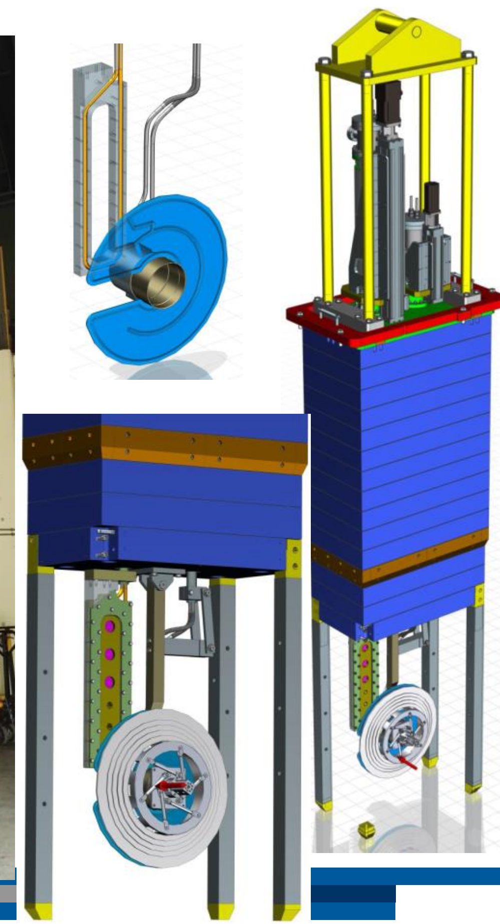
H. Weick,
C. Karagiannis

university of groningen



Target wheel plug (details)
- 4.2 ton (heaviest plug)
- includes target ladder (6 position)
- 2 linear drives + TW motor
- active cooling

Plug test setup



Power Converter

A. Wiest,
W. Freisleben et al.

Scope

- in sum ~250 PC required
  - 9 PC with high-power (up to 500 kW)
  - other PC medium-power for SC magnets
- Voltage range: from 30V to 745V
- Current range: from 15A to 1.480A

Features

- common topology proposed
- energy recovery system
- all PC are bipolar
- PC include Active Power Correction Factor
- Two different DC voltages for ramp and flat-top
- **QD electronics integrated within the PC rack**
- Output filter , switching frequency up to 90kHz
  - very small current ripple

Status

- ✓ in-kind (Council) of India
- ✓ Specifications released (2017)
- Prototype PC under construction
  - FAT expected Q3/2017
  - SAT Q4-18/Q1-19, with CERN FoS SM
- In-kind contract thereafter