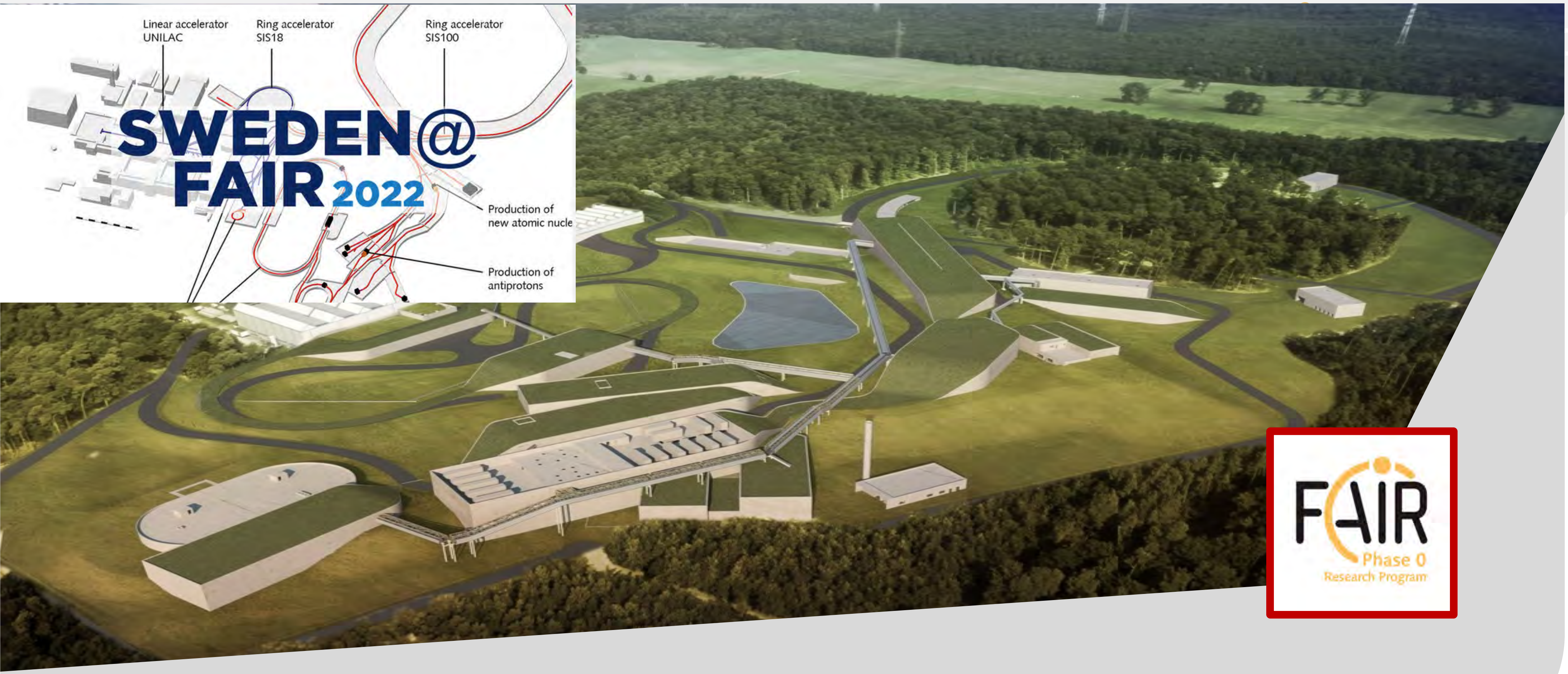


FAIR Phase 0 Research Program

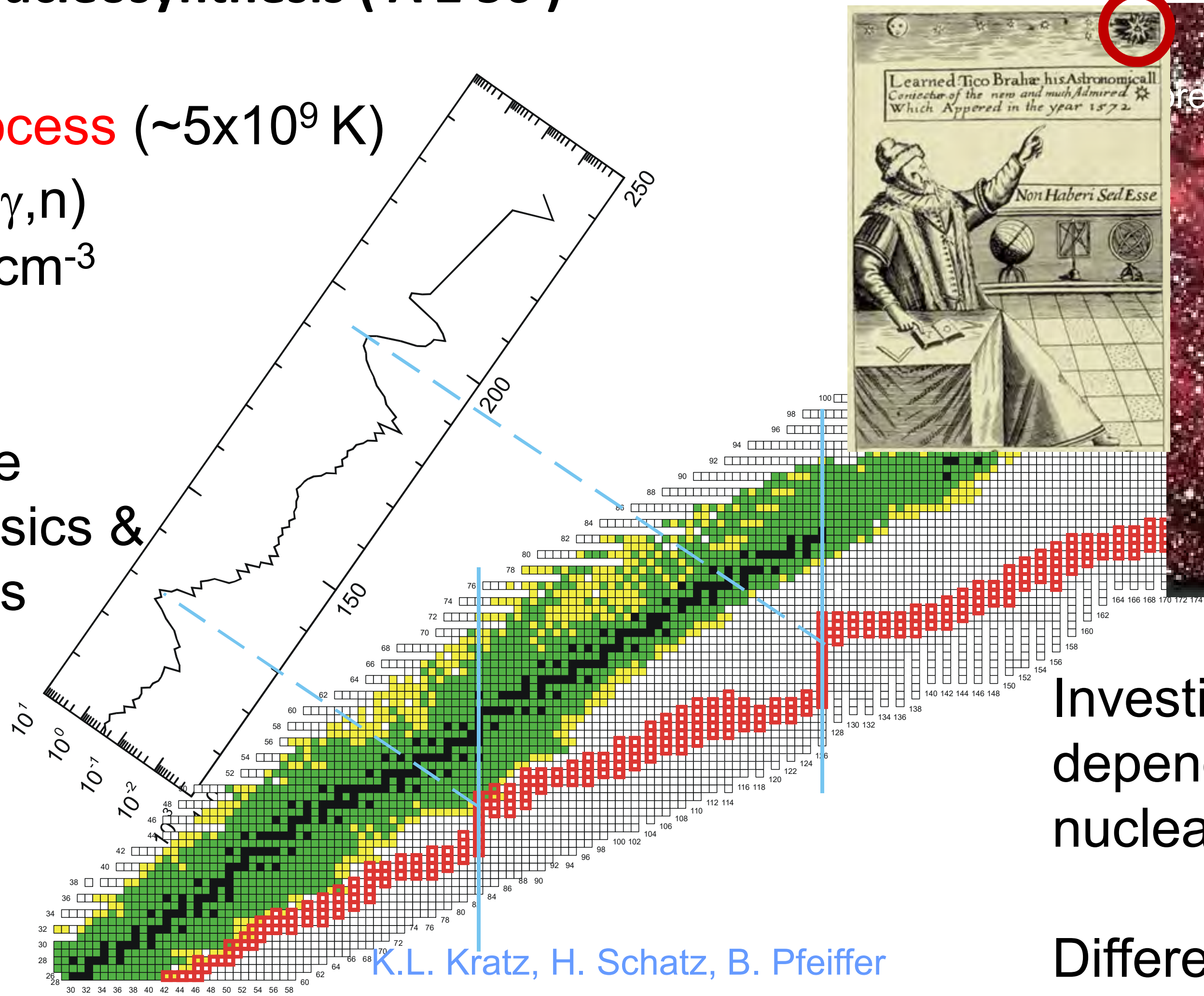
Super FRS: status, plans, challenges, hopes, help needed

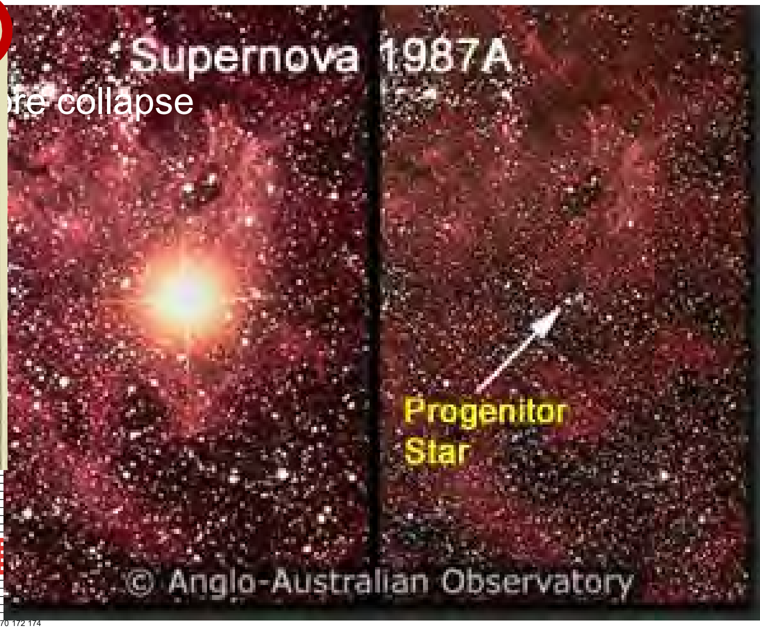
Haik Simon – GSI Darmstadt

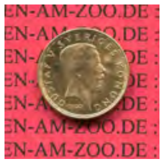
Hopes: Universe in the Labaratory: Exotic Nuclei
Sites of Nucleosynthesis (A ≥ 56)

e.g. r-process (~5x10^9 K)
(n,γ) ↔ (γ,n)
n ≥ 10^{20} cm^{-3}

Nuclear
StrucTure
Astrophysics &
Reactions



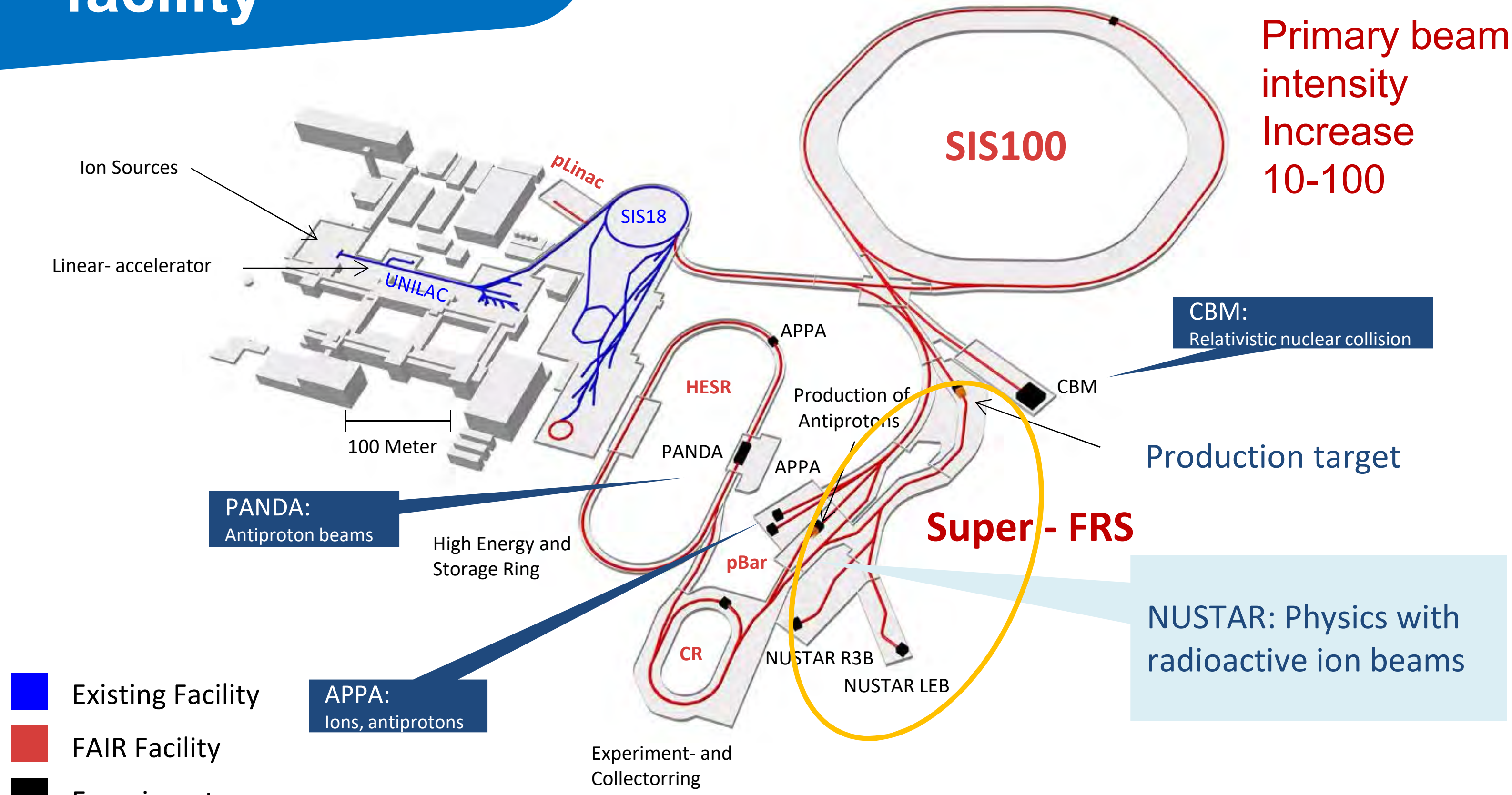




Investigate abundance pattern depends strongly on nuclear structure - extrapolation !

Different probes in variety of NUSTAR experiments → J. Gerl

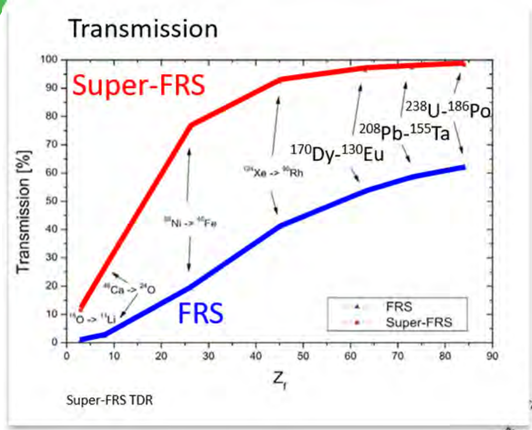
FAIR – schematic view of the facility

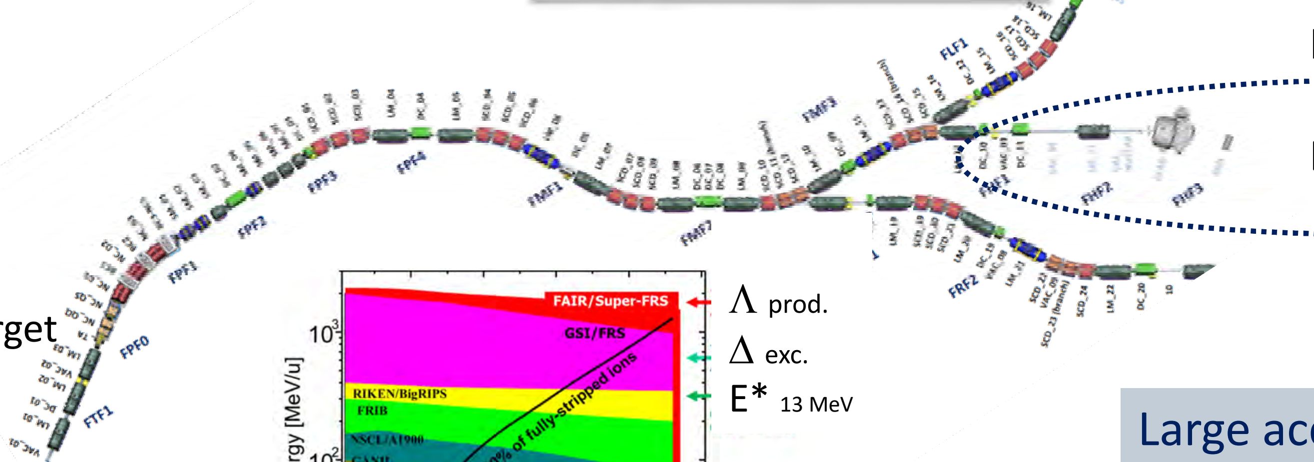


Primary beam intensity Increase 10-100

Gains in primary beam intensity & separator perfomance matched

Super-FRS (@SIS18/SIS100) workhorse for NUSTAR





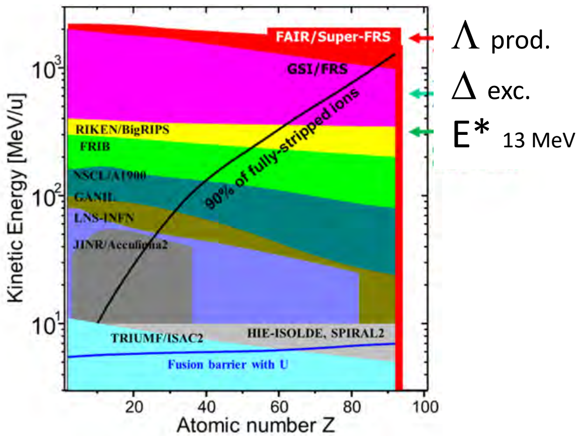
Low energy Branch with Energy buncher

High energy Branch

Early Science Objective

Ring Branch

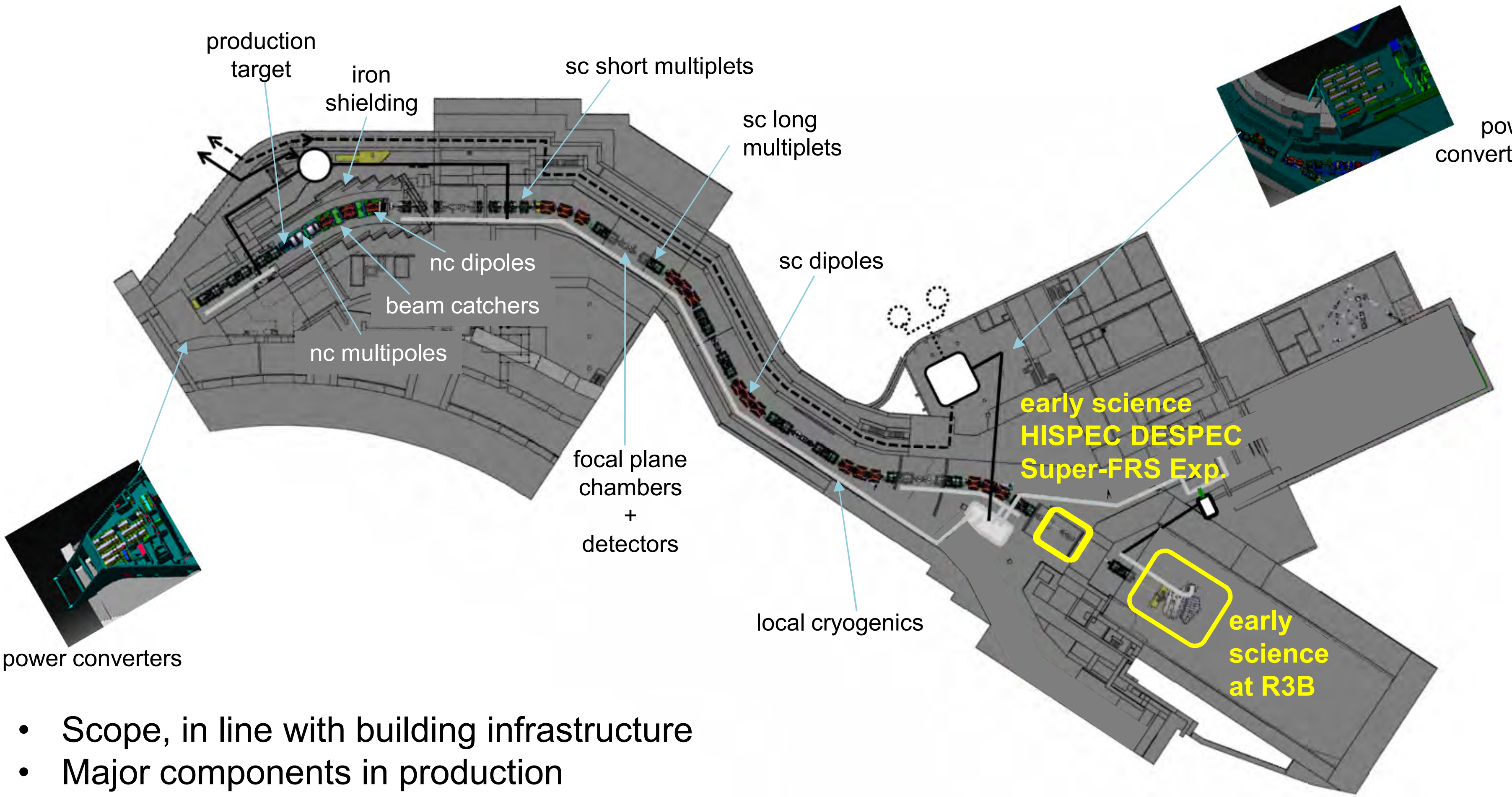
One of worlds most powerful separators for exotic nuclei



Technical Design Report:
H. Geissel, M. Winkler, H. Weick, et al. (2009)

Large acceptance
High rigidity, minimized losses
→ Thick production targets
→ Most effective use of primary beam for experiments

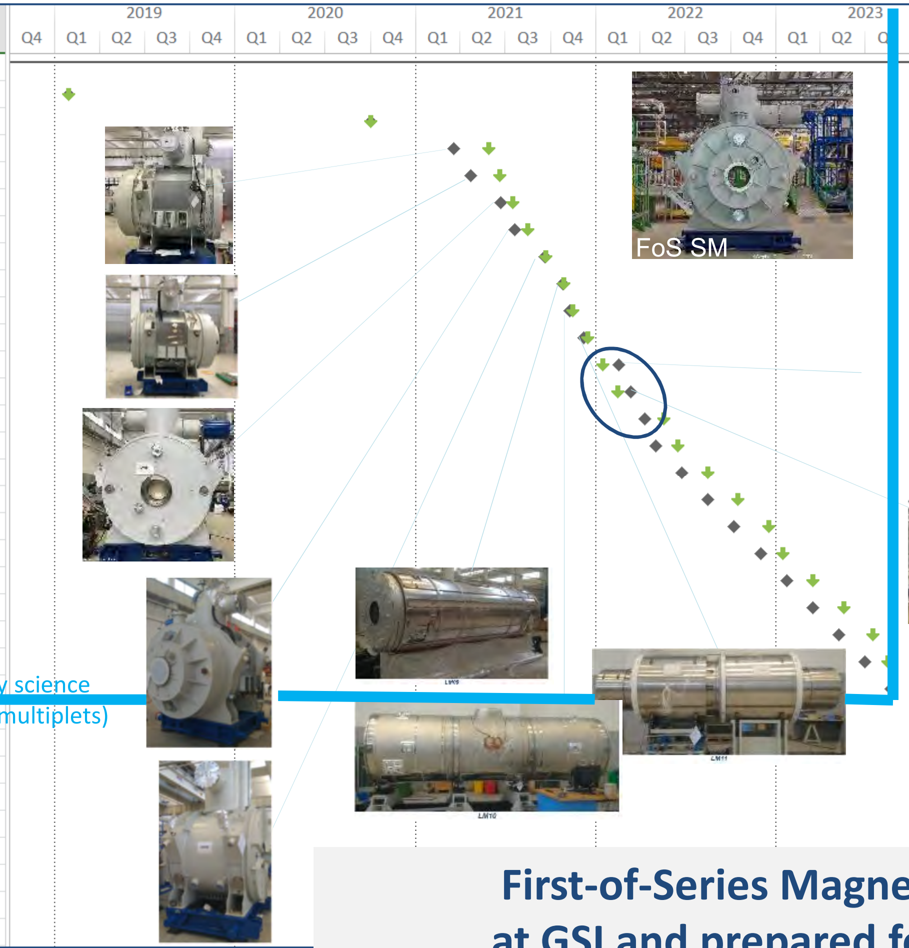
Status: Main components for early science aiming for 2026/2027



- Scope, in line with building infrastructure
- Major components in production

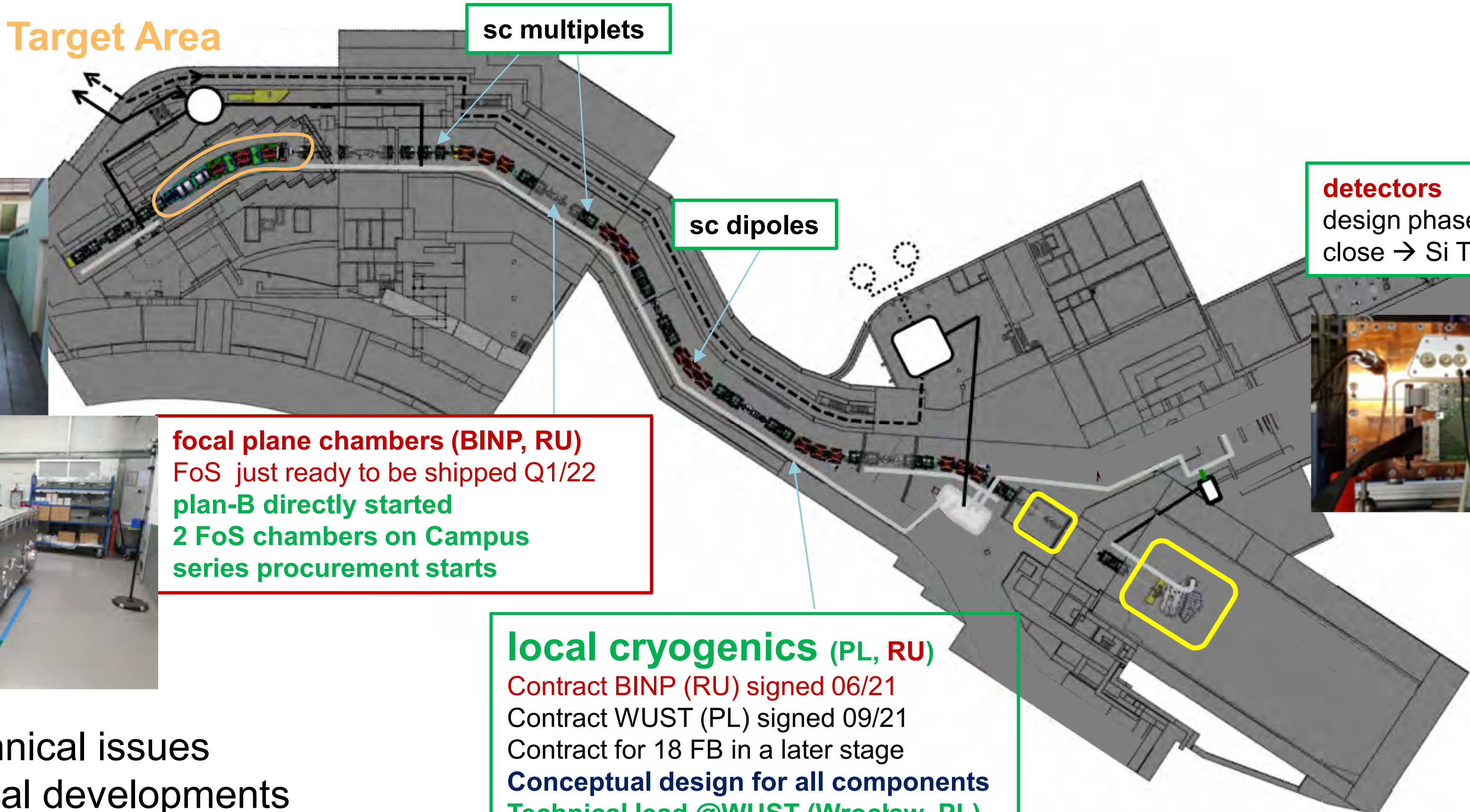
Status: Example for major component: sc multiplets in series production

Nomencla	ASG-Name	Task Name
		FAT
FPF2YMQ12	FoS SM	SM_02 FoS
FHF1YMQ11	FoS LM	LM_11 FoS
FSP1YMQ01	SM-02	SM_08 (spare)
FPF3YMQ11	SM-01	SM_04
FPF2YMQ13	SM-03	SM_03
FPF3YMQ12	SM-04	SM_05
FPF3YMK14	SM-08	SM_07
FTF1YMQ06	LM-09	LM_01
FTF1YMQ09	LM-10	LM_02
FTF1YMQ04	LM-11	LM_03
FPF3YMQ13	SM-05	SM_06
FPF2YMQ11	SM-06	SM_01
FHF2YMQ11	LM-29	LM_13
FPF4YMQ11	LM-14	LM_04
FMF1YMQ21	LM-20	LM_06
FHF1YMQ21	LM-15	LM_12
FRF3YMQ21	LM-16	LM_22
FLF2YMQ21	LM-17	LM_16
FMF1YMQ11	LM-18	LM_05
FMF3YMQ21	LM-25	LM_10
FMF2YMQ11	LM-21	LM_07
FMF2YMQ21	LM-22	LM_08
FMF3YMQ11	LM-23	LM_09



First-of-Series Magnets tested at GSI and prepared for tunnel

Status & Challenges: Russian in-kind: replacement strategy necessary



detectors
design phase about to close → Si ToF alternative

focal plane chambers (BINP, RU)
FoS just ready to be shipped Q1/22
plan-B directly started
2 FoS chambers on Campus
series procurement starts

local cryogenics (PL, RU)
Contract BINP (RU) signed 06/21
Contract WUST (PL) signed 09/21
Contract for 18 FB in a later stage
Conceptual design for all components
Technical lead @WUST (Wrocław, PL)
Reprocurement of Branch Box running

- No technical issues
- No critical developments
- Reprocurements prepared

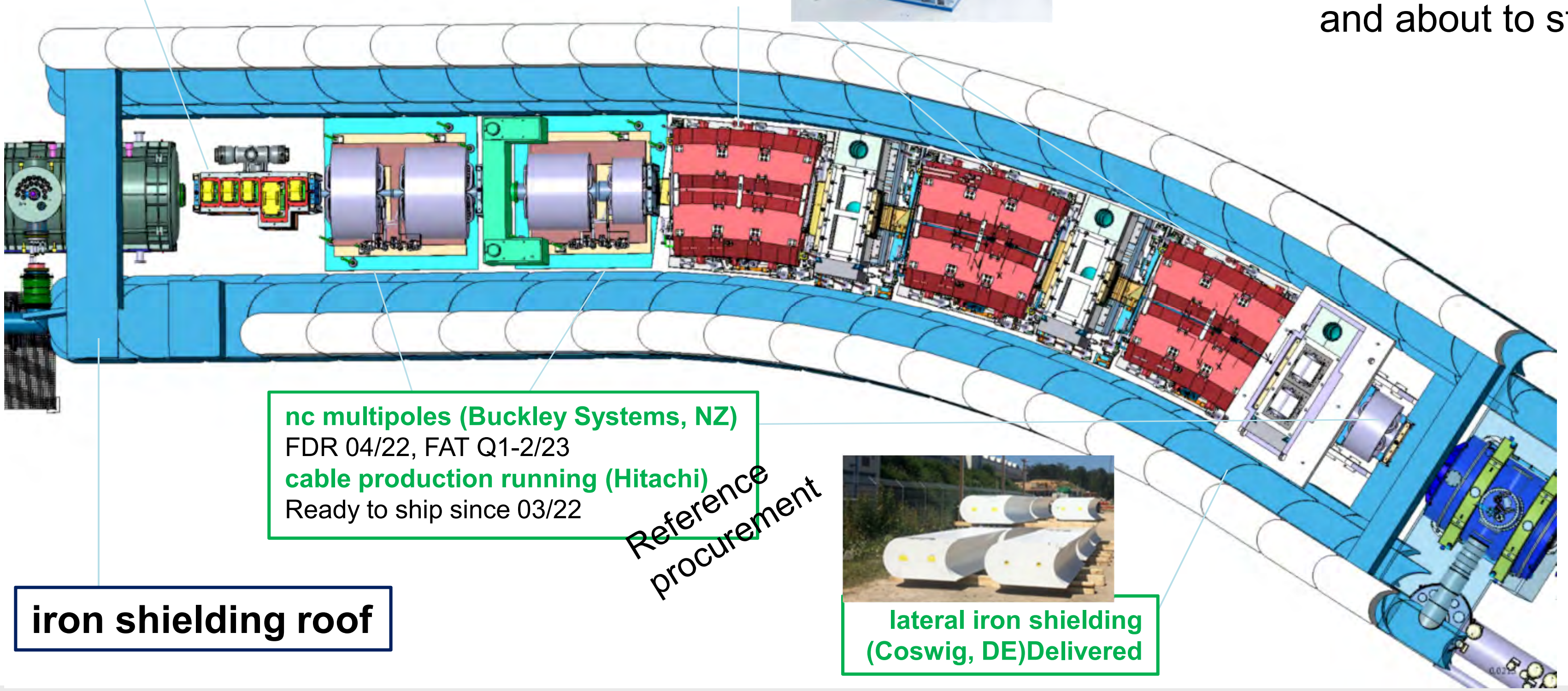
Status & Challenges: Russian in-kind: replacement strategy necessary

Target Area

nc dipoles (2 of 3 BINP)
FoK dipole on campus 1/3
FDR yoke ready, production about to be started, cable delivery Q1/23
Tender starts asap (kickoff next week).

- No technical issues
- No critical developments
- Reprocurements prepared and about to start.

Target chamber



nc multipoles (Buckley Systems, NZ)
FDR 04/22, FAT Q1-2/23
cable production running (Hitachi)
Ready to ship since 03/22

Reference procurement

lateral iron shielding (Coswig, DE)Delivered

iron shielding roof

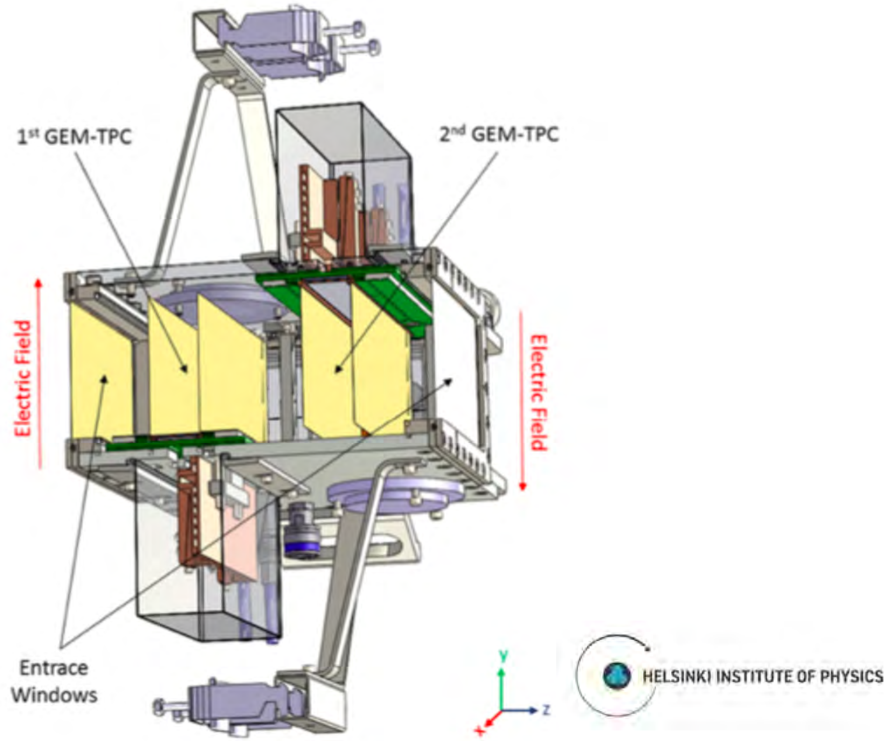
Status: Next steps

- Apart from Ion Optical Hardware:
  Instrumentation / Related Analysis / Software
  is key factor for the performance of the separator
- Short Development Cycles → Late in the chain

- Cutting Edge technology
  with synergies to HEP-Astrophysics
  Communities

Technical challenges in instrumentation

Example: GEM TPC for high rate tracking (Super-FRS)



F. Garcia, *et al.*, Nucl. Instr. and Meth. A 884 (2018) 18–24.
A. Prochazka, *et al.*, GSI Scientific Report (2014) 500doi:10.15120/GR-2015-1-FG-SFRS-04.

Beam Particle ID
→ Bρ-ΔE-TOF method:
Requirements

$B\rho = A/Z \cdot \beta \cdot \gamma$	→	A/Z, P
$TOF = L/\beta$	↗ ↘	
$\Delta E \sim Z^2/\beta^2$	→	Z

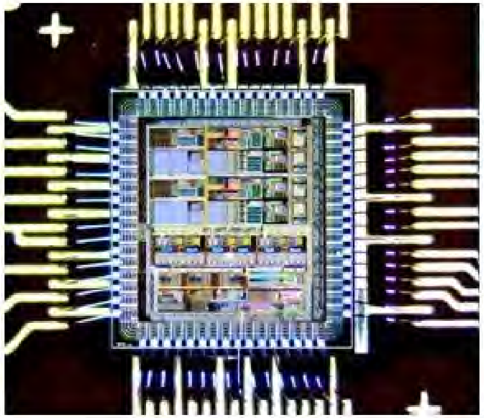
Pos res. $\sigma \leq 1$ mm
Timing res. σ: 50 ps
ΔE resolution σ: 1-2 %
p…U: large dynamic range

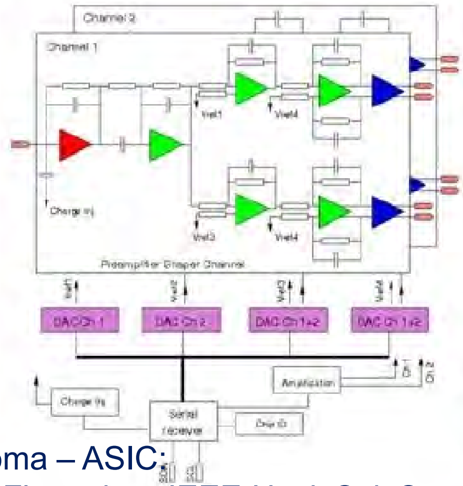
Rate capability some MHz
high rate also required for calorimetry with gas detectors

-sampling techniques / timestamped readout
digital signal processing

Technical challenges in instrumentation
Example: GEM TPC for high rate tracking (Super-FRS)

P̄ANDA – EMC: Barrel Readout Electronics





APFEL ASIC 1.5 overview:

Analog Readout

- Each readout channel consist of
  - charge sensitive preamplifier
  - third order shaper stage
  - differential output driver
- Two outputs per channel with different amplification to cover the dynamic range
- Two equivalent channels per chip

Digital Part

- Serial interface on chip for the autocalibration to detect the right DC voltages for a given temperature to cover the whole dynamic range
- Optional charge injection
- Read and write of the DAC settings
- Chip ID for single chip bus communication

K. Brinkmann/U. Thoma – ASIC:
P. Wieczorek and H. Flemming, *IEEE Nucl. Sci. Sym. & Med. Imag. Conf.* (2010) 1319

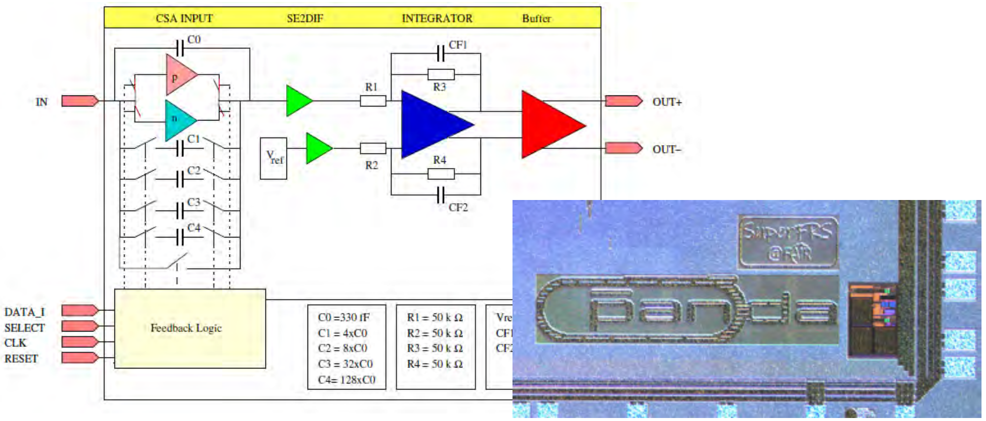
APFEL ASIC (0,35µm AMS): 2 outputs with different GAIN
Digital interface for configuration
Rate/ch. ~350kHz
Power <= 50 mW/ch (22k Ch.)

➔ Similar Demands for GEM-TPC
ASIC developments & Systems

Technical challenges in instrumentation

Example: GEM TPC for high rate tracking (Super-FRS)

AWAGS ASIC

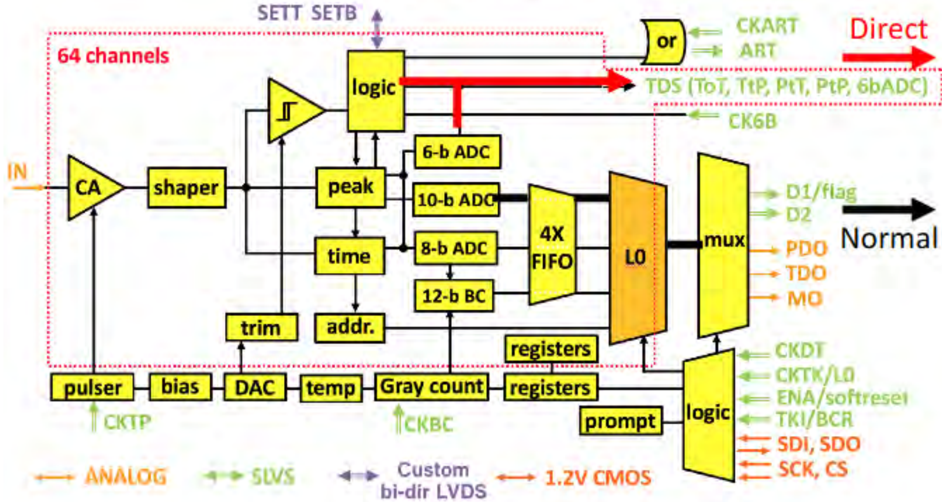


P. Wieczorek, H. Deppe, H. Flemming,
Low noise amplifier with adaptive gain setting (AWAGS),
accepted from JINST as TWEPP2021 proceeding.

ASIC with adaptive gain;
- very large dynamic range

AWAGS

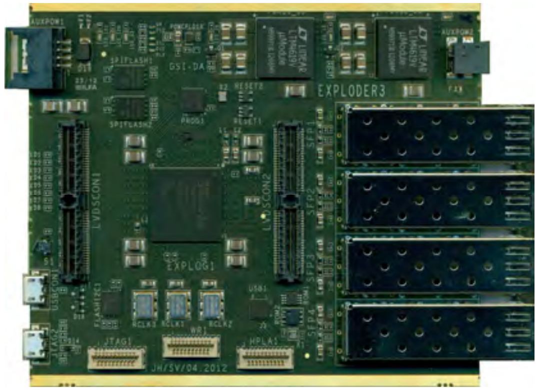
VMM3 block diagram



VMM3a: „Swiss army knife“ ASIC (HEP)
ATLAS small wheel (µMEGAS)
Perfect fit for GEM readout ?

Availability of building blocks allows
for optimized solutions → build systems !

Enabling technologies
- Precision timing (few...100 ps)



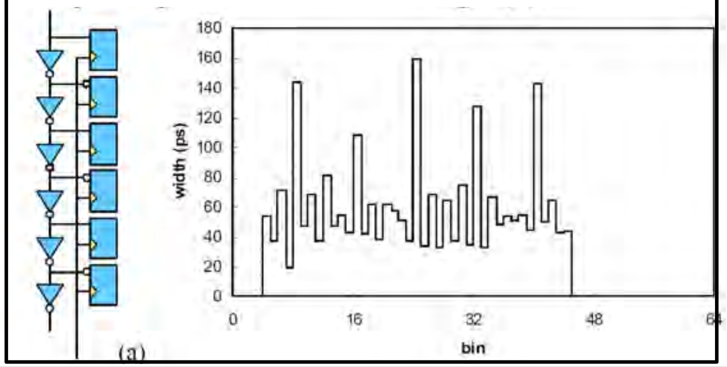
Design & Production of **systems** based on developed technologies

- Time distribution systems
  - e.g. Based on WR network (… KM3NeT)
  - https://white-rabbit.web.cern.ch/
  - CAMPUS wide (e,g, ToF: Separator – Exp.)
- FPGA TDCs down to 7ps resolution
- Precise position measurement
- Amplitude information via time over threshold
- E.g. ToF Wall based on plastic scintillator

  σ_t=14ps, σ_E/E=1%

The 10-ps Wave Union TDC: Improving FPGA TDC Resolution beyond Its Cell Delay
Jinyuan Wu and Zonghan Shi

IEEE Nucl. Sci. Symp. Conf. Rec. (2008)



Status: Current Field of intense collaboration

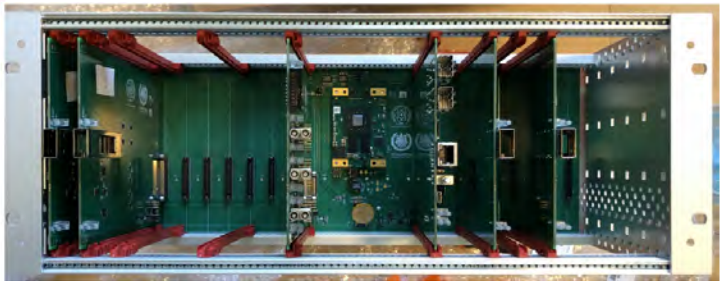
- Distributed high rate DAQ (km scale, few 10ps resolution time base)

produced in SE

Design: Michael Munch (Aarhus)
Review: Håkan T Johansson

Collaboration CTH-AAU-GSI

prototype:
Heimdal/Bifrost
fibre signal
exchange points



Series production/testing to come

CHALMERS

Strong links
to experiment

FAIR Phase 0 Research Program

GSI

FAIR In-Kind Contract

Contract No:
IKC/PSP 2.4.6.3.1.2
on
the in-kind Contribution (IKC)

Super-FRS experimental DAQ system

for the Construction of the FAIR facility

according
to the Technical Document 4 attached to the FAIR Convention

between

the Facility for Antiproton and Ion Research in Europe GmbH (FAIR),
Limited Liability FAIR Company subject to the German law,
located at Planckstraße 1, 64291 Darmstadt,
represented by the Managing Directors
hereinafter referred to as "the Company",

and

Vetenskapsrådet (Swedish Research Council)
located at Västra Järnvägsgatan 3, Box 1035, 101 38 Stockholm
represented by the Director General
hereinafter referred to as "the Shareholder"

and

Chalmers tekniska högskola AB, Department of Physics,
located at SE 41296 Göteborg, Sweden
represented by the Head of Department
hereinafter referred to as "the Provider" and/or "Contractor"

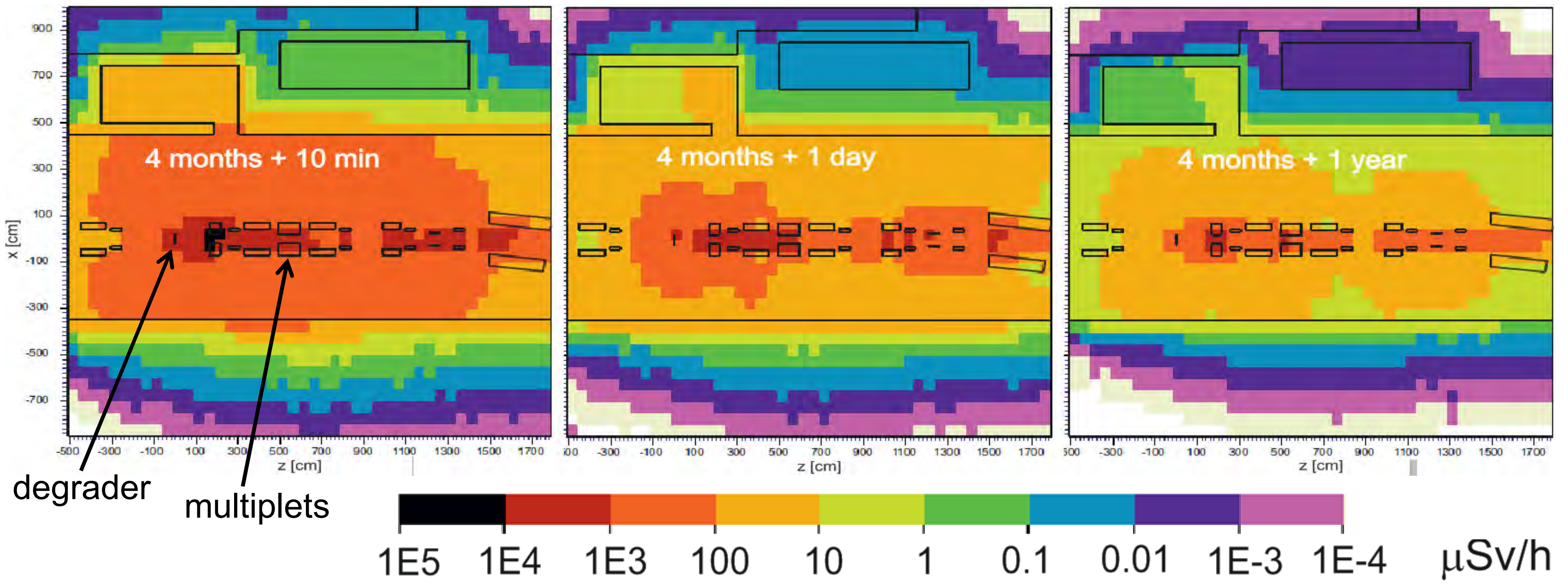
hereinafter collectively referred to as "the Parties",

which have agreed on the following:

Future demands with „First science scenario“ - Intense SIS100 beams

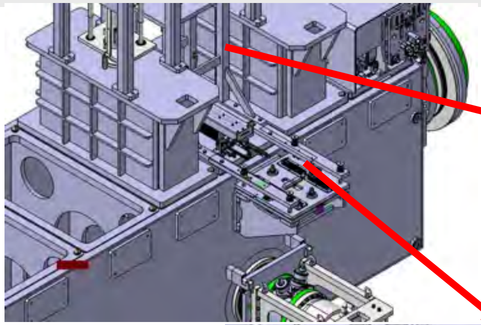
- Dose rate by activation pre-separator mid focus, calculated with FLUKA
- Al degrader and magnets as components
- Beam up to: 0.6×10^{10}/s fission fragments for 2×10^{11} ^{238}U/s on target.

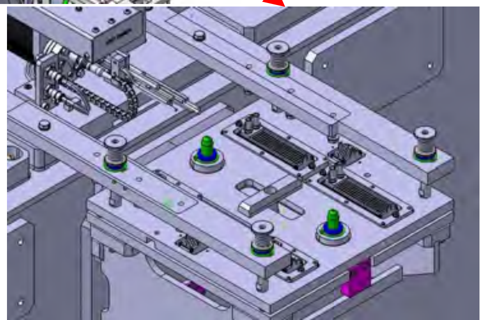
beam on target + cooling time

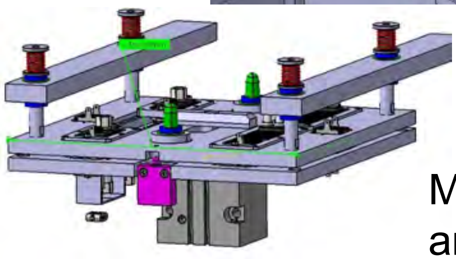


→ **remote handling**

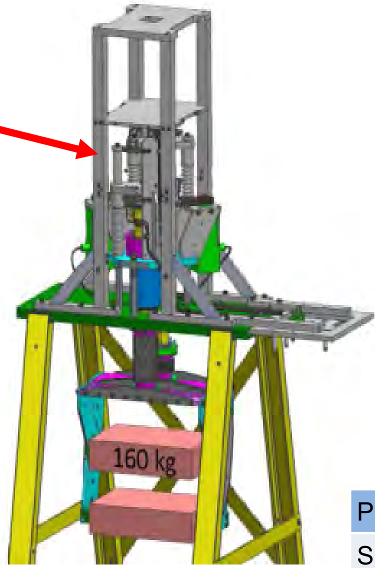
High intensity - remote handling



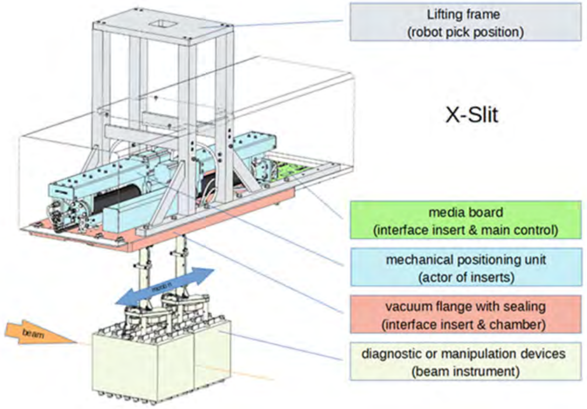




Media board



Slits-Y



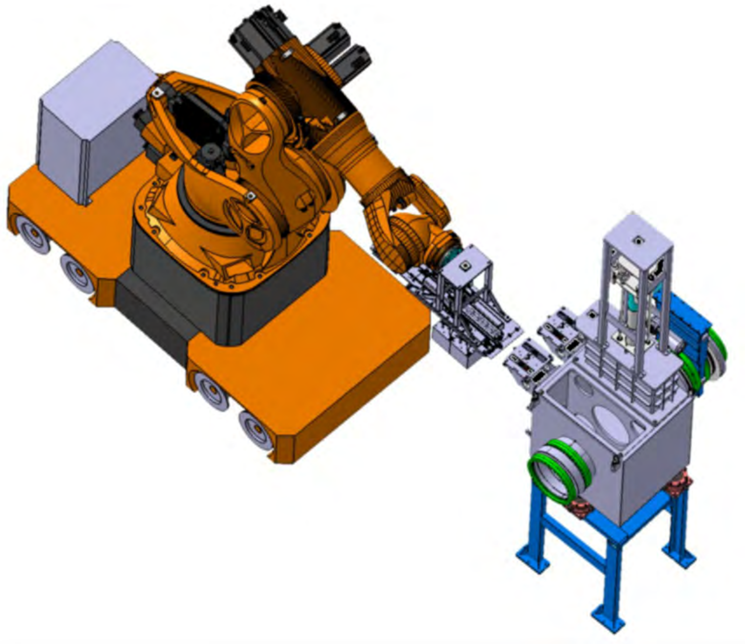
Slits-X

Plug	Mass	Flange	Height
Slits-X	495kg	390mm	1170mm
Slits-Y	570kg	390mm	1725mm

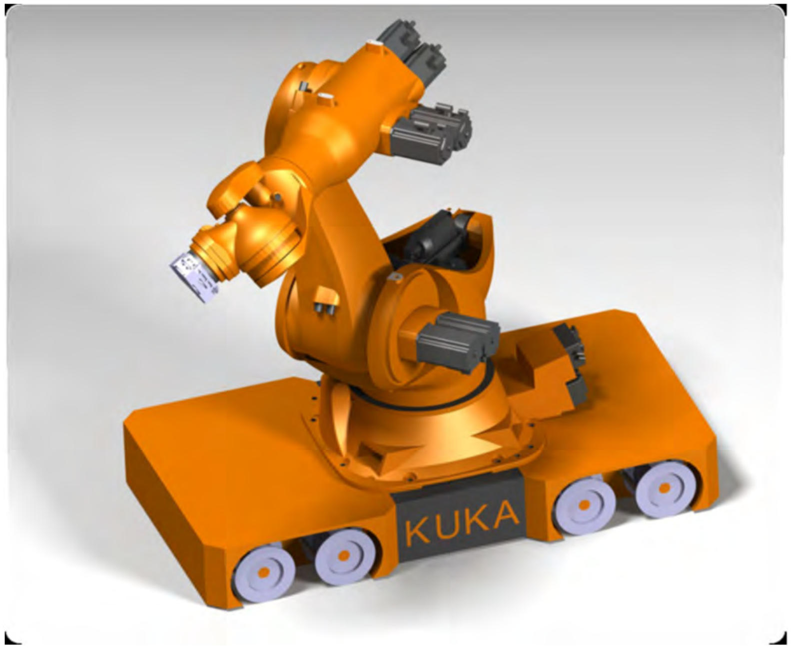
X and Y slits are the heaviest plugs that requires remote handling

Media board developed,
and already being tested at GSI
Induction proximity sensor,
pneumatically operated

Remote handling – robotics concept

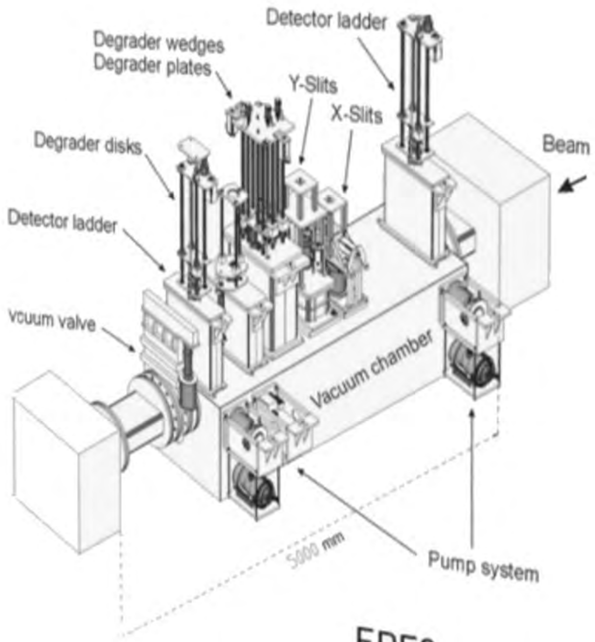


Robot system handling the beamline insert

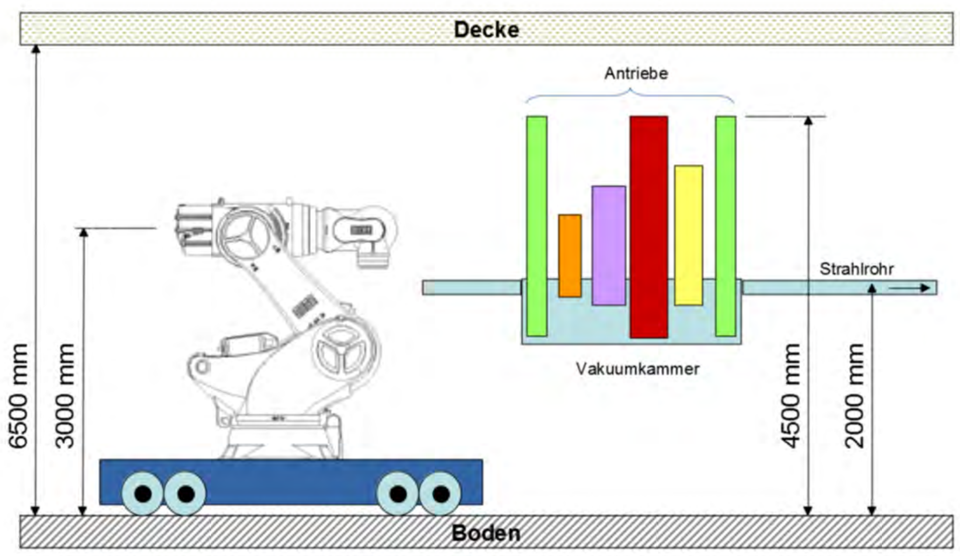


KUKA TITAN
handling mounted
on KUKA
omnimove

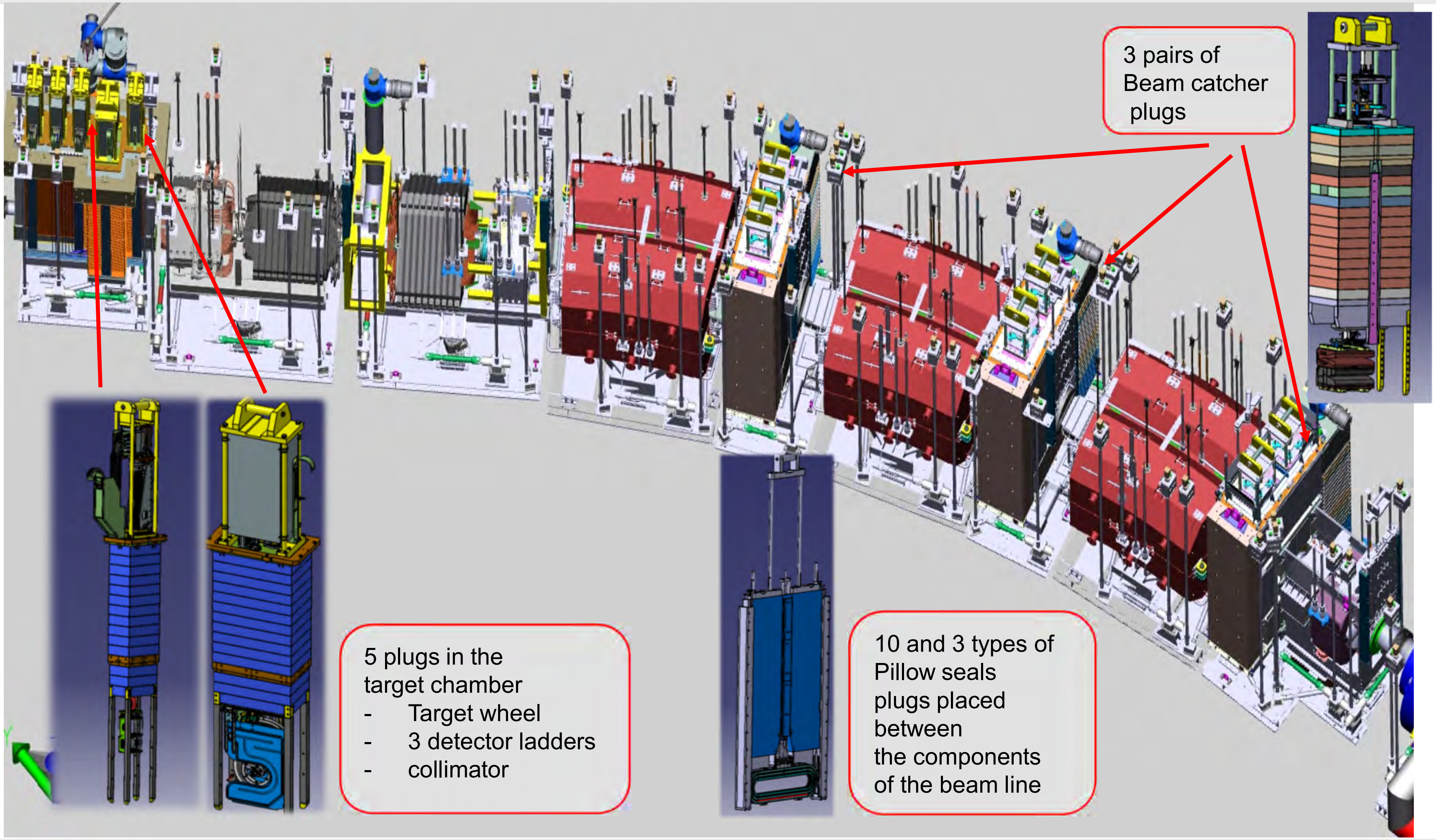
Remote handling – robotics concept



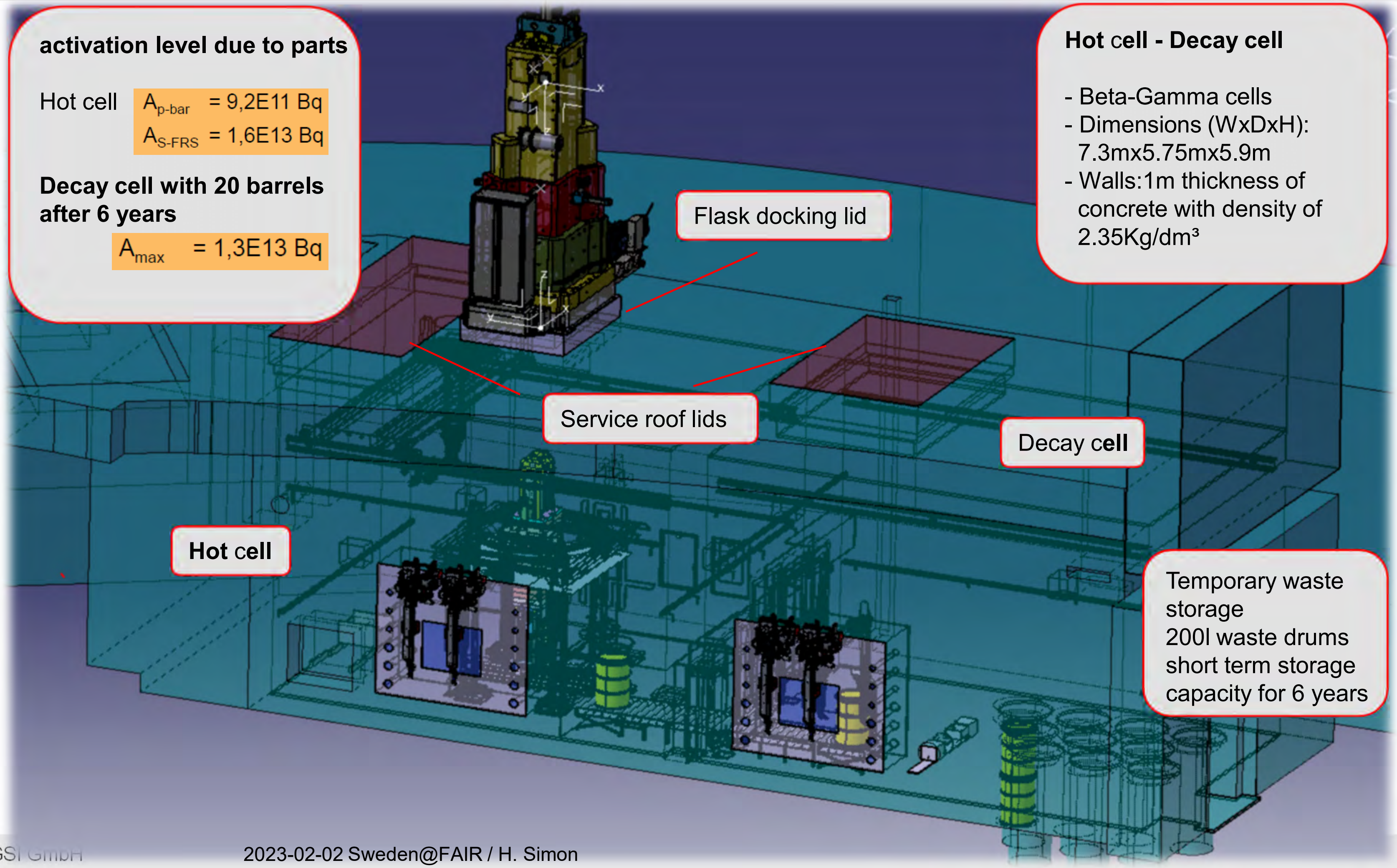
FPF2



Remote handling - Super FRS target region



Hot cell layout



Hopes/help needed: Areas of work & techniques

- Several areas of collaboration in instrumentation packages
  - high performance DAQ, production, high rate detector upgrade
  - Sampling techniques and related firmware/software solutions
  - ps timing

- Hot cell and remote handling
  - Industrial robots, handling concepts, training
  - Hot cell equipment – interior and interfaces

- Controls
  - Industrial controls
  - Software developments

- Completion of the MSV (2030+)
  - LEB buncher specctrometer, (LEB, RB) (i.e. sc-magnets, cryogenics, vacuum, power converters, related instrumentation and controls)

Thanks

- Super-FRS project group

Stay tuned: www.gsi.de/superfrs