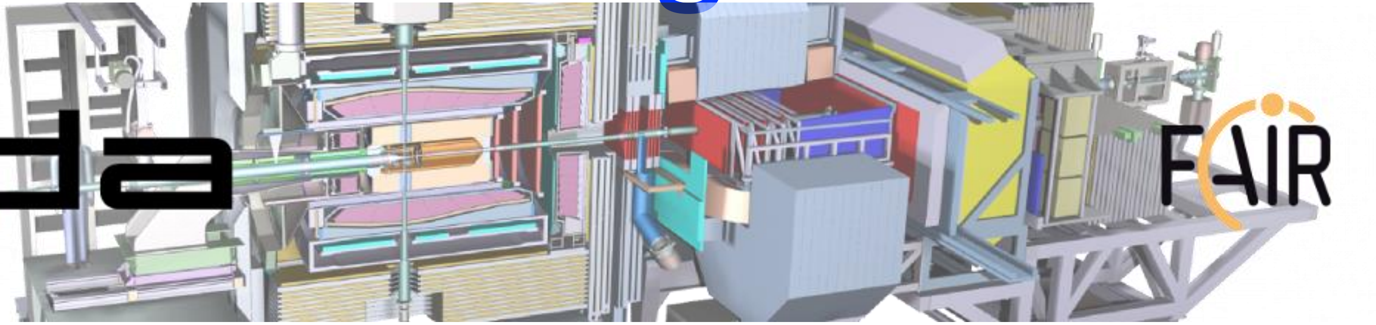
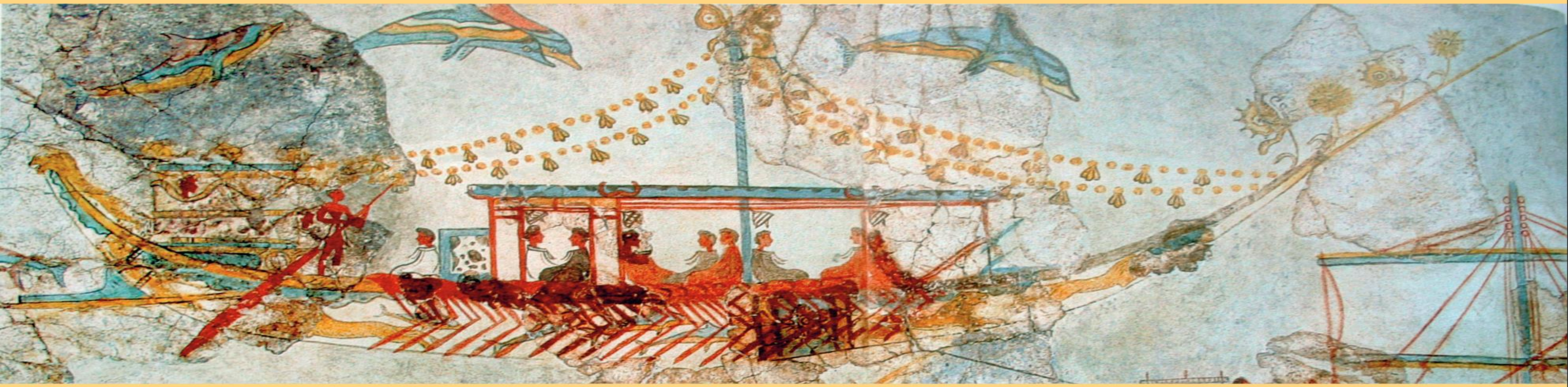
PANDA Detector Design at FAIR



Anastasios Belias / GSI

On behalf of the PANDA Collaboration

9th International Conference on New Frontiers in Physics



ICNFP 2020 / 4-12 Sep 2020 / Kolymbari, Crete

PANDA Detector Design at FAIR

Antiprotons @ FAIR

PANDA Detector

Outlook & Opportunities

Anastasios Belias / GSI

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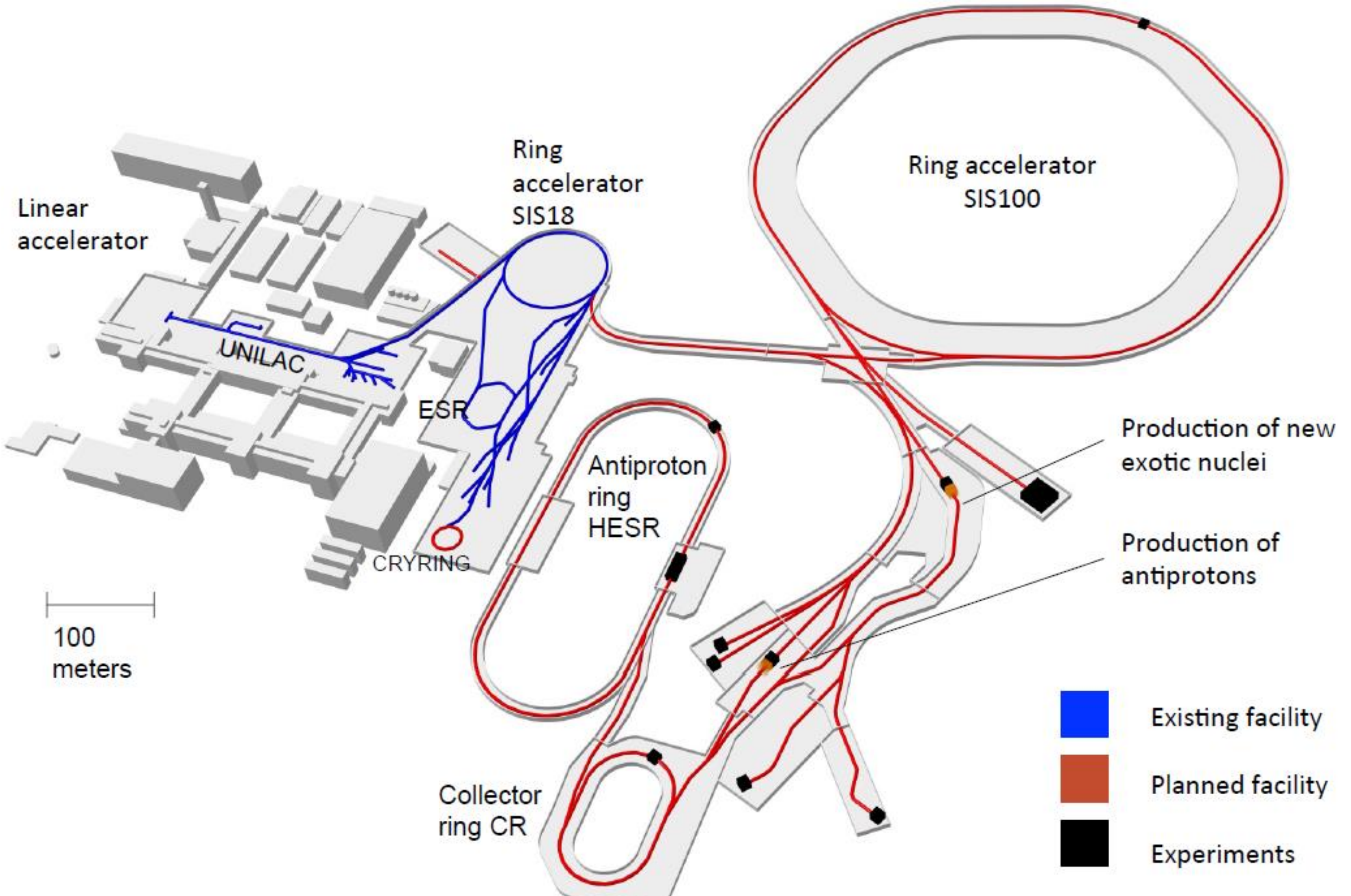
Facility for Antiproton and Ion Research

@ GSI, near Darmstadt, Germany



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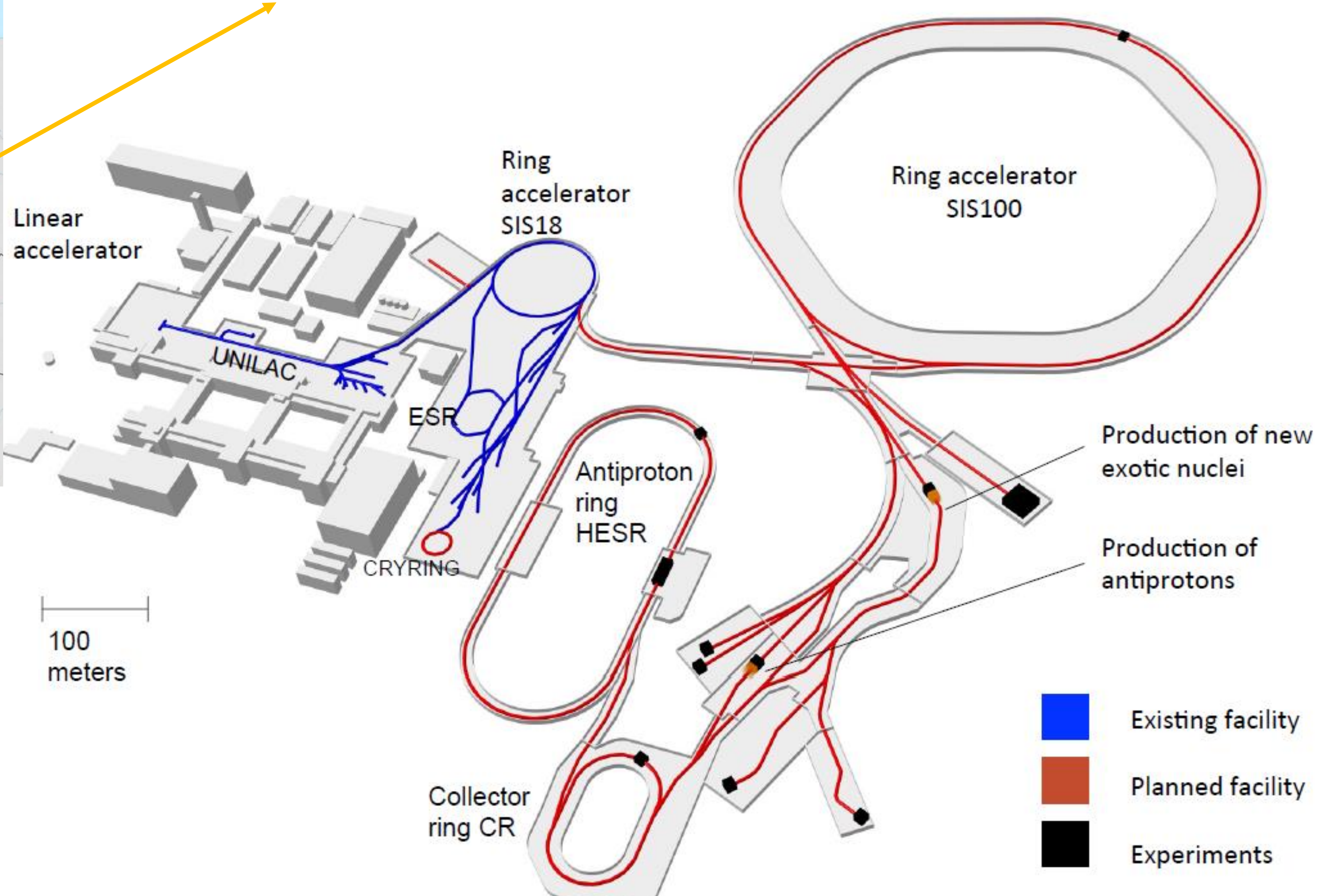


FAIR

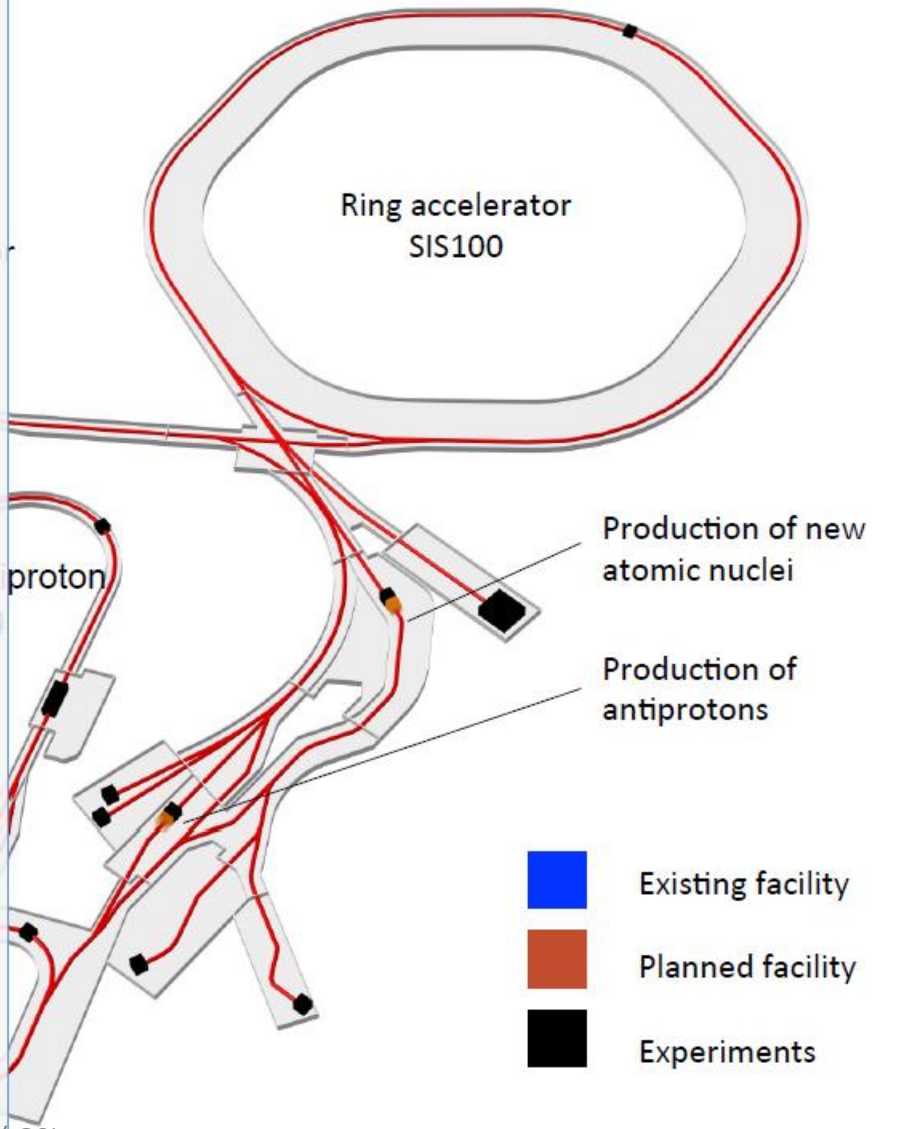
... accelerates particle beams from (anti)protons up to uranium ions with

- very high intensities
  - up to a factor of ~100 increase for primary Uranium beams (~ 5 x 10^{11} U^{28+} ions /s),
  - up to a factor of ~10.000 increase for secondary rare isotope beams
- high pulse power (up to ~ 50 kJ / 50 ns)
- suite of storage cooler rings equipped with stochastic and electron cooling for brilliant beam quality

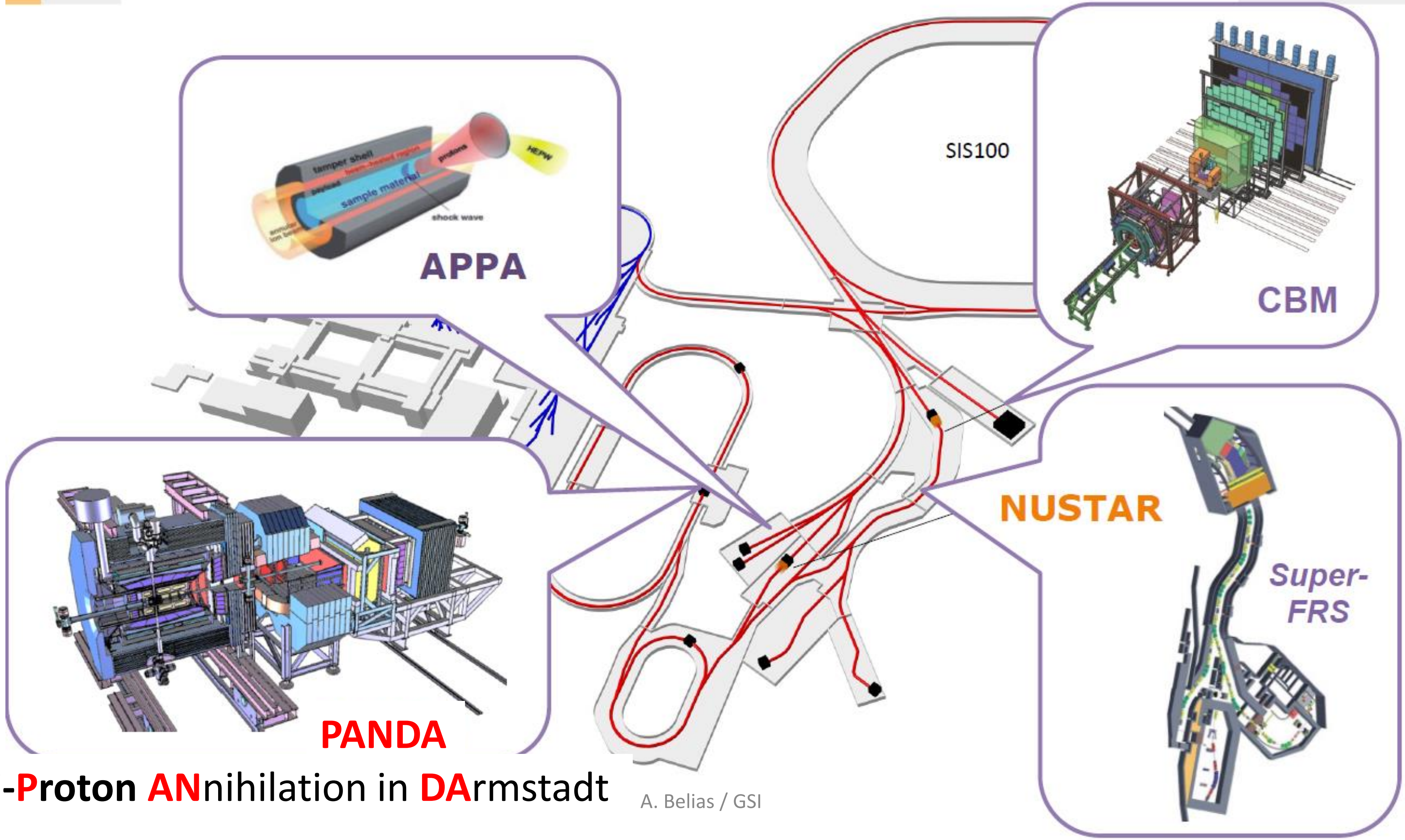
... develops and exploits innovative particle separation and detection methods, as well as novel computing techniques

... to perform forefront experiments towards the production and investigation of

New Extreme States of Matter.



FAIR – four research pillars

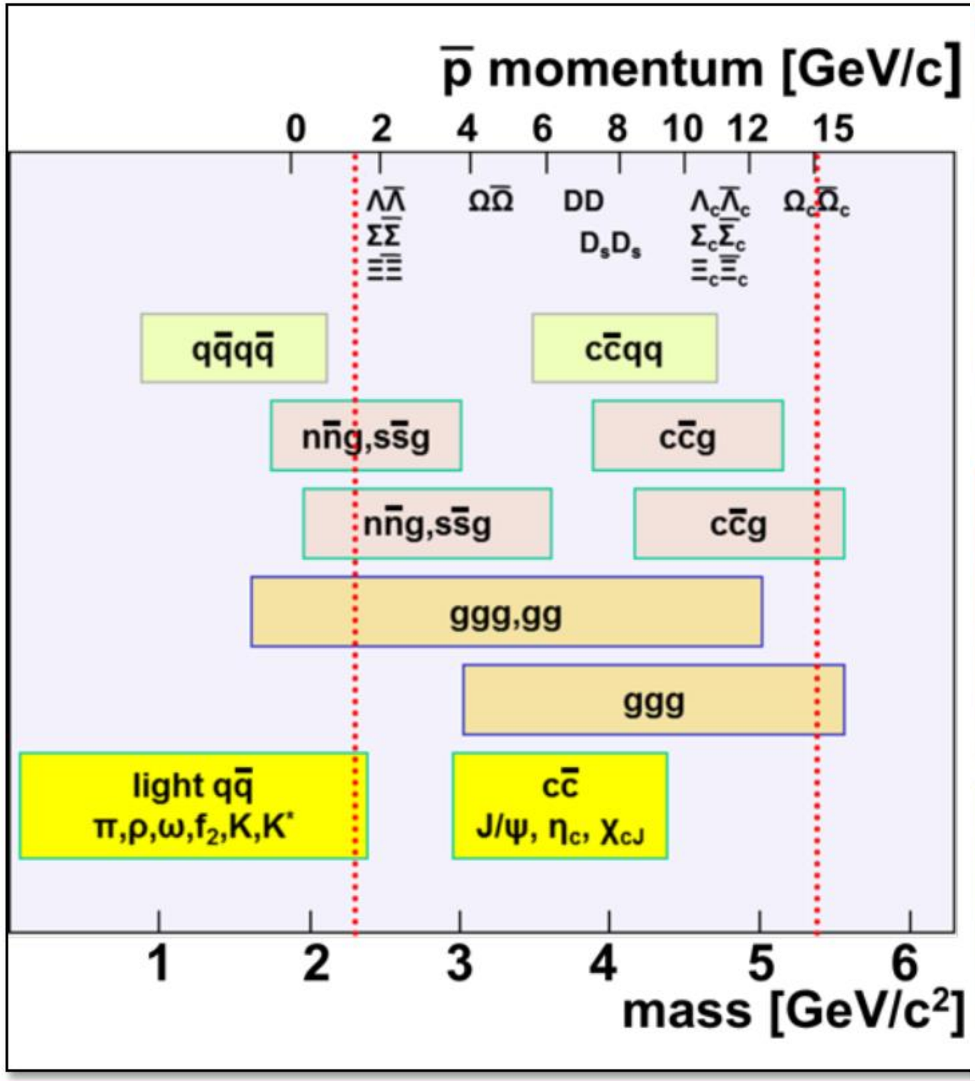


anti-Proton ANnihilation in DArmstadt

PANDA Physics Objectives

Antiprotons – Unique Probes for Discoveries and Precision Physics

→ talk by Miriam Kümmel



Hadron Spectroscopy

Experimental Goals: *mass, width & quantum numbers J^{PC} of resonances*

Charm Hadrons*: charmonia, D-mesons, charm baryons*

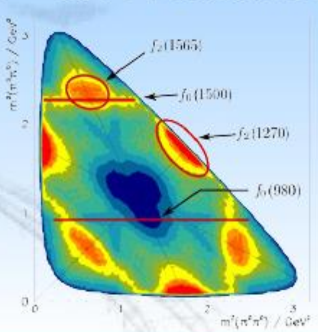
→ Understand new XYZ states, $D_s(2317)$ and others

Exotic QCD States*: glueballs, hybrids, multi-quarks*

Spectroscopy with Antiprotons:

Production of states of all quantum numbers

Resonance scanning with high resolution



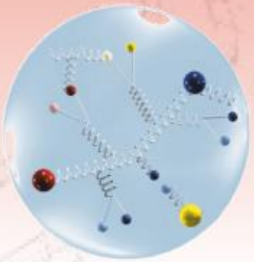
Hadron Structure

Time-like Nucleon Formfactors

→ Measurable in annihilation, discrepancy with space-like

Generalized Parton Distributions

Drell-Yan Process



Nuclear Physics

Hypernuclei*: Production of double Λ-hypernuclei*

→ γ-spectroscopy of hypernuclei, YY interaction

Hadrons in Nuclear Medium

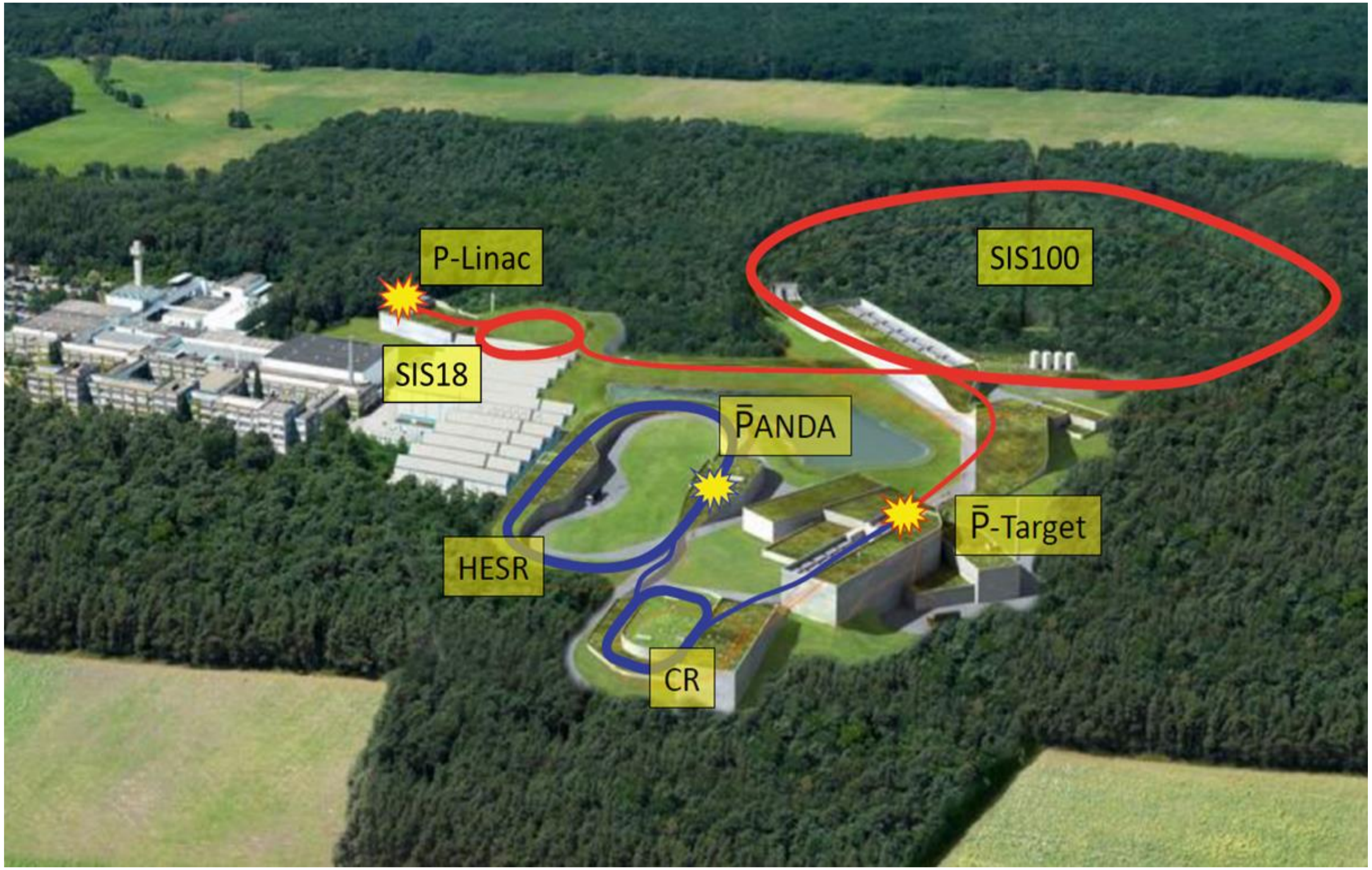
Antiprotons at FAIR

Antiproton production

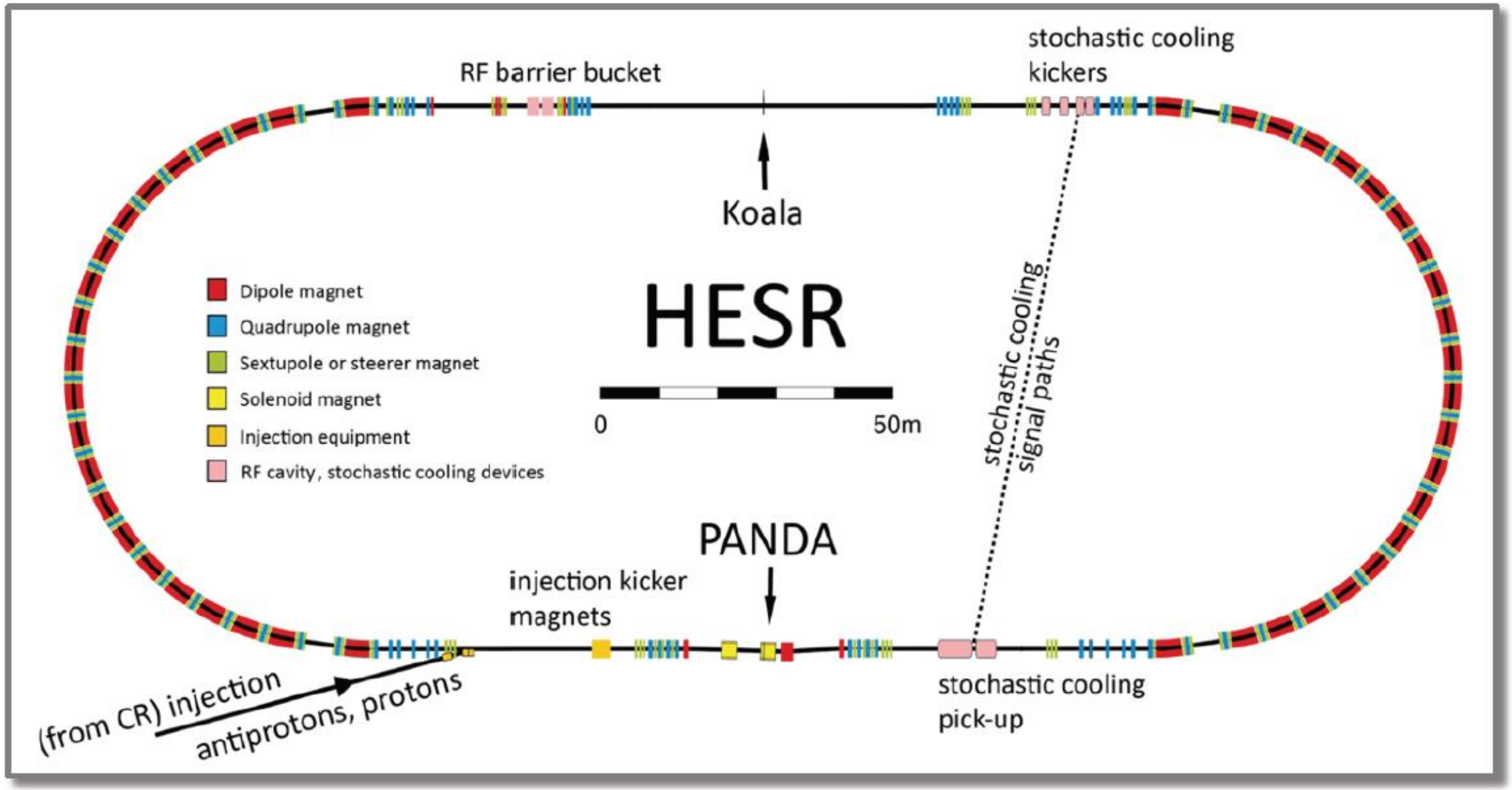
- Proton Linac *(70 MeV)*
- Accelerate p in SIS18/100 *(4/29 GeV)*
- Produce p̄ on Ni/Cu target *(3 GeV)*
- Collection in CR, fast cooling
- Accumulation in HESR
- PANDA luminosity ≤ $2 \times 10^{31} cm^{-2} s^{-1}$
- p̄ momentum: 1.5 – 15 GeV/c
- Fixed target: cluster jet/pellet

- Full FAIR version (Phase 3, after 2026)

Accumulation in RESR, slow cooling
Storage in HESR
PANDA luminosity ≤ $2 \times 10^{32} cm^{-2} s^{-1}$



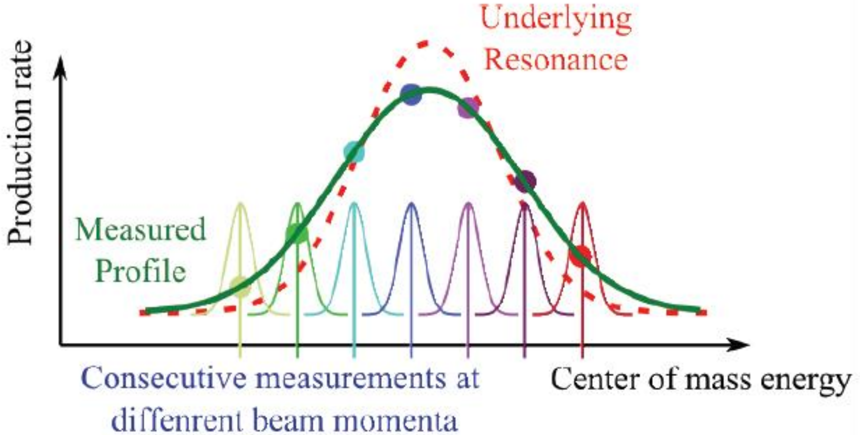
HESR - High Energy Storage Ring



Circumference	575 m
Momentum	1.5 – 15 GeV/c

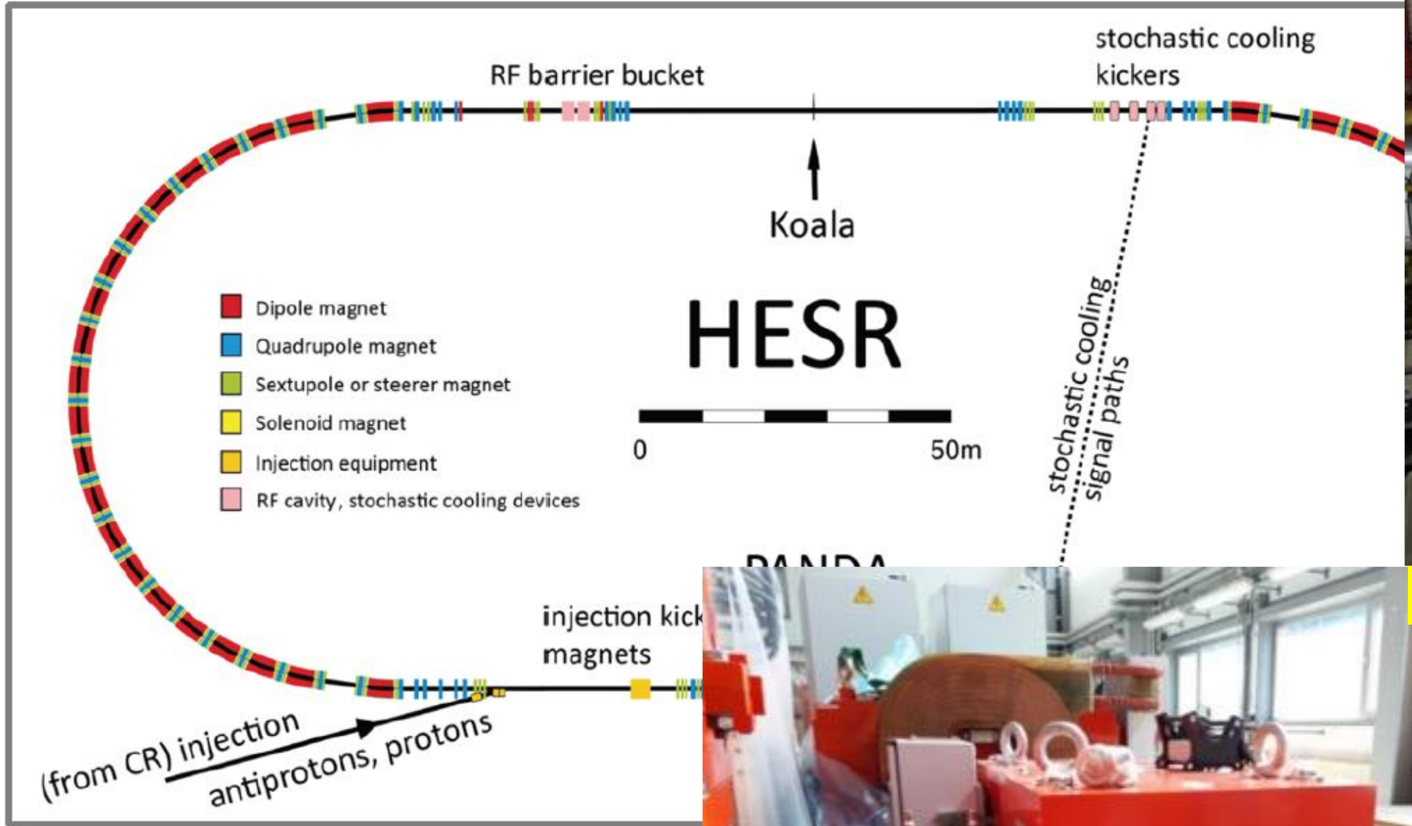
Stochastic cooling
over full momentum range
$\longrightarrow \Delta E \approx 50$ keV

Production experiments
with high-precision beam energy



Mode	High luminosity (HL)	High resolution (HR)
$\Delta p/p$	$\sim 10^{-4}$	$\sim 4 \times 10^{-5}$
L ($cm^{-2}s^{-1}$)	2×10^{32}	2×10^{31}
Stored $\bar{p}$	10^{11}	10^{10}

HESR - High Energy Storage Ring



HESR components-FZ Jülich

Mode	High lumi
Δp/p	~
L ($cm^{-2}s^{-1}$)	2x
Stored p̄	1

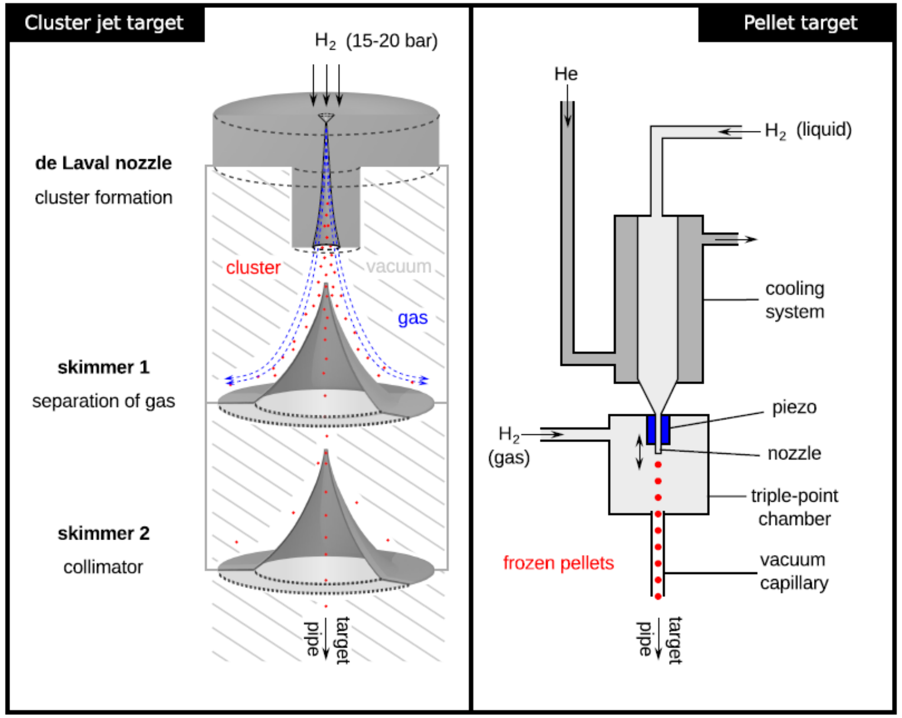
PANDA Targets

Cluster Jet Target

- Expansion of pre-cooled and compressed hydrogen gas into beam pipe
- Cluster jets move with supersonic speed during condensation
- Size: 10^3-10^5atoms/cluster

Project status:

- **TDR approved**
- Continuous development
- Nozzle improvement
- Better alignment by tilting device
- **Goal:**
  $4 \times 10^{15} cm^{-2}$ target density already achieved
- Continuous improvements



Pellet Target

- Small droplets of frozen hydrogen created in triple point chamber
- Pellet diameter: 10 – 30 µm
- Vertical injection into target tube
- Falling speed: 60 m/s
- Flow rate: 100,000 pellets/s
- $> 4 \times 10^{15} cm^{-2}$ feasible

Project status:

- Prototype under way
- Pellet tracking prototype ready
- TDR in progress, due 2020

Photo of the cluster-jet beam (false colour). Visible are the two highly intense core beams.

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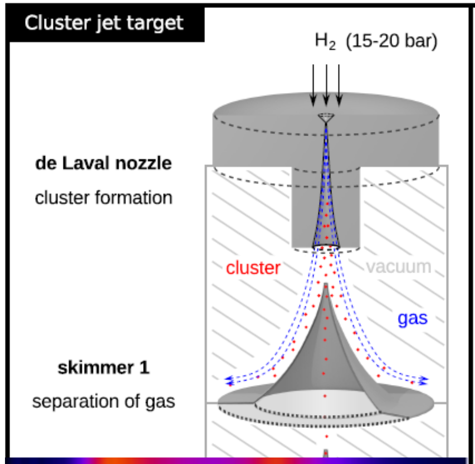

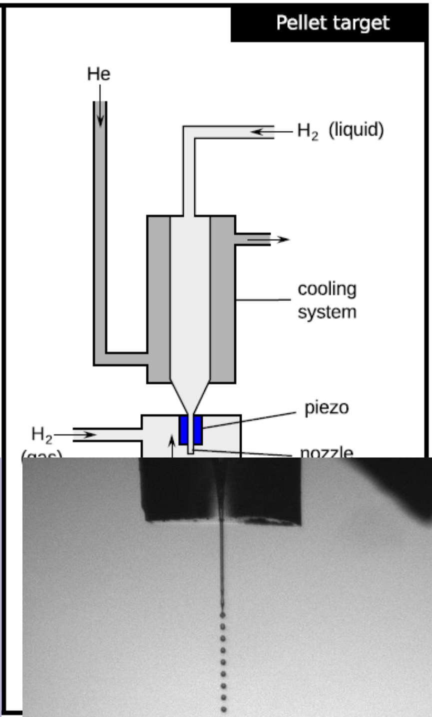

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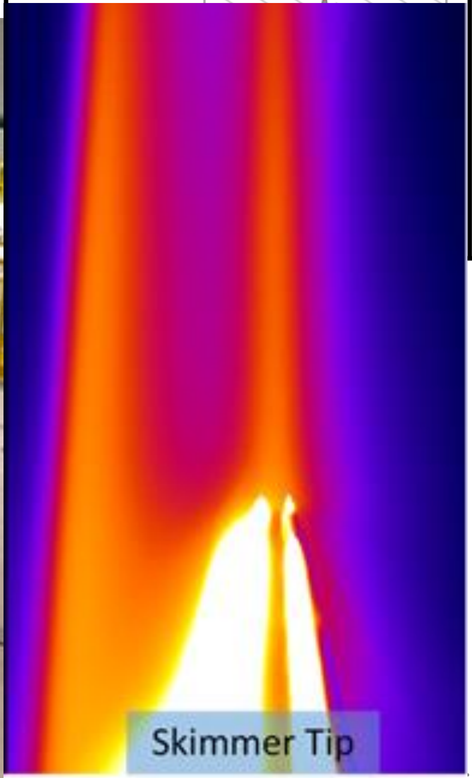


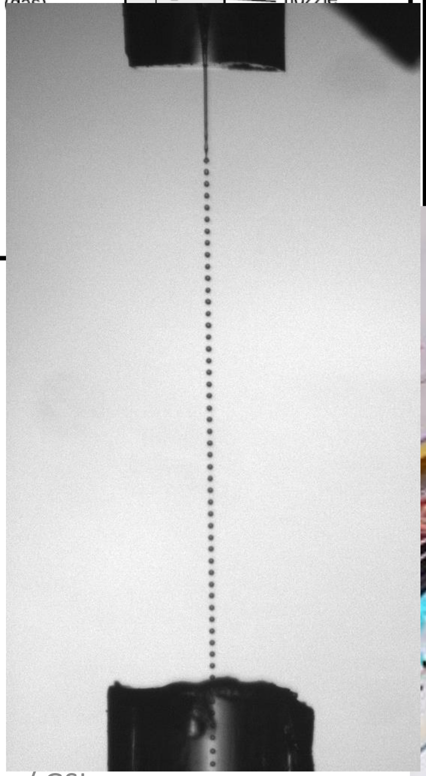
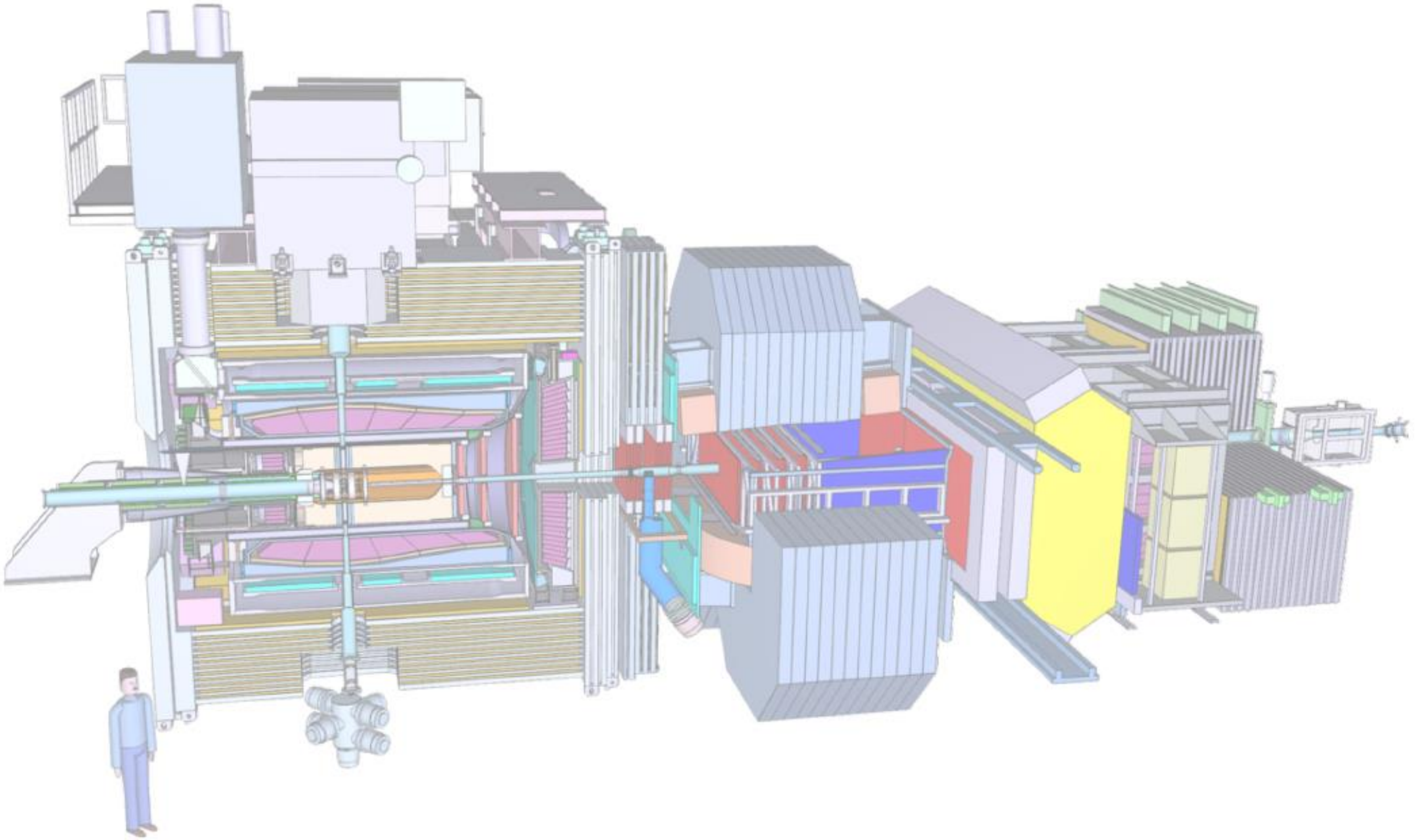


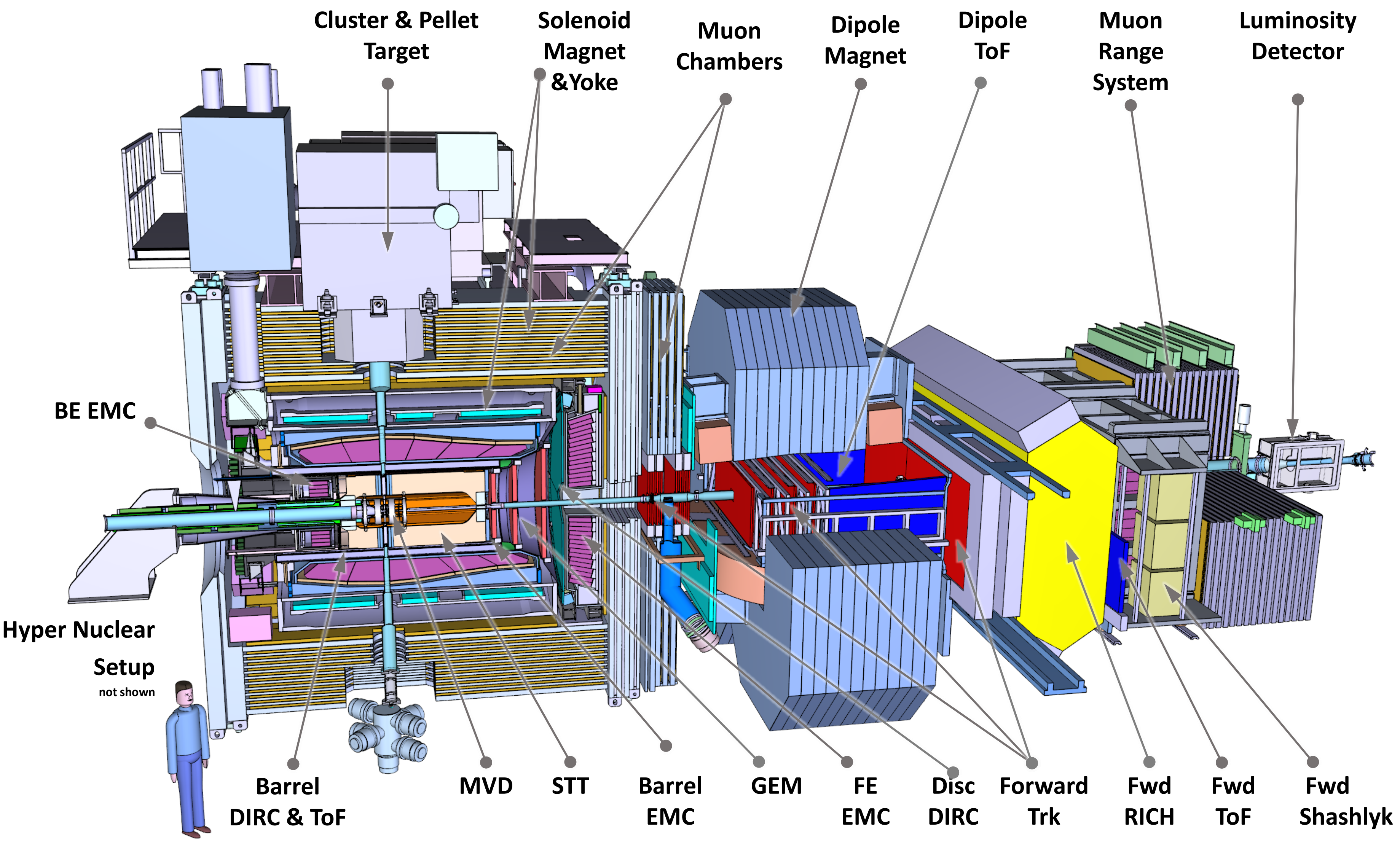
Photo of the cluster-jet beam (false colour). Visible are the two highly intense core beams.

Detector Requirements

- 1.5 – 15 GeV/c antiprotons on fixed target
  → asymmetric layout
- 4π acceptance
- High rate capability: up to
  20MHz average interaction rate
- Efficient event selection for data reduction
- Continuous data acquisition
- Momentum resolution: ~1%
- Precision vertex information for D, K^0_s, Υ
- γ detection for 1 MeV – 10 GeV
  → crystal calorimeter
- Good Particle ID (e, μ, π, K, p)
  → dE/dx, ToF, RICH/DIRC, muon chambers



The PANDA Detector



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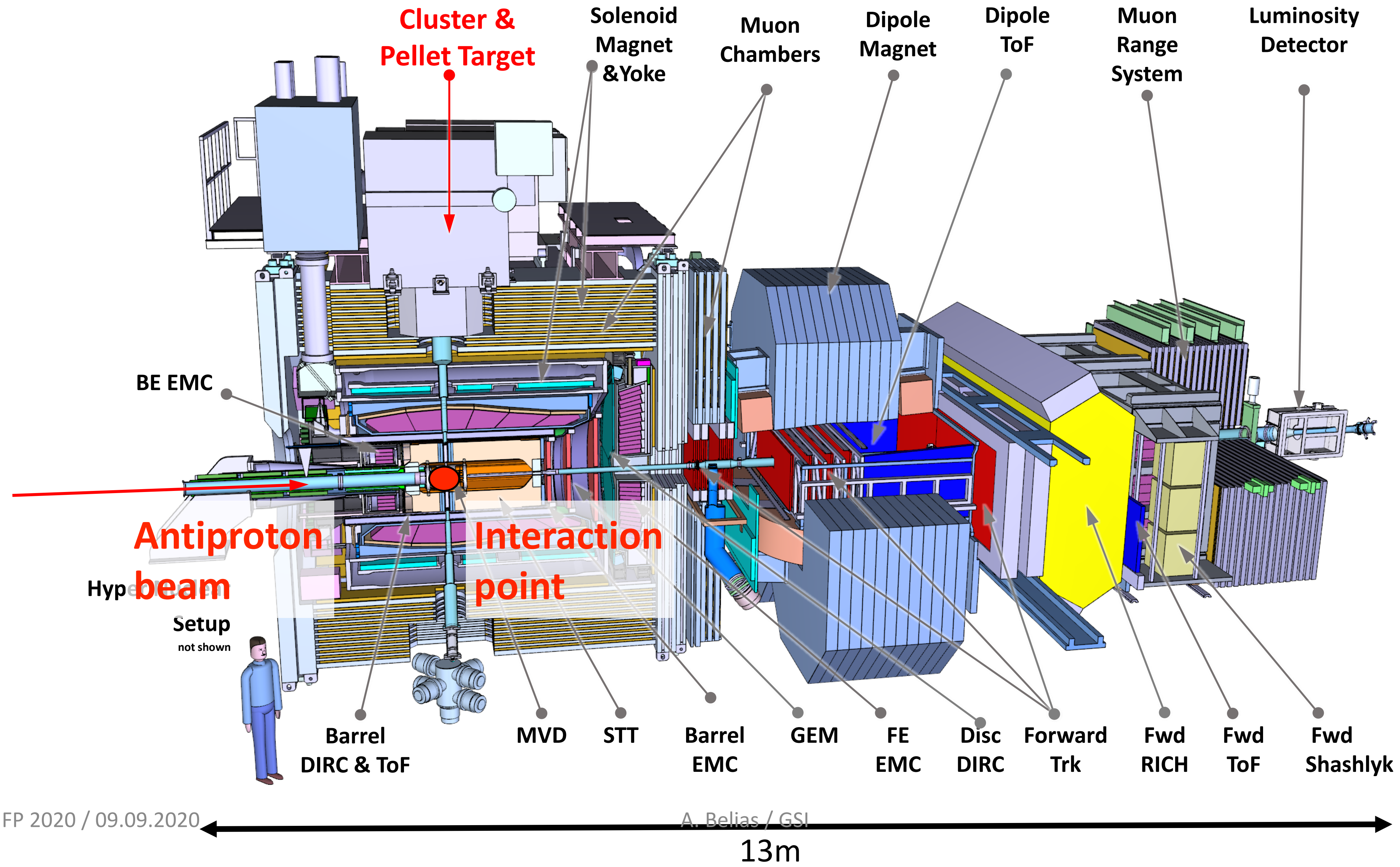

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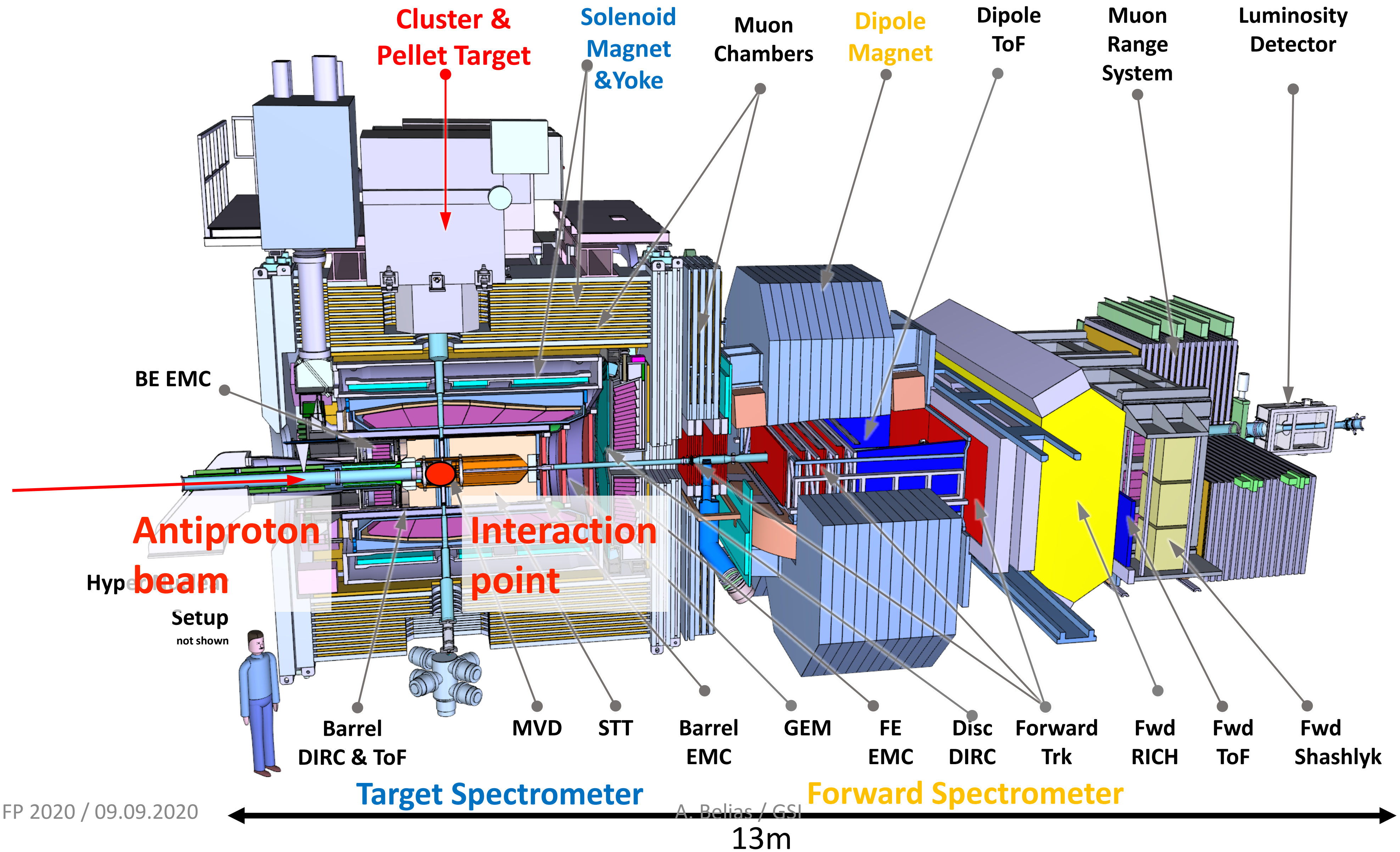


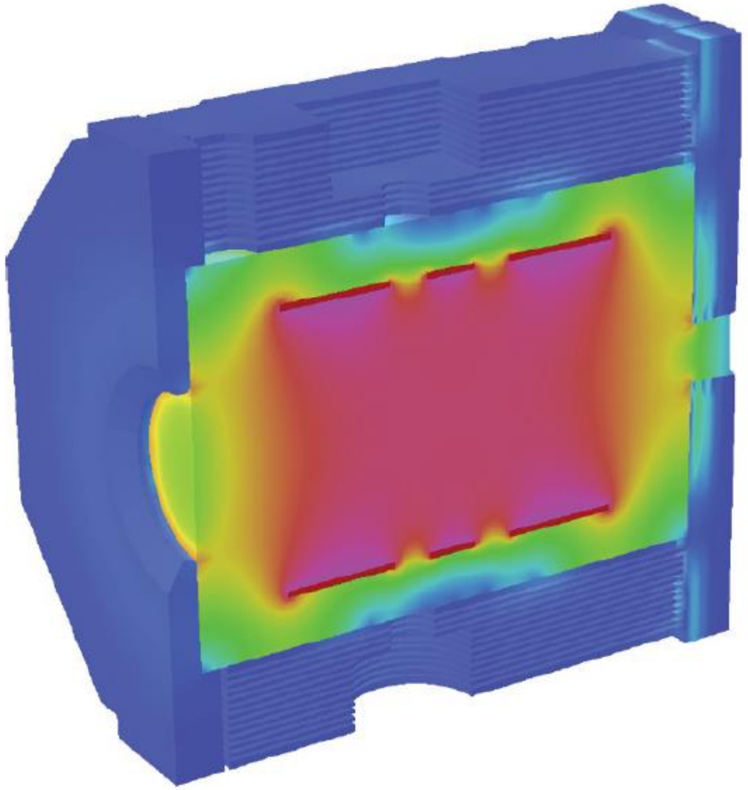
PANDA Magnets

Solenoid Magnet

- Super conducting coil, 2 T central field (B_z)
- Segmented coil for target
- Instrumented iron yoke – muon chambers
- Doors laminated, instrumented, retractable

Status

- Design and production contract with BINP started
- Cooperation with CERN for cold mass
- Conductor production development
- Joint venture, BINP and Russian Institutes
- Yoke production started



Inner bore: ∅ 1.9 m /L: 2.7 m

Outer yoke: ∅ 2.3 m /L: 4.9 m

Total weight: 300 t

Dipole Magnet

- Normal conducting racetrack design, 2 Tm
- Forward tracking detectors partly integrated
- Dipole also bends the beam
- HESR component

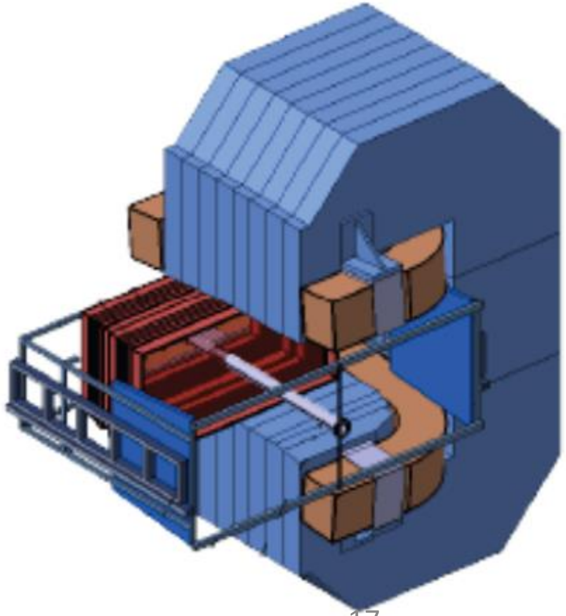
Status

- Design contract with BINP started

Vertical acceptance: ± 5°

Horizontal acceptance: ± 10°

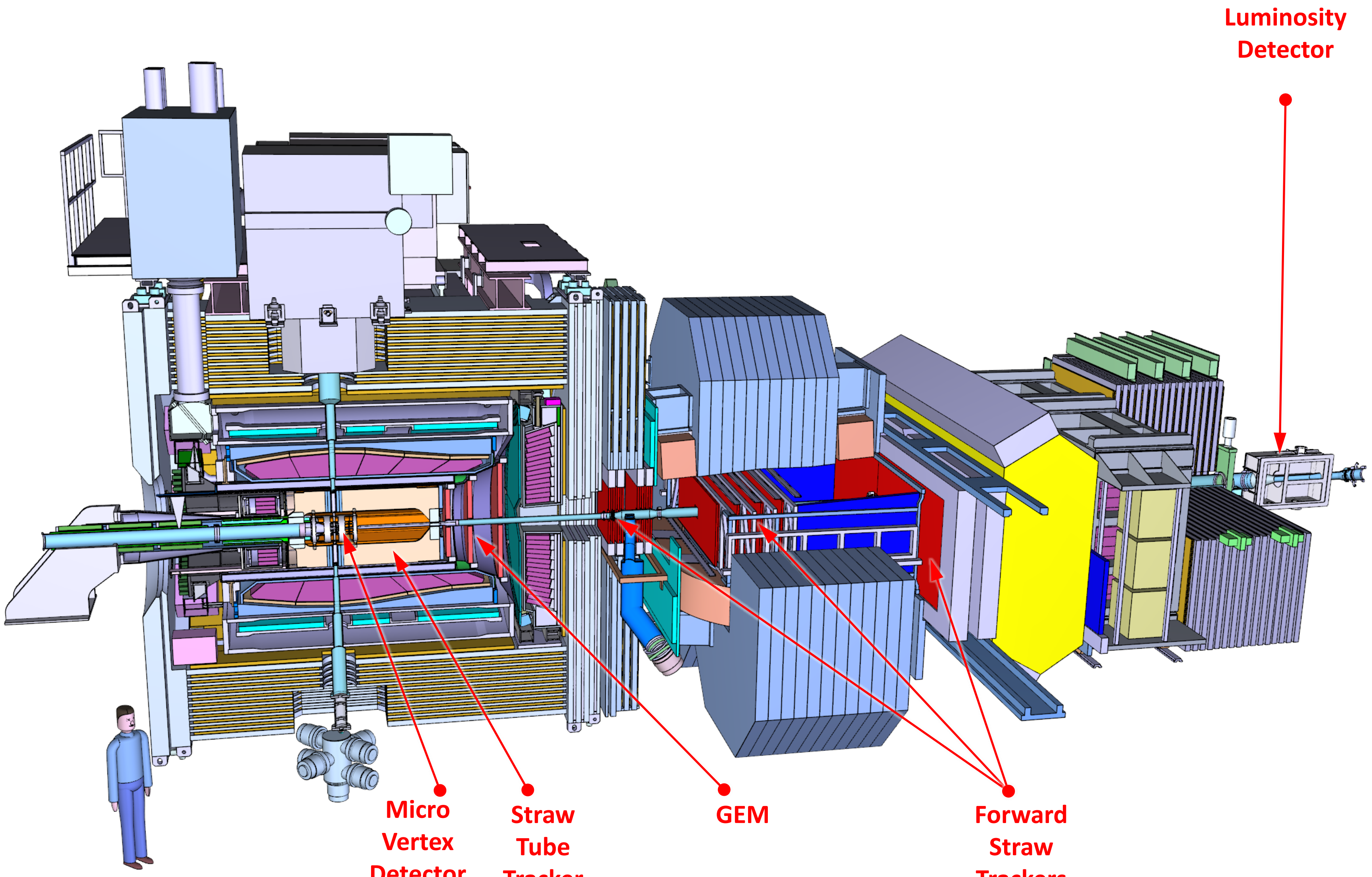
Total weight: 200 t



PANDA – Solenoid Magnet in production

PANDA Solenoid Magnet production-BINP

The PANDA Detector - Tracking



Micro-Vertex Detector

Design of the Silicon MVD

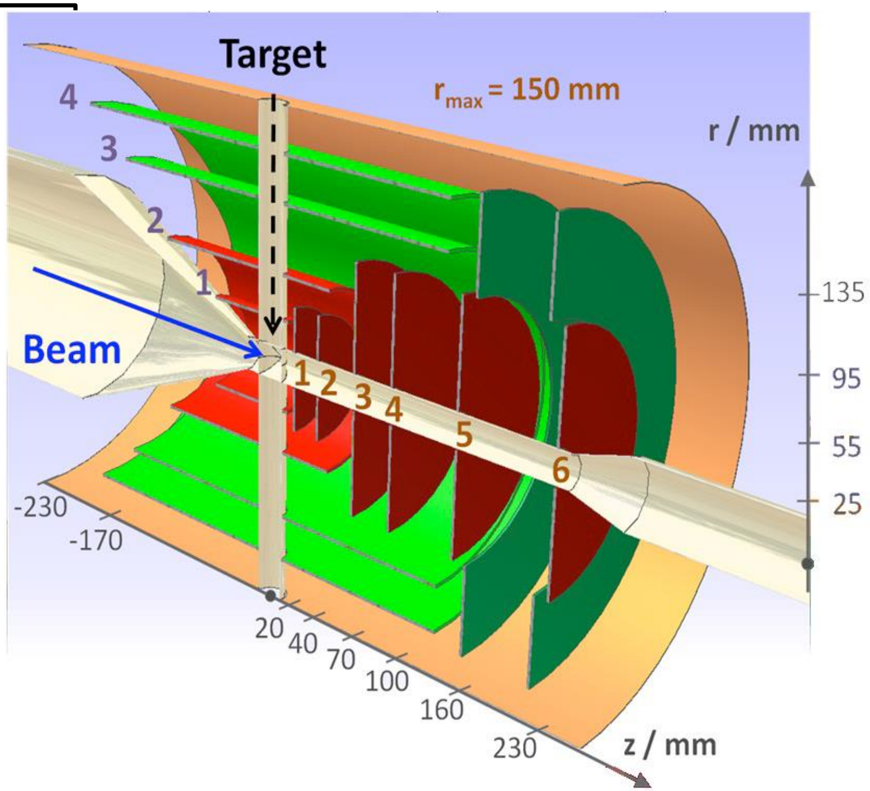
- 4 barrels and 6 discs
- Hybrid pixels – inner layers
  - $100 \times 100\ \mu m^2$
  - ToPiX ASIC, 0.13 µm CMOS
- Double sided strips – outer layers
  - Rectangles and trapezoids
  - 130 (70) µm pitch 90 (15) stereo angle
  - ToASt ASIC 110 nm CMOS
- Mixed forward disks (pixels/strips)
- 6 ns timing resolution
- 50 µm vertex resolution, δp/p~2%

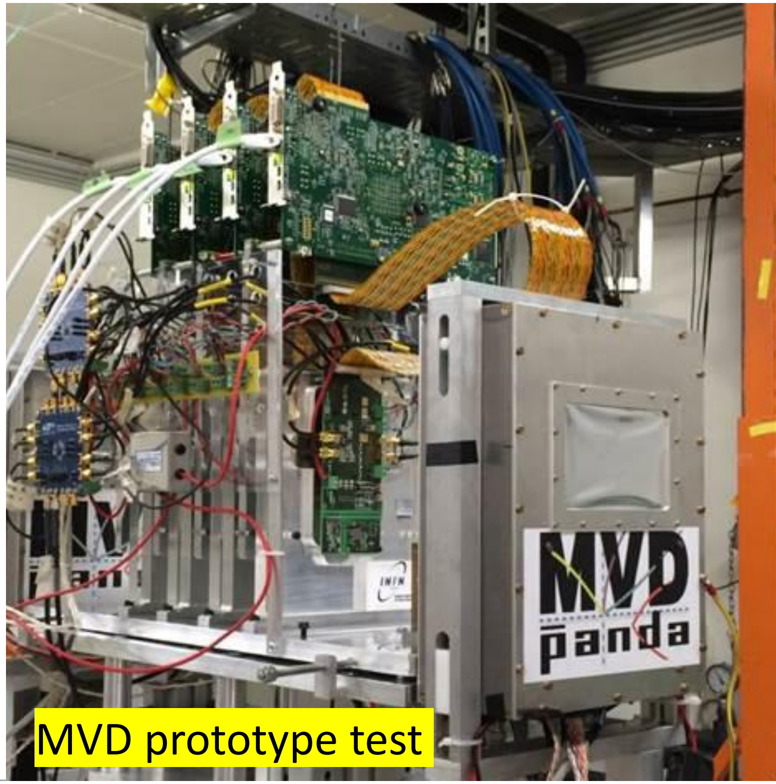
Challenges

- Low material budget X/Xo ≤ 1 % / layer
- Radiation tolerance < $10^{14} n_{1MeV\ eq}\ cm^{-2}$
- Continuous readout @clk 160 MHz of 10.5×10^6 channels

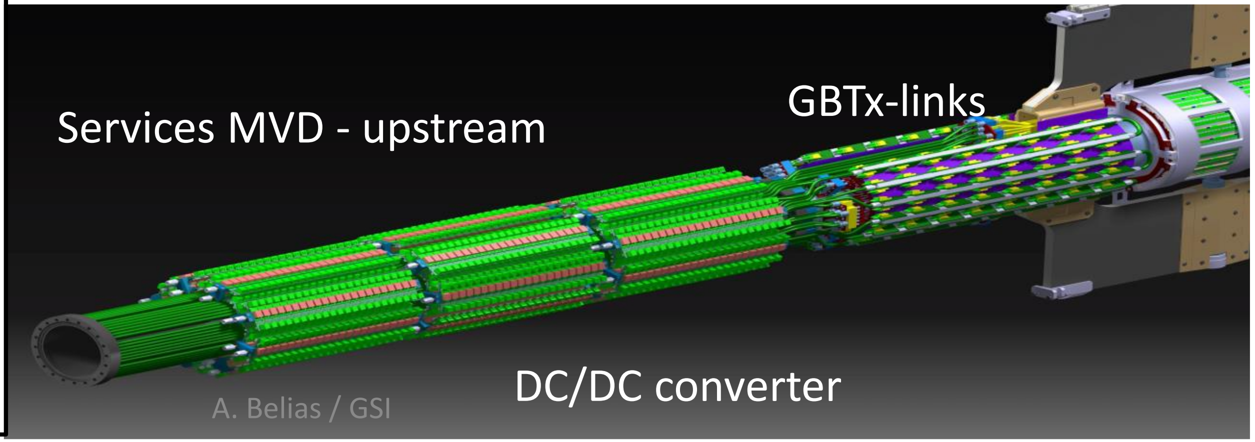
Project status

- **TDR approved**
- ASIC prototypes tests & adaptation
- Radiation hard links GBTx & DC/DC (CERN)
- **Detailed service planning & prototypes**





MVD prototype test

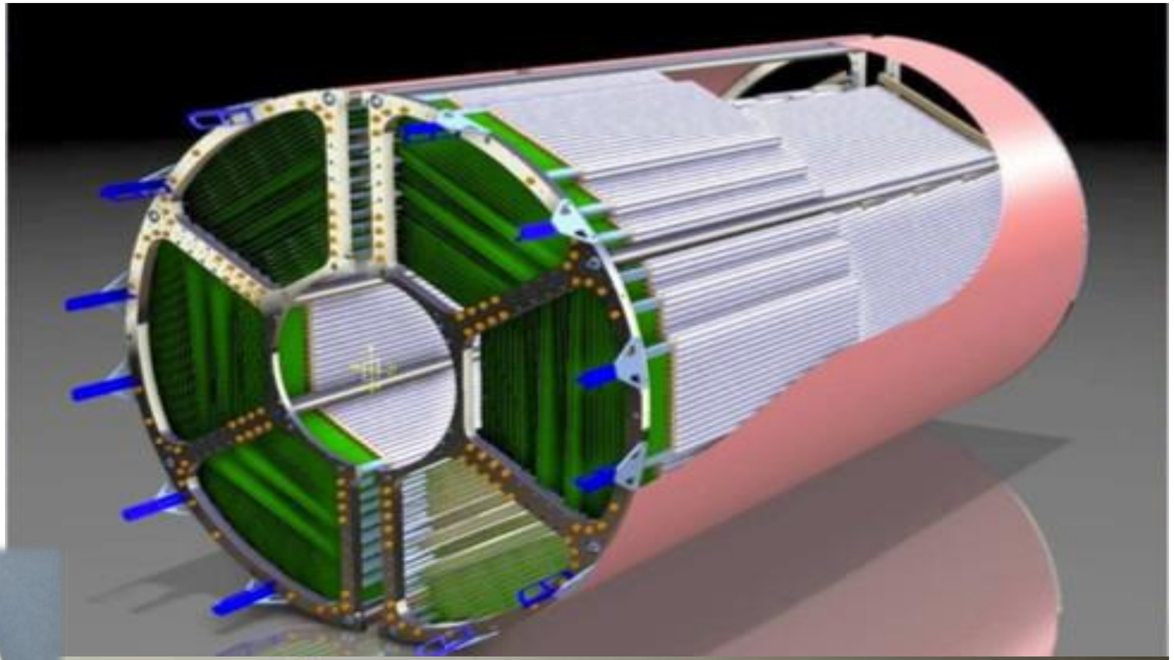


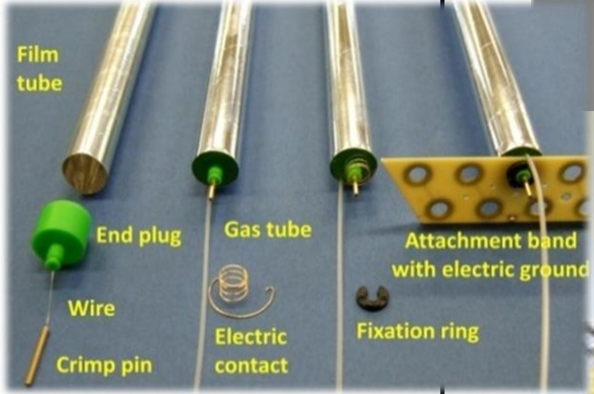
Straw Tube Tracker

Detector Layout
- Layers of drift tubes
- R_{in}= 150 mm, R_{out}= 420 mm, l=1500 mm
- Tube made of 27 µm thin Al-mylar, O=1cm
- **Self-supporting straw double layers at ~1 bar overpressure (Ar/CO_2) developed at FZ Jülich**
- 4600 straws in 21-27 layers, of which 8 layers skewed at ~3°
- **Resolution: r,ϕ ~150µm, z ~1mm**

Material Budget
- 0.05 % X/X_0 per layer
- **Total 1.3% X/X_0**

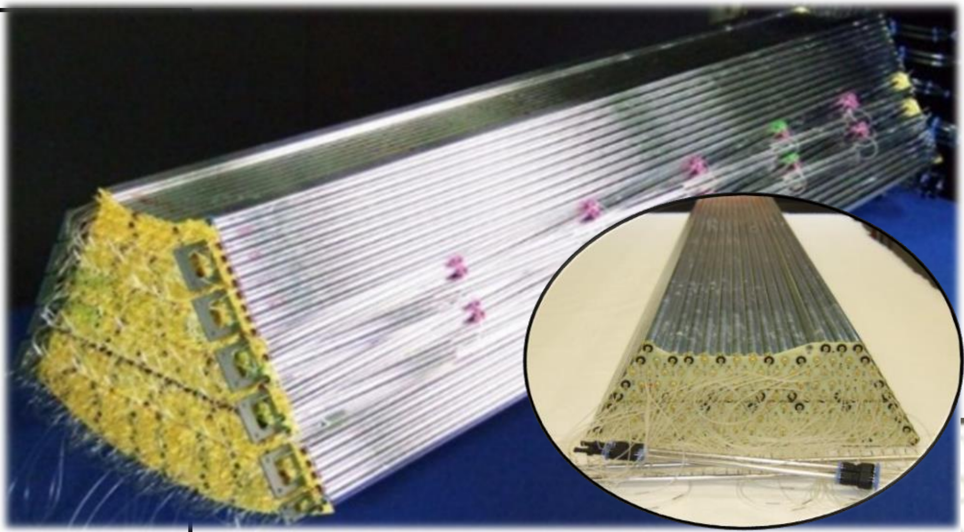
Project Status
- **TDR Approved**
- Readout prototypes & beam tests
- Ageing tests: up to 1.2 C/cm^2
- Straw series production finished
- Module production starting

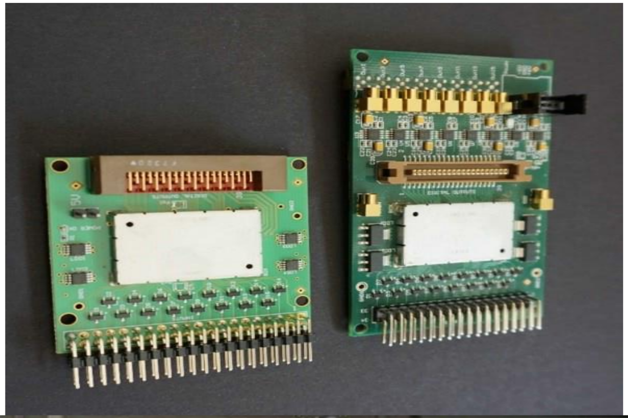




STT model

Straw Tube Tracker Developments

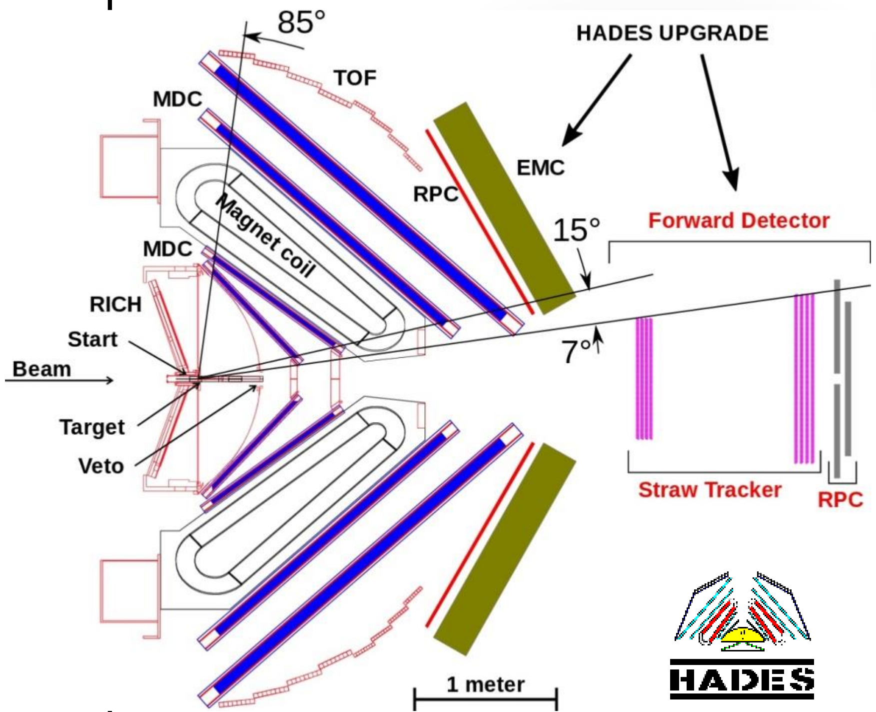




Mechanics status
- Modules assembly scheme
- Prototype frame installed

Electronics readout
- **ASIC (PASTTREC) &TDC FPGA**
  AMS 0.35μm CMOS
  - time and ToT and PID quality
- Sampling FADC (upgrade)
  - time and pulse area

Testbeam campaigns 2018/2019
- Characterize readout type
- Optimize operational parameters
- Resolution: σ < 130 μm
- PID: p/MIP ~ 4σ @ 0.8 GeV/c



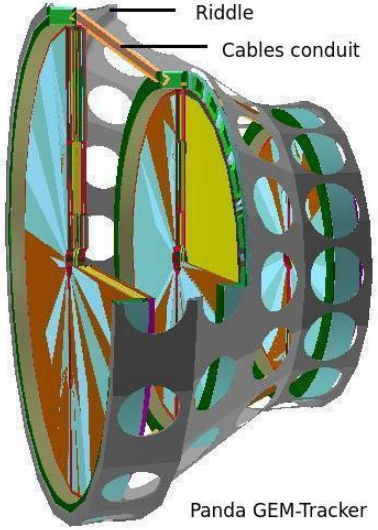
PANDA Straw Tube Tracker in HADES
Hyperon Physics @GSI
2019: Installation
2020+: Data Taking

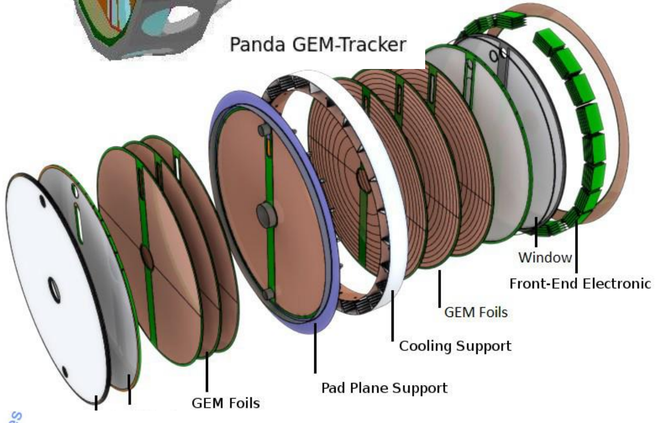
Gaseous Electron Multiplier Tracker

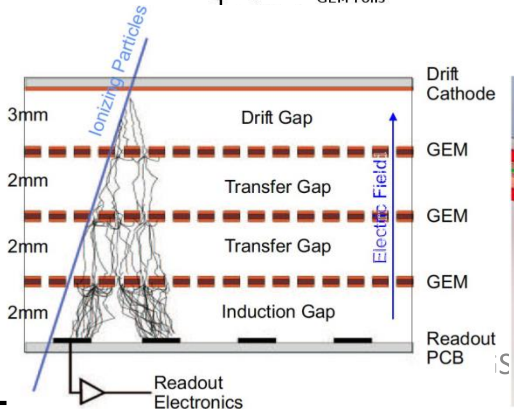
Forward Tracking inside Solenoid
- Tracking in high occupancy region
- Important for large parts of physics

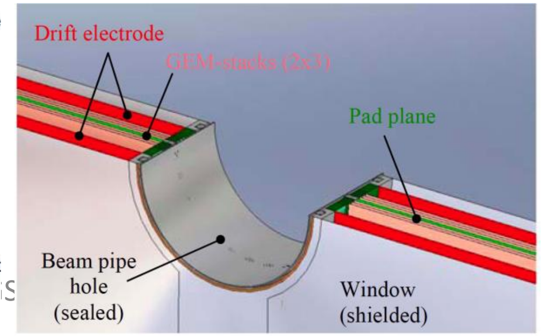
Detector design
- 3 stations with 4 projections each
  ➔ Radial, concentric, x, y
- Central readout plane for 2 GEM stacks
- Large area GEM foils developed at CERN technology transfer
  (50µm Kapton, 2-5µm copper coating)
- Outer diameter (mm): 900, 1120,1480
- ADC readout for cluster centroids
  ➔ Approx. 35000 channels total
- Challenge to minimize material

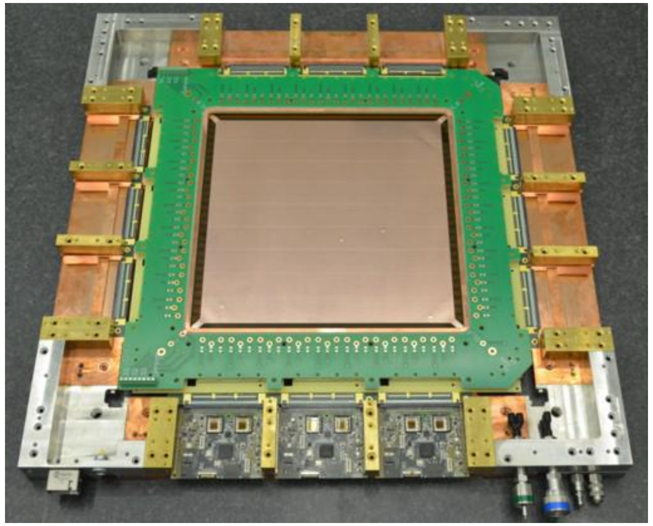
Project status
- Advanced mechanical concept
- Demonstrator construction ongoing, GEM foils by TECHTRA received
- Readout electronics tests
- **TDR in 2020**











2D Demonstrator

Challenges → Opportunities:
- Completion of demonstrator
- Test large area GEM foils
- Readout electronics tests
- Full size prototype design
- Quality control
- Operations control

Forward Tracker

Tracking in Forward Spectrometer

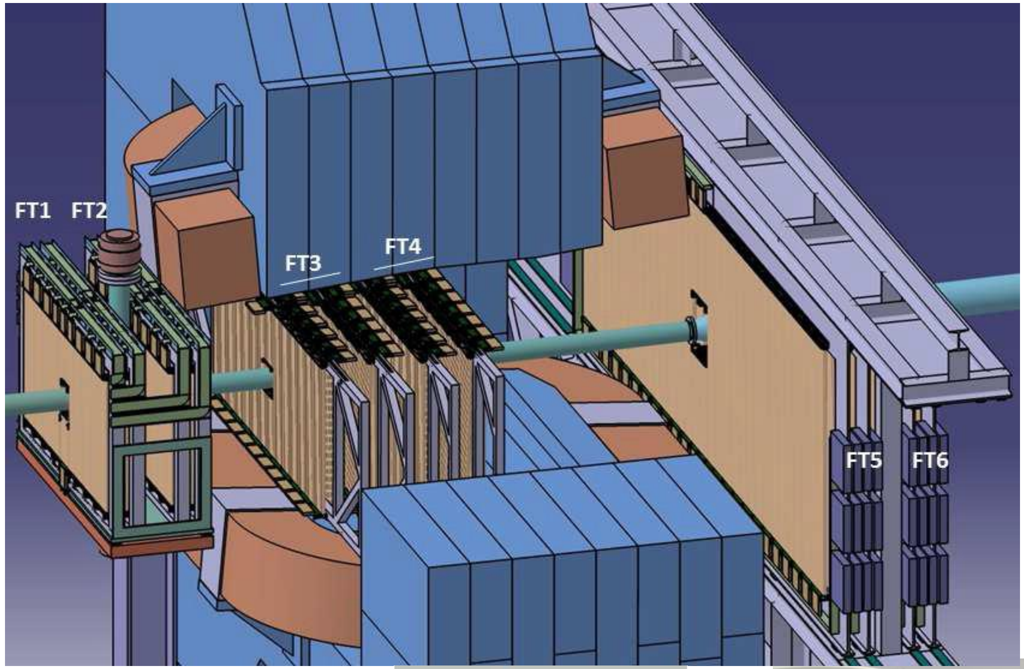
- **3 stations with 2 chambers each**
  - FT1&2 : between solenoid and dipole
  - FT3&4 : in the dipole gap
  - FT5&6 : large chambers behind dipole
- **Straw tubes arranged in double layers**
  - 27 µm thin Al-mylar, O=1cm tubes
  - Stability by 1 bar overpressure, as STT
- 4 projections 0°/+ -5°/0° per chamber
- Readout ASIC (PASTREC) & TDC FPGA

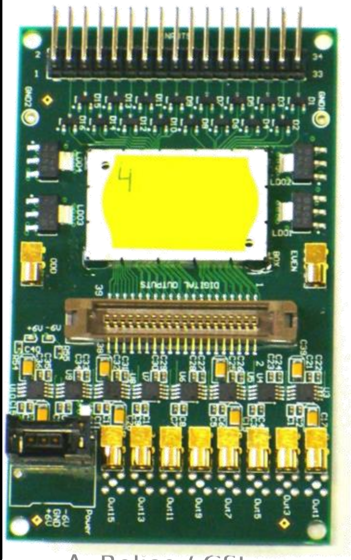
Project status

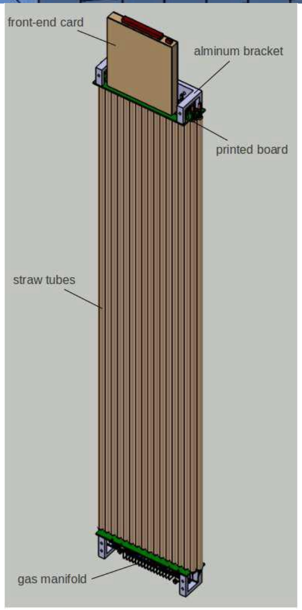
- **TDR approved**
- Testbeam campaigns 2018/2019
- Ongoing aging tests: up to ~1 C/cm^2

PANDA Straw Tube Tracker in HADES
Hyperon Physics @GSI
2019: Installation
2020+: Data Taking

FAIR Phase 0 Research Program







Luminosity Detector

Elastic scattering:

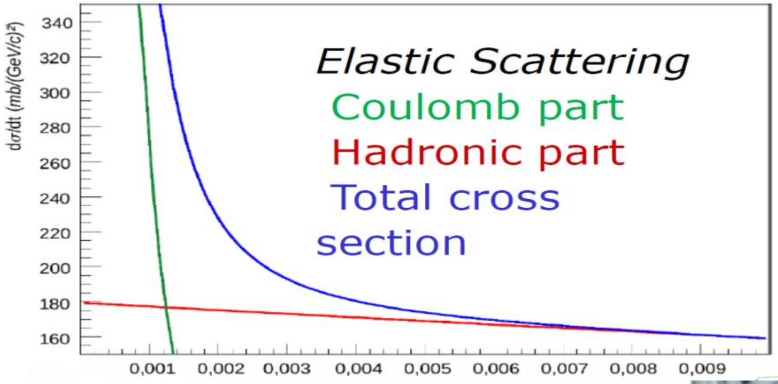
- Coulomb part calculable
- Tracking scattered p̄
- Acceptance 3-8 mrad

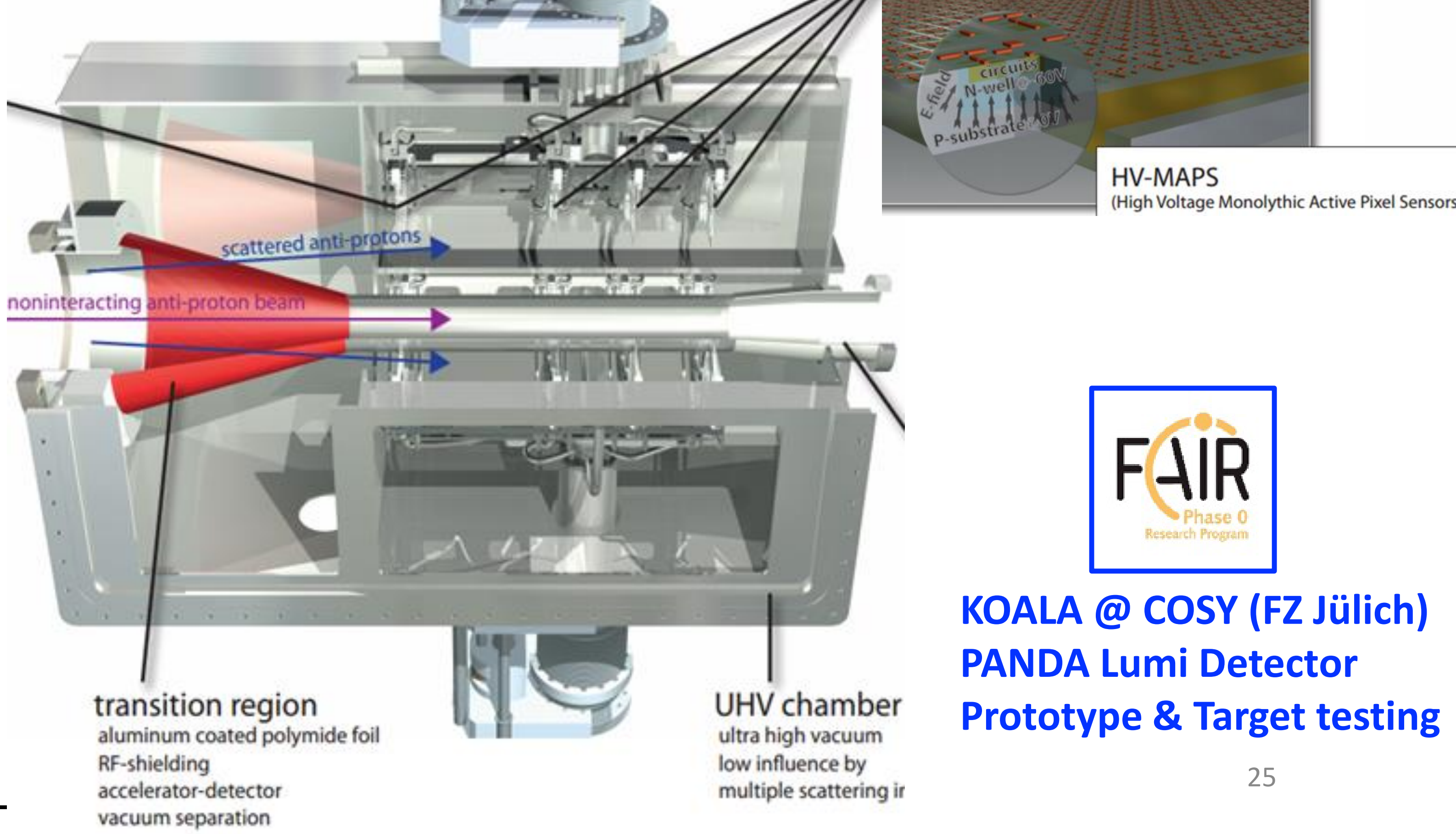
Detector layout:

- Roman pot system at z=11 m
- **Silicon pixels (80x80 µm2):**
  4 planes of HV MAPS (50 µm thick)
  - Active pixel sensor HV CMOS (Mu3e)
  - Digital processing on chip
  - Faster and more rad. hard
  - **Testbeams: S/N ~ 20**
    Efficiency ~99,5 %
- CVD diamond supports (200 µm)
- Retractable half planes in sec. vacuum

Project status:

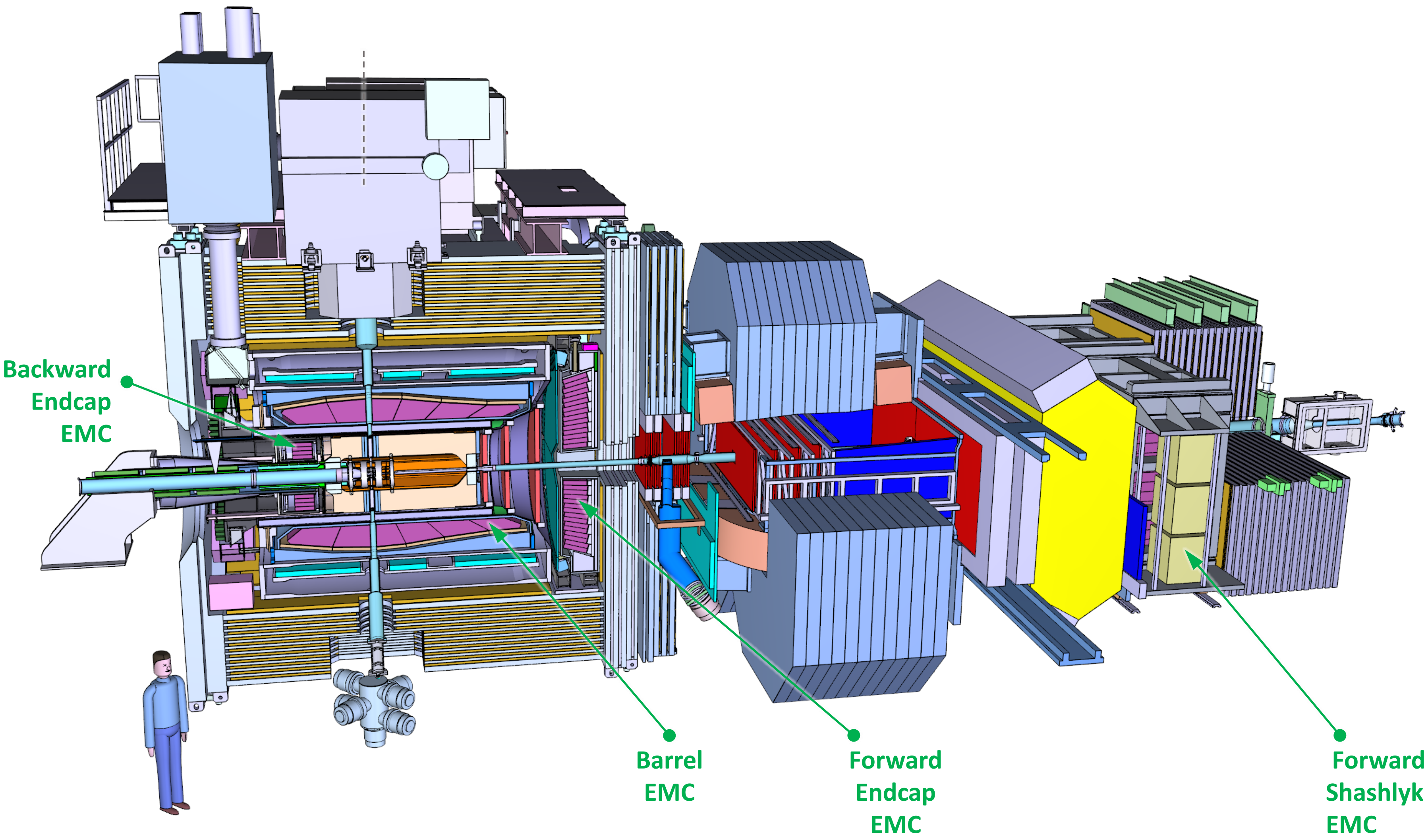
- **TDR approved**
- Mechanical vessel, vacuum, cooling ready
- CVD diamond supports available
- New large sensors (2x2.3 cm2) due tests





KOALA @ COSY (FZ Jülich)
PANDA Lumi Detector
Prototype & Target testing

The PANDA Detector - Calorimetry



Target Electromagnetic Calorimeter

Crystal Calorimeter based on ~15,500 high quality second-generation PWO II ($PbWO_4$) crystals

- Small radiation length X_0 = 0.89 cm (20cm ≈ 22 X_0)
- Short decay time τ=6.5 ns
- Increased light yield, at -25°C
- Time resolution <2ns
- Coverage: 99.8% of 4π
- **TDR approved**

Challenges

- temperature stable to 0.1 °C
- control radiation damage

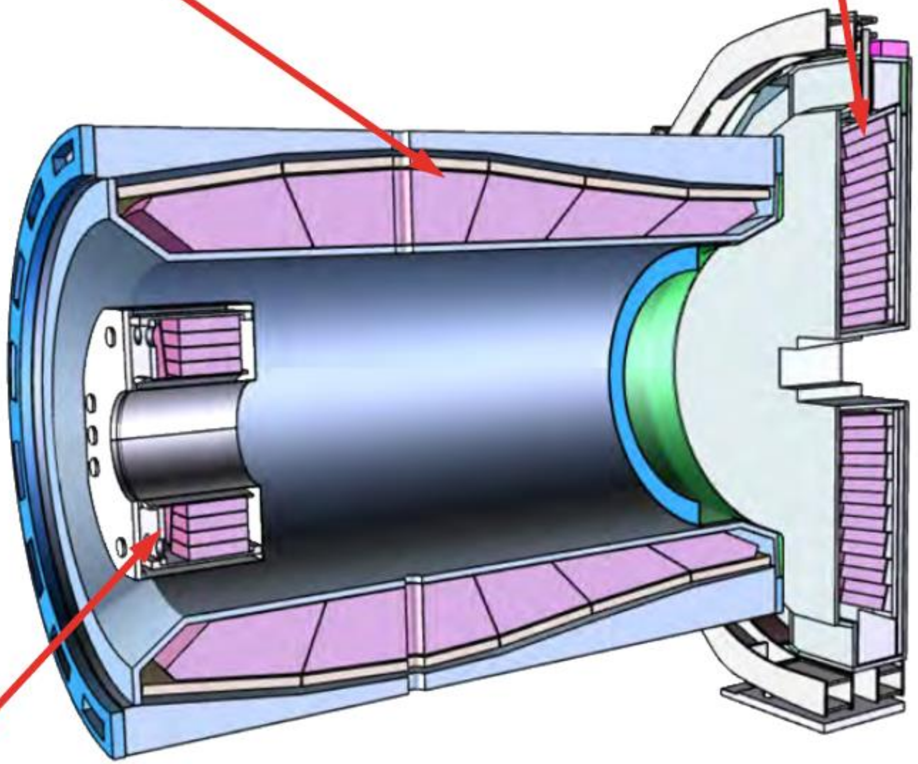
Large Area APDs

Barrel Calorimeter

11000 crystals PWO II
LAAPD readout, 2x1cm²
σ(E)/E~1.5%/√E + const.

Forward Endcap

4000 crystals PWO II
High occupancy in center
LA APD and VPTT



Backward Endcap for hermeticity, 530 crystals PWO II

Barrel & Backward Endcap EMC

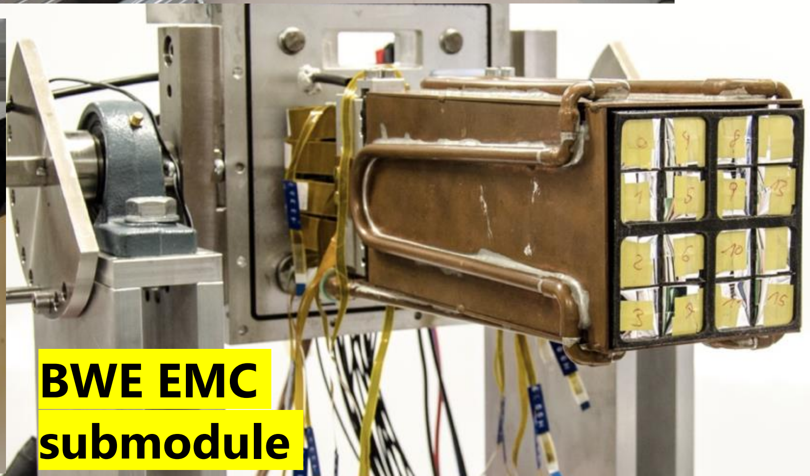
PWO Crystal Production
- Main part ~60% produced at BTCP (Russia)
- New producer Crytur (Czech Republic)
- Tests on scintillation yield, optical transmission, radiation hardness

APD Screening
- Screening of 30000 APDs
- Facility (RUB) full shift operation

Barrel EMC Status
- All alveoles produced
- PWO crystal production ongoing
- APD readout ASIC (GSI) all produced
- First slice(of 16) assembled

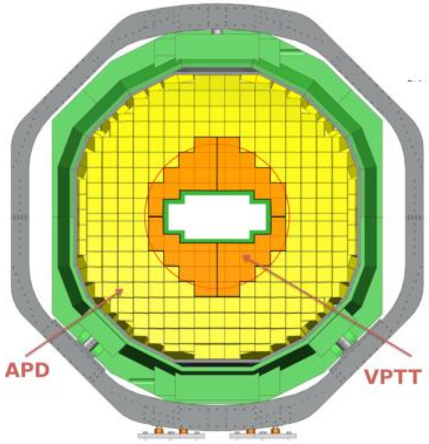
Backward Endcap EMC Status
- Submodule design ready
- Prepare series production
- Readout new ASIC tests successful

Activities at MAMI - BWE EMC data taking with A1 spectrometer for high-resolution electron scattering in coincidence with hadrons (FAIR Phase 0)



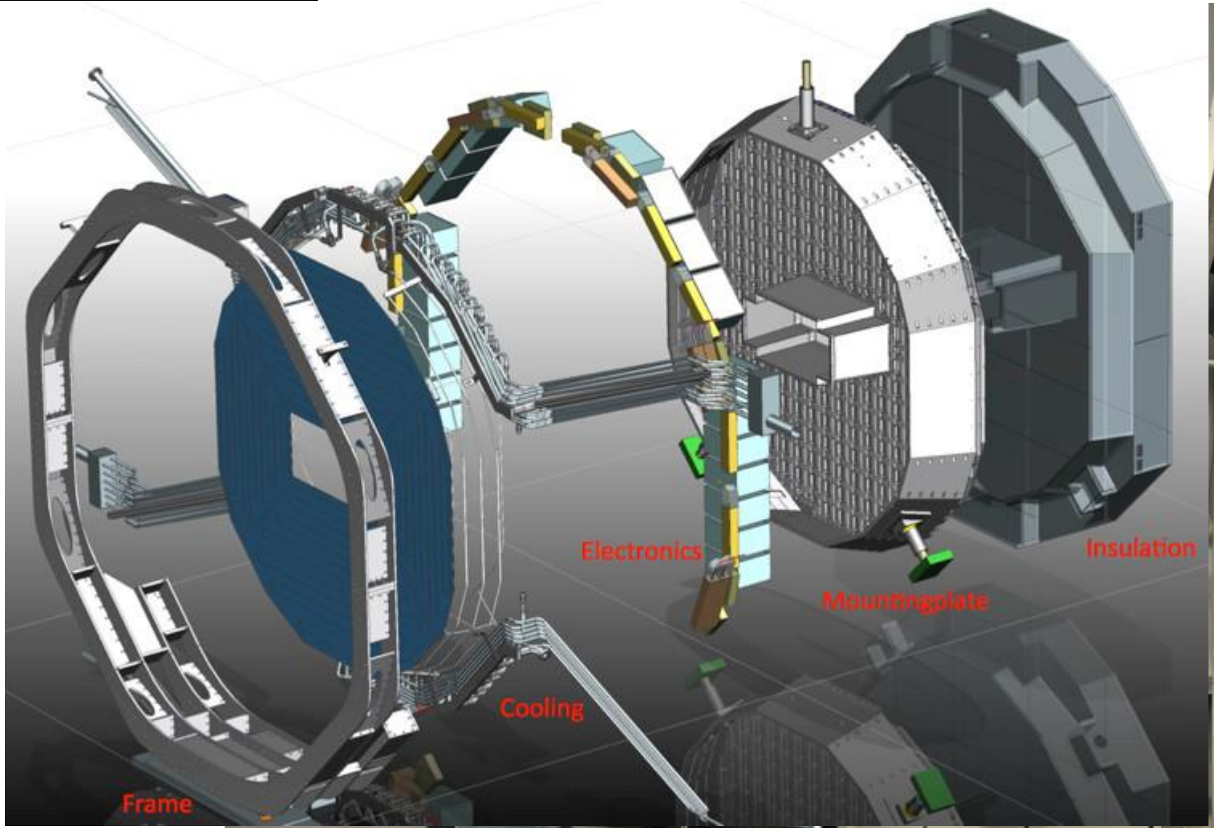
Forward Endcap EMC

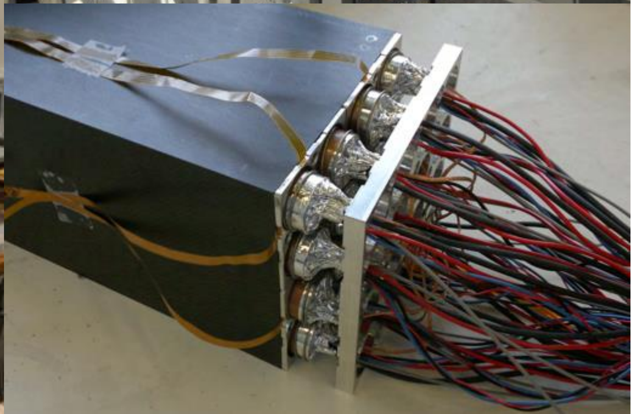
- Production well advanced
- All crystals are produced
- Sensors:
  Photo Tetrodes (VPTT)
  and LA APD



- VPTT modules production done
- APD screening progress
- APD modules assembly started
- FADCs for digitization
- SADC boards produced (w/ Versatile Link/VL+)
- Tests & calibration with cosmics started
- Cooling system available, work on controls
- Pre-assembly support prepared

First detector system to be fully assembled





Forward Spectrometer Calorimeter

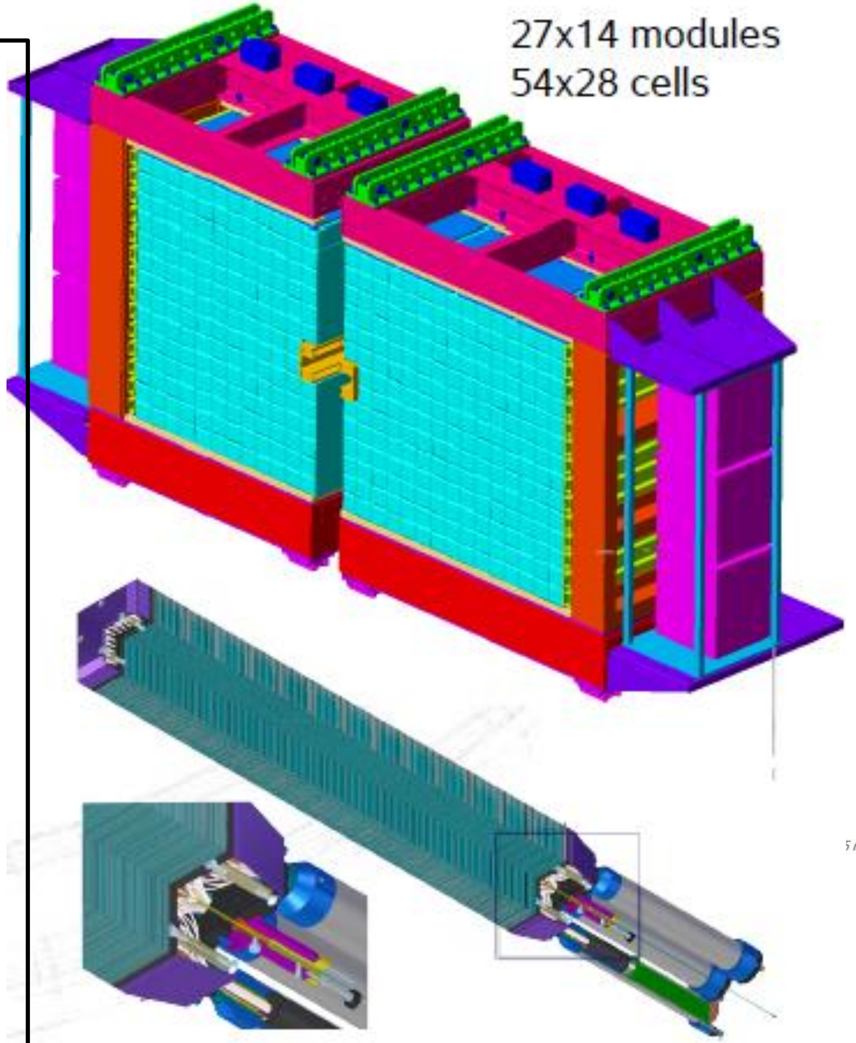
Forward electromagnetic calorimeter
- Interleaved scintillator and absorber layers
  - 380 layers of 0.3 mm lead and 1.5 mm scintillator, total length 680 mm
  - Transverse size 55x55 mm^2
- WLS fibers for light collection
- Active area size 297x154 cm^2
- PMTs for photon readout
- FADCs for digitization

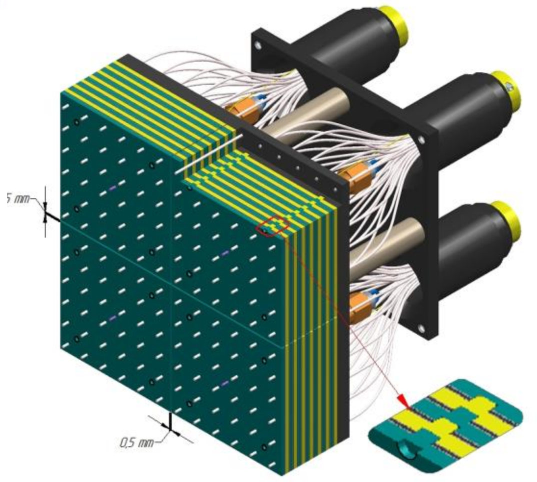
Project Status
- **TDR approved**
- Module design 2 x 2 cells of 5.5 x 5.5 cm^2 verified
- Tests with electrons and tagged photons:

→ Energy resolution
- $\frac{\sigma_E}{E} = 5.6/E \oplus 2.4/\sqrt{\mathrm{E[GeV]}} \oplus 1.3\ [\%]$ (1-19 GeV e$^-$)
- $\frac{\sigma_E}{E} = 3.7/\sqrt{\mathrm{E[GeV]}} \oplus 4.3\ [\%]$ (50-400 MeV γ)

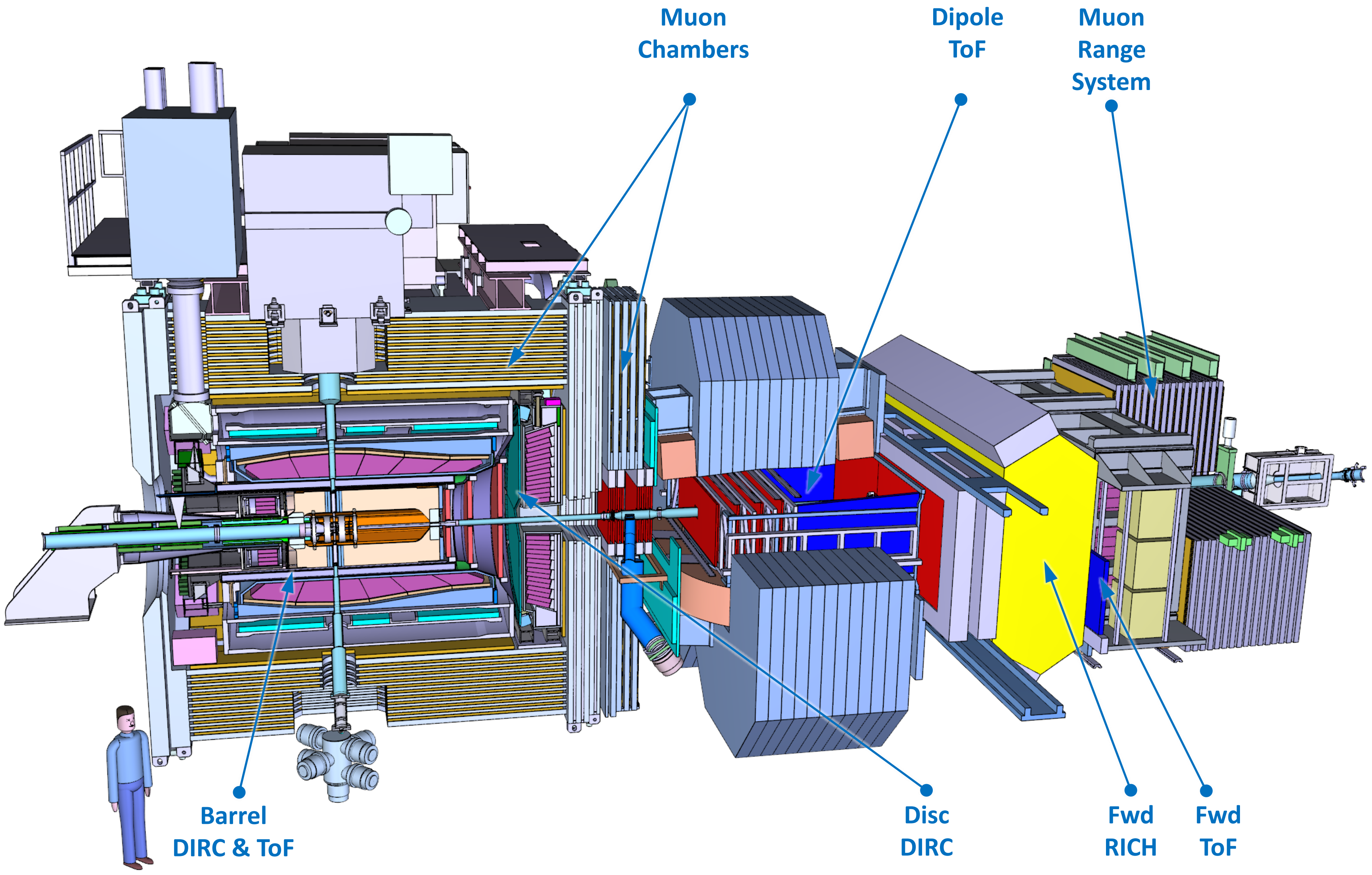
→ Time resolution
- 100 ps/$\sqrt{\mathrm{E[GeV]}}$

27x14 modules
54x28 cells





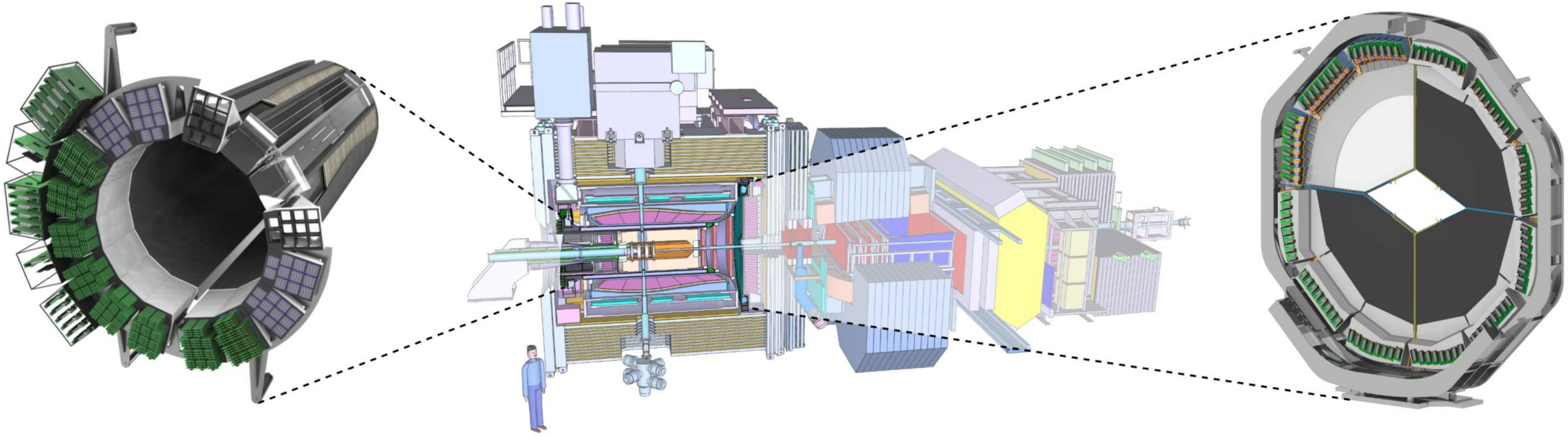
The PANDA Detector – Partcile ID



Target Spectrometer – DIRC Counters

Detection of Internally Reflected Cherenkov light pioneered bv BaBar

- Cherenkov detector with SiO_2 radiator
- Detected patterns give β of particles



Barrel DIRC

- Design similar to BaBar DIRC
- Polar angle coverage:
  22° < θ < 140°
- PID goal:
  3σ π/K separation up to 3.5 GeV/c

Key technologies:

- Fast single photon timing in high B-fields with small pixels and long lifetime
- High-quality fused silica radiators

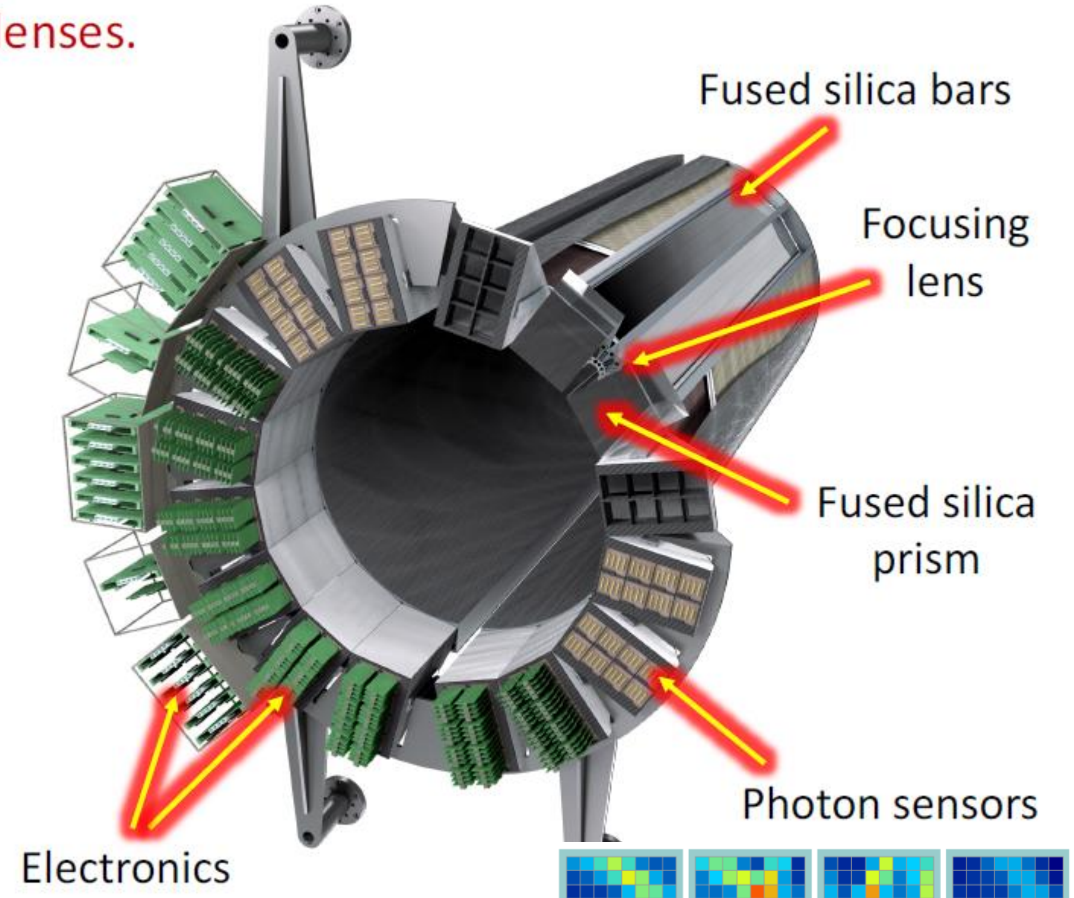
Endcap Disc DIRC

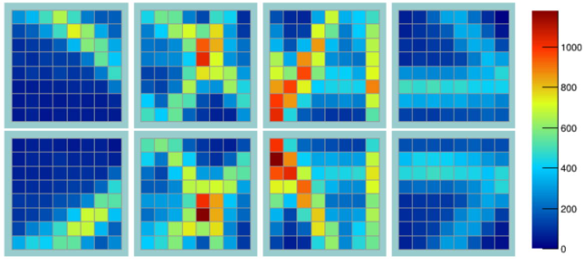
- Novel type of DIRC
- Polar angle coverage:
  5° < θ < 22°
- PID goal:
  3σ π/K separation up to 4 GeV/c

Barrel DIRC

Compact fused silica prisms, 3 bars per bar box, 3-layer spherical lenses.

- 48 radiator bars (16 sectors), synthetic fused silica,
  17mm (T) × 53mm (W) × 2400mm (L)
- Focusing optics: innovative 3-layer spherical lens
- Compact expansion volume:
  30cm-deep solid fused silica prisms
  ~8,000 channels of lifetime-enhanced MCP-PMTs
- Fast FPGA-based readout electronics
  ~100ps per photon timing resolution (DiRICH)
- Expected performance (simulation and particle beams):
  25-110 detected photons per particle,
  ≥ 3 s.d. π/K separation at 3.5 GeV/c





Conservative design – similar to proven BABAR DIRC, validated with particle beams since 2015.

TDR published, call for tenders for most costly long-lead items (bars, sensors) underway

Optimizing simulation and reconstruction code with experimental data from GlueX DIRC

Endcap Disc DIRC

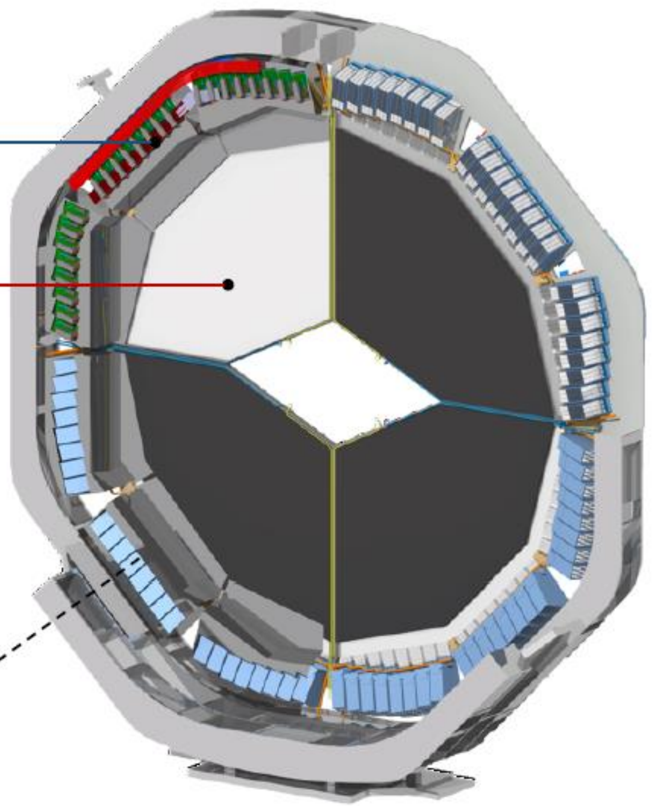
Optics made of synthetic fused silica

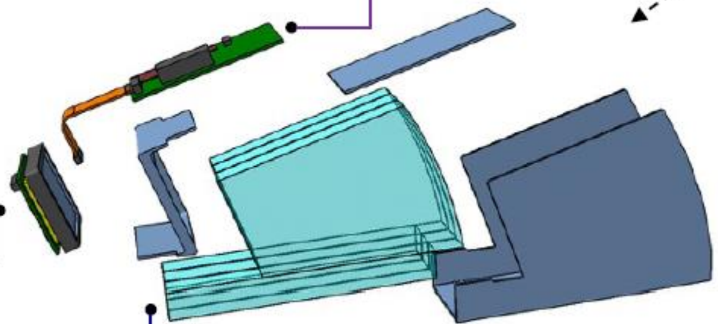
4 independent quadrants

Focusing elements convert angle to position information

2-inch MCP-PMT with a pitch of 0.5 mm

ASIC-based readout





Quadrant plate dimension:

20mm thickness

1056mm outer radius

Sensors: 96 MCP-PMTs

(lifetime-enhanced,~3x100 pixels)

Optical band pass filter for chromatic dispersion mitigation

TOFPET ASIC readout

~29k channels

Expected performance

~25 detected photons per particle,

≥ 3 s.d. π/K separation at 4 GeV/c

Novel design, validated with particle beams since 2016.

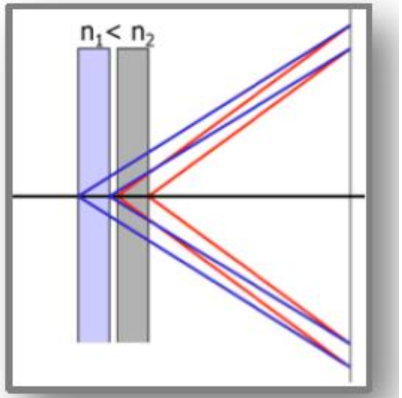
TDR recently approved

first-of-series quadrant in 2026

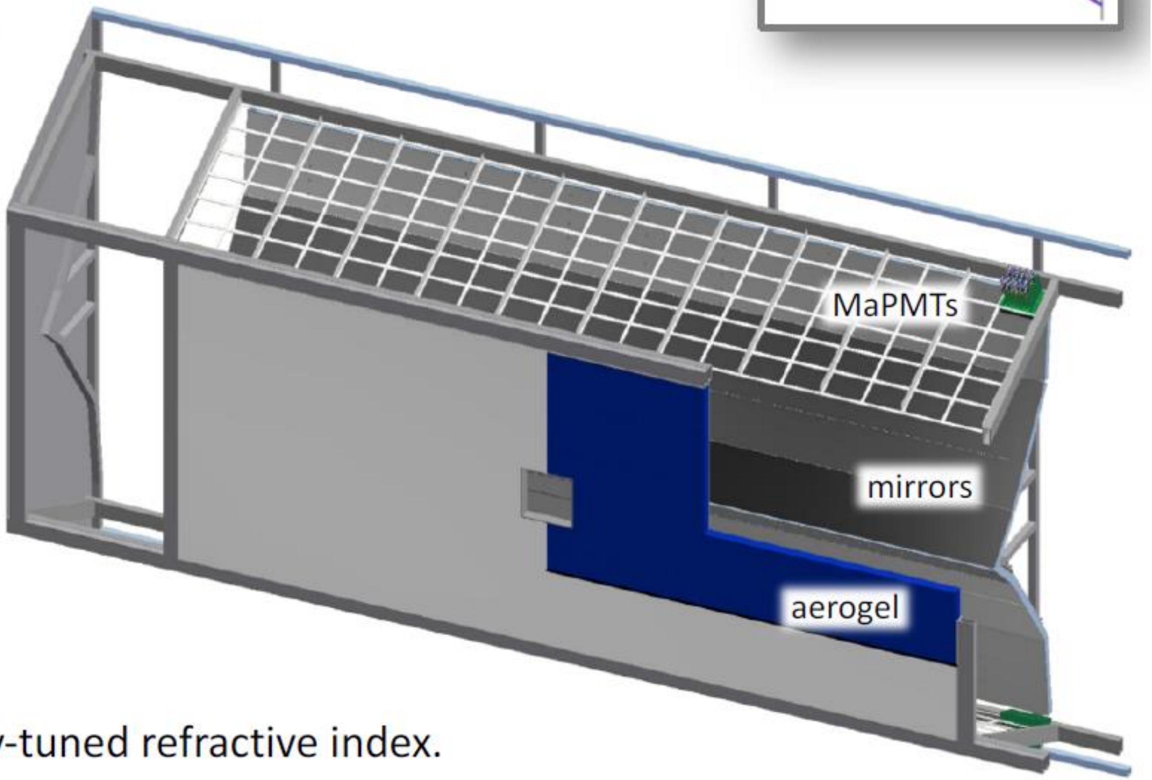
Forward RICH

Design based on “Focusing Aerogel”

Increase light yield without deterioration of photon resolution
by combining multiple tiles with different refractive index



- Coverage: $\theta_x < 10°$, $\theta_y < 5°$
- 40mm thickness focusing aerogel tiles (2 or 3 layers), n≈1.05
- Focusing mirrors direct Cherenkov photons to sensor array above/below beam
- Mirrors: 2mm float glass, Al+SiO_2 coating
- Sensors: ~240 Hamamatsu H12700 MaPMTs
- Fast FPGA-based readout electronics: DiRICH
  (same as PANDA Barrel DIRC, HADES/CBM RICH)
- Expected performance:
  ≥ 3 s.d. π/K separation for 2 – 10 GeV/c

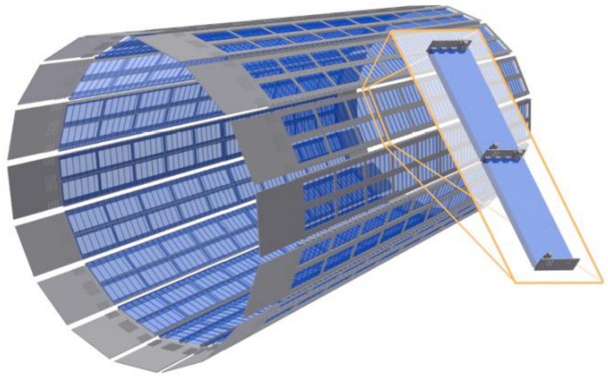


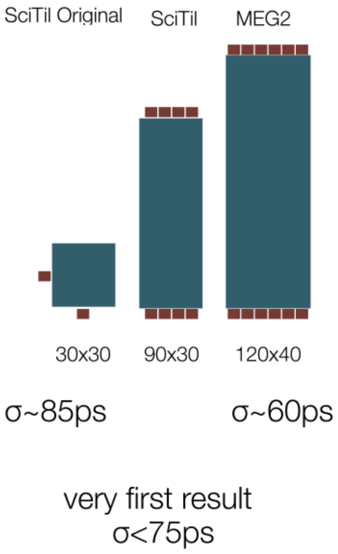
Key technology: high-quality transparent aerogel tiles with finely-tuned refractive index.
Prototype test at with electrons at BINP in 2019 – TDR due 2020

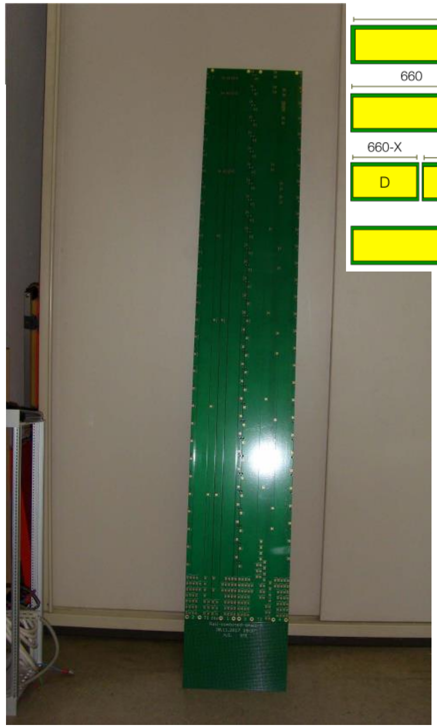
Barrel Time of Flight

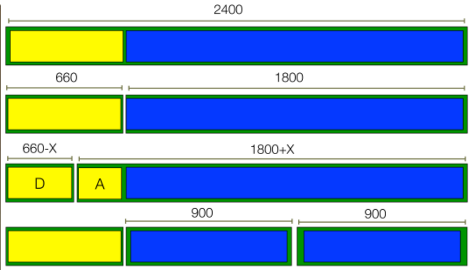
Scintillator Tile Hodoscope
- Scintillator tiles 5 mm thick
- Photon readout with SiPMs (3x3 mm^2)
  - High PDE, time resolution, rate capability
  - Work in B-fields, small, robust, low bias
- System time resolution: <100 ps achieved
- ToFPET ASIC for SiPM readout
- Layout: long multilayer PCB for transmission (“railboard”)

Project status
- **TDR approved**
- Study of scintillator thickness (3-6 mm):
  - 5mm thickness confirmed as optimal
- SiPM radiation hardness studies planned
- First-of-series (1/16) module in progress









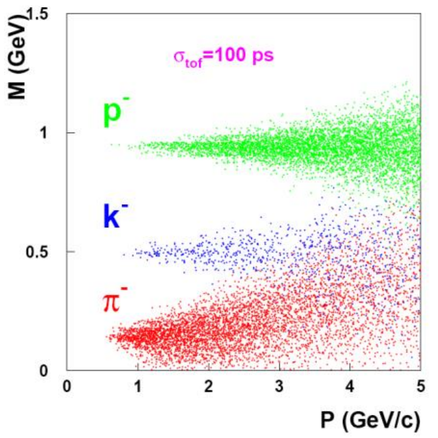
Prototype readout “railboard” 1m long!

Forward Time of Flight

Forward Spectrometer
- Time of Flight essential
- Relative timing to Barrel ToF

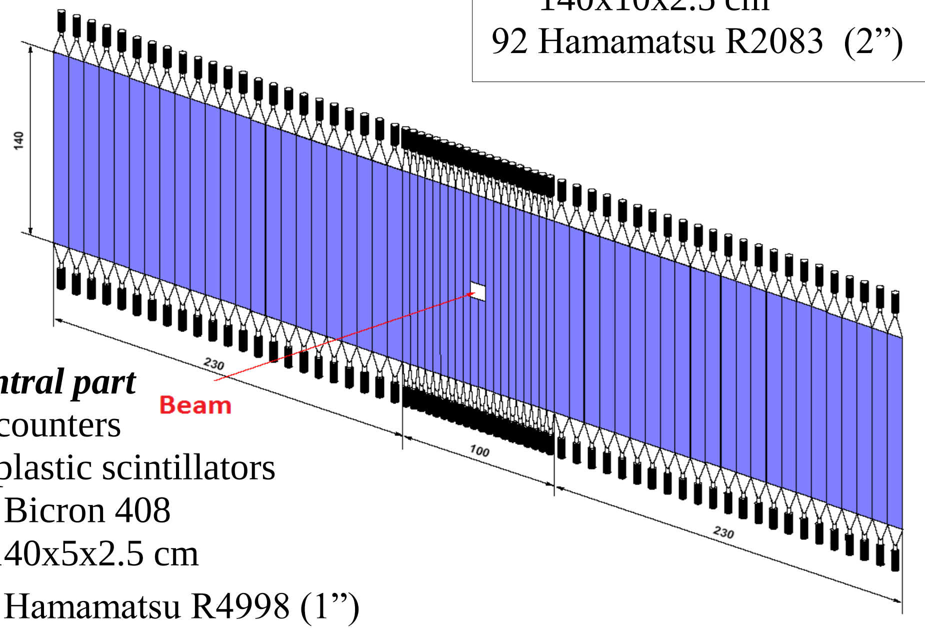
Detector layout
- Scintillator wall at z=7.5m made of 140 cm long slabs
- Bicron 408 scintillator
- PMT readout on both ends
- 10 cm wide slabs on the sides, 5 cm wide slabs in the center
- Readout TDC FPGA

Project status
- **TDR approved**
- Readout optimization ongoing
- Design laser calibration system



Goal: Time-of-flight with σ(t) better than 100 ps

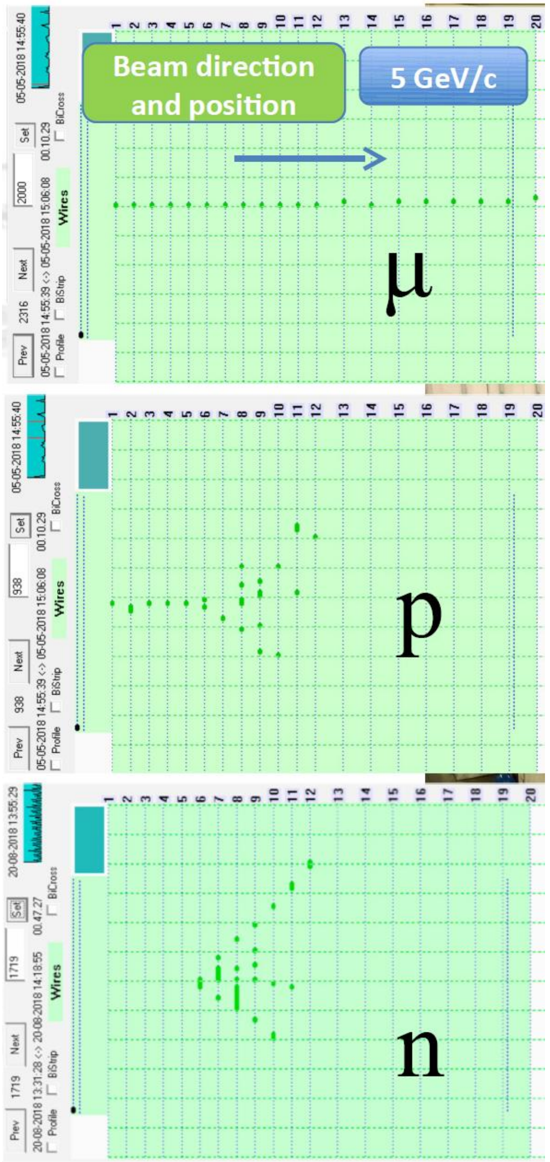
Side parts
2x23 counters
46 plastic scintillators
Bicron 408
140x10x2.5 cm
92 Hamamatsu R2083 (2")



Central part
20 counters
20 plastic scintillators
Bicron 408
140x5x2.5 cm
40 Hamamatsu R4998 (1")

Muon Detector System

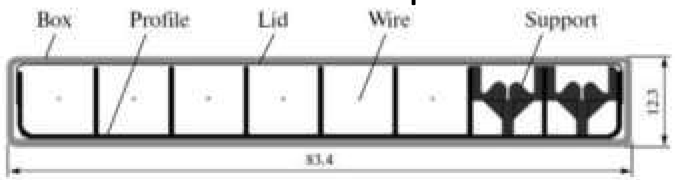
Testbeam results:
- μ, p and n easily resolved

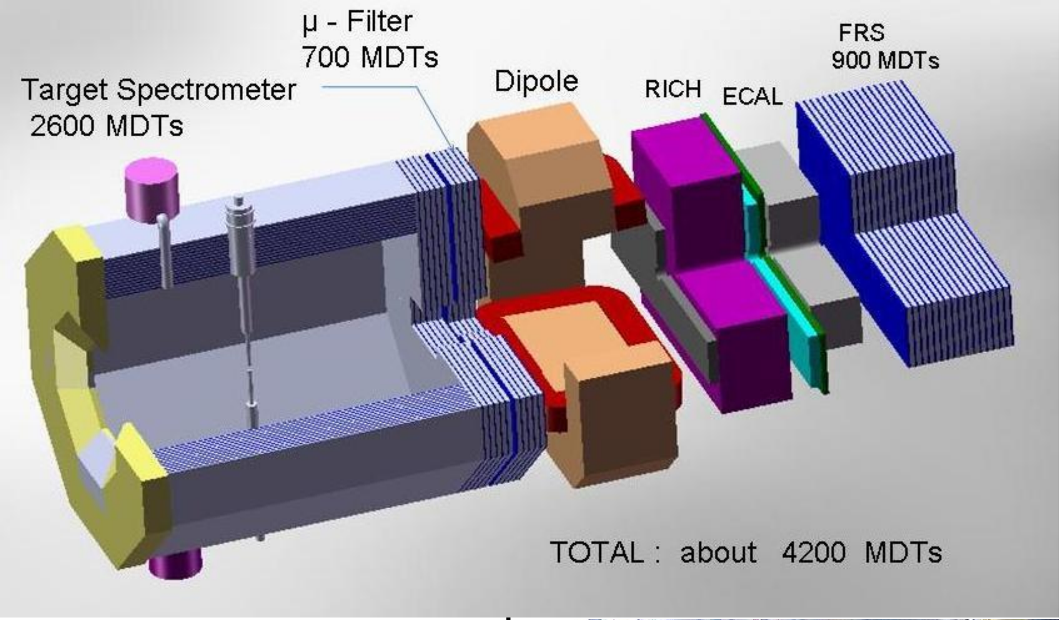


Muon system rationale
- Low momenta, high BG of pions

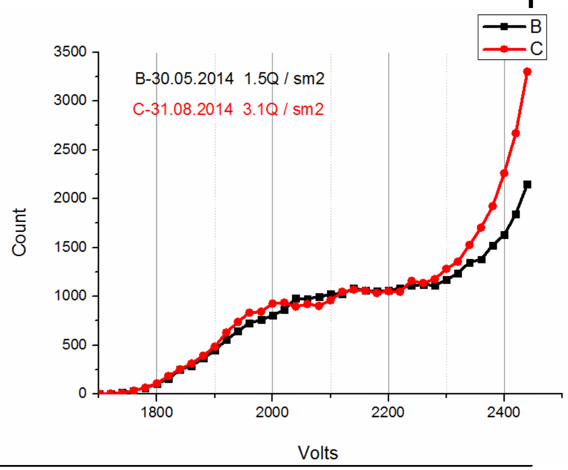
➔ Multi-layer range system

Muon system layout
- *Barrel*: 12+2 layers in yoke
- *Endcap*: 5+2 layers
- *Muon Filter*: 4 layers
- *Fw Range System*: 16+2 layers
- *Detectors:* Drift tubes with wire & cathode strip readout





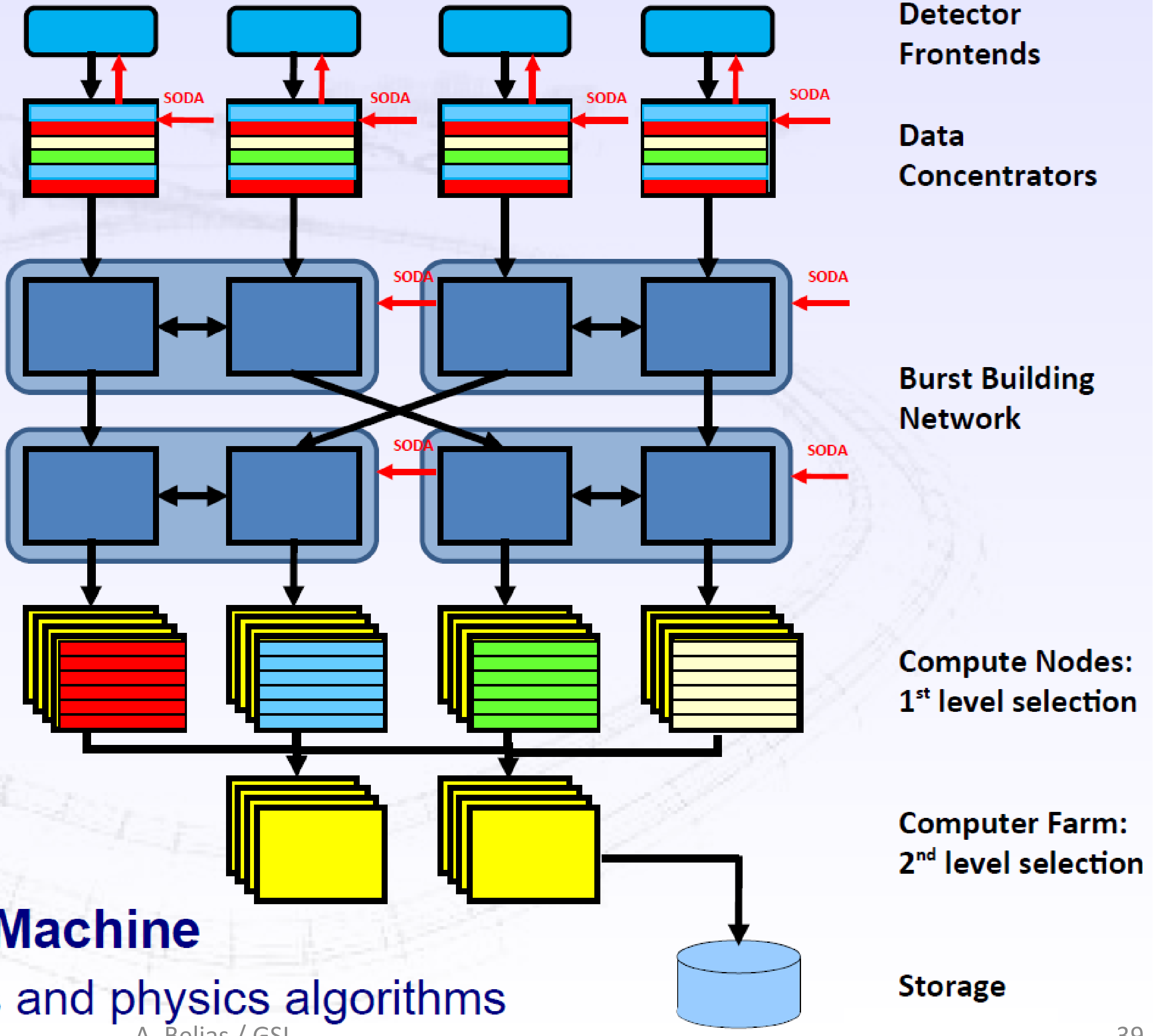
Project status
- **TDR approved**
- Testbeams at CERN, aging, cosmic
- Aging tests up to $3C/cm^2$
- Digital FEE (Artix-7) development
- Production designs



Data Acquisition (DAQ)

Self triggered readout

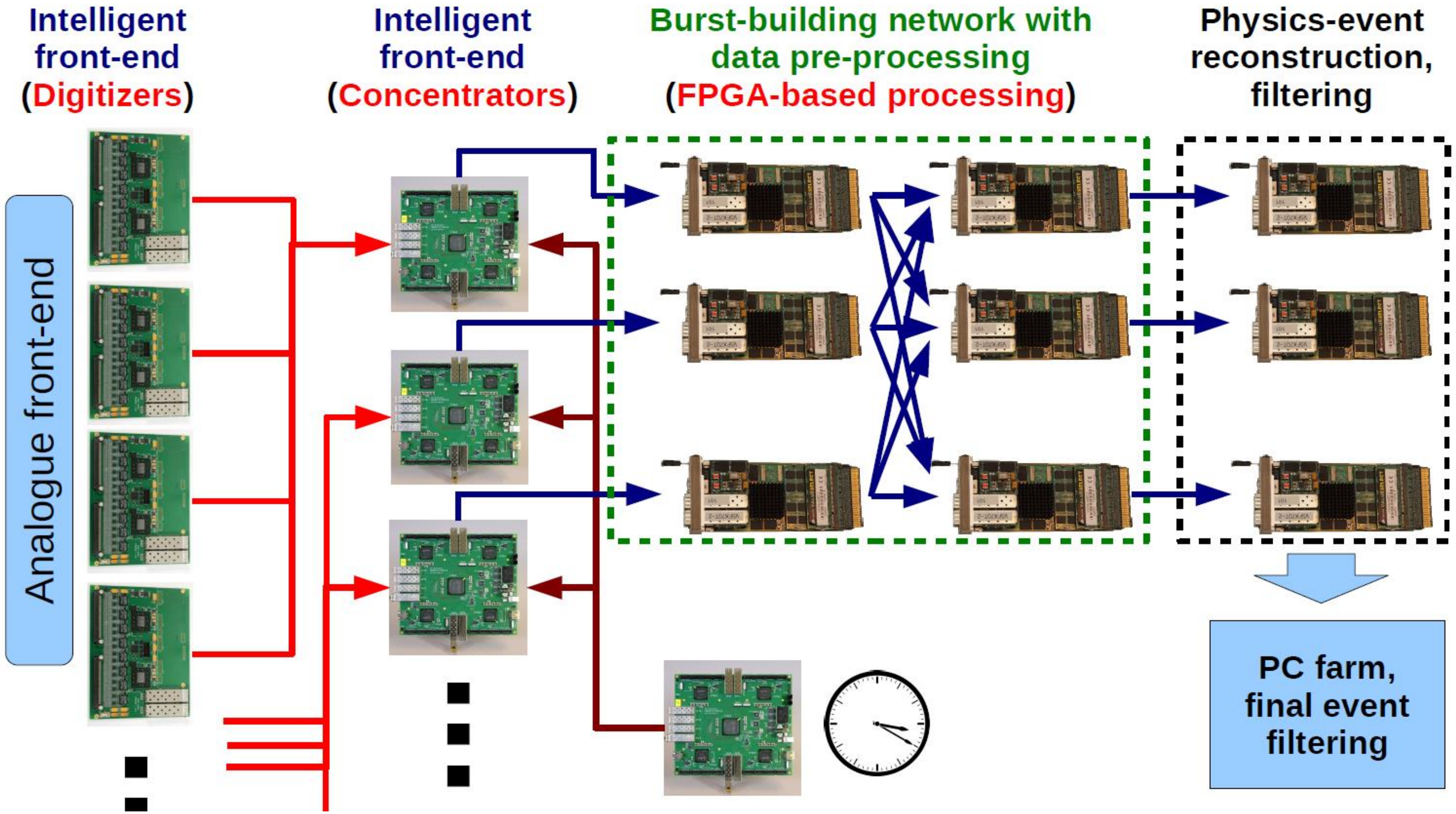
- Components:
  - Time distribution: SODA
  - Intelligent frontends
  - Powerful compute nodes
  - High speed network
- Data Flow:
  - Data reduction
  - Local feature extraction
  - Data burst building
  - Event selection
  - Data logging after online reconstruction



→ **Programmable Physics Machine**

Online selection schemes and physics algorithms are a key for successful measurements

Data Acquisition (DAQ)



4.1.2 FPGA based Compute Nodes

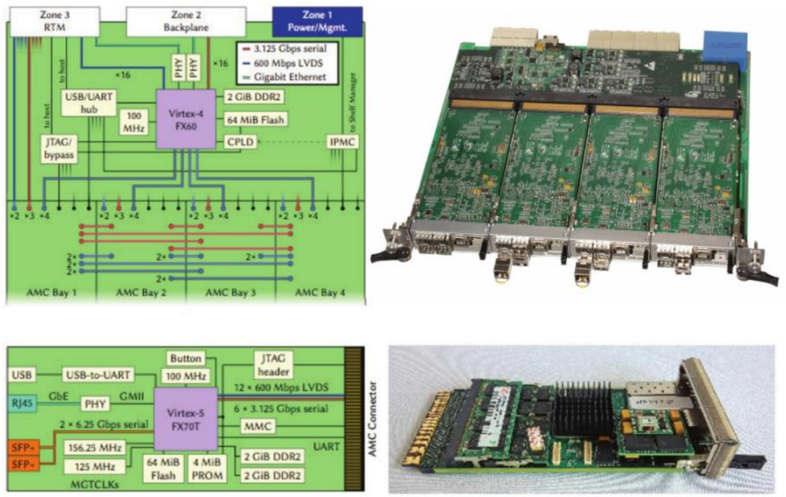


Figure 4.4: ATCA compliant FPGA based compute node. (top): carrier board; (bottom) xFP daughter The architecture is based on XILINX ® Virtex FPGAs. A single CN can support up to 16 optical links total of 18 GB DDR2-RAM. The FPGAs are equipped with embedded PowerPC - CPUs, running Linux op systems for slow control functions.

DAQ TDR – in review by FAIR

Detector Control System (DCS)

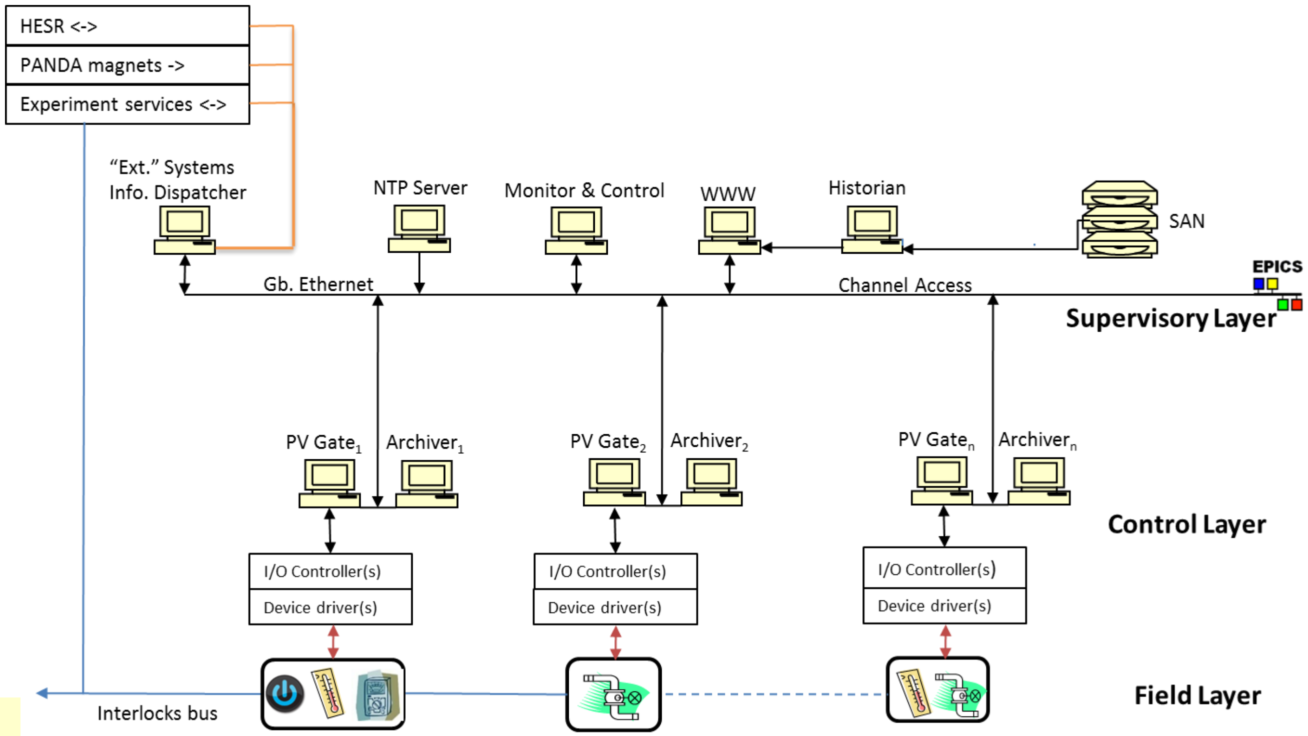
Control, Monitor and Archive for all PANDA sub-systems

Operations parameters:
- HV, LV, currents,
- gas-flows, cooling

Environmental parameters:
- Temp., Hum.

Interface to HESR, Magnets
Detector Safety

DCS TDR – in review by FAIR



Supervisory Layer
Controls GUI interface
Databases & configurations
Interface: HESR, DAQ

Control Layer
I/O controllers
Device Drivers
Archiving sub-system

Field Layer
PANDA sub-systems specific
Interface: Detector Safety System

EPICS - **E**xperimental **P**hysics and **I**ndustrial **C**ontrol **S**ystem

- ❑ Decentralized architecture
- ❑ Freely scalable
- ❑ Allows "partitioning") each subdetector has its own DCS

Outlook – Detector Phases

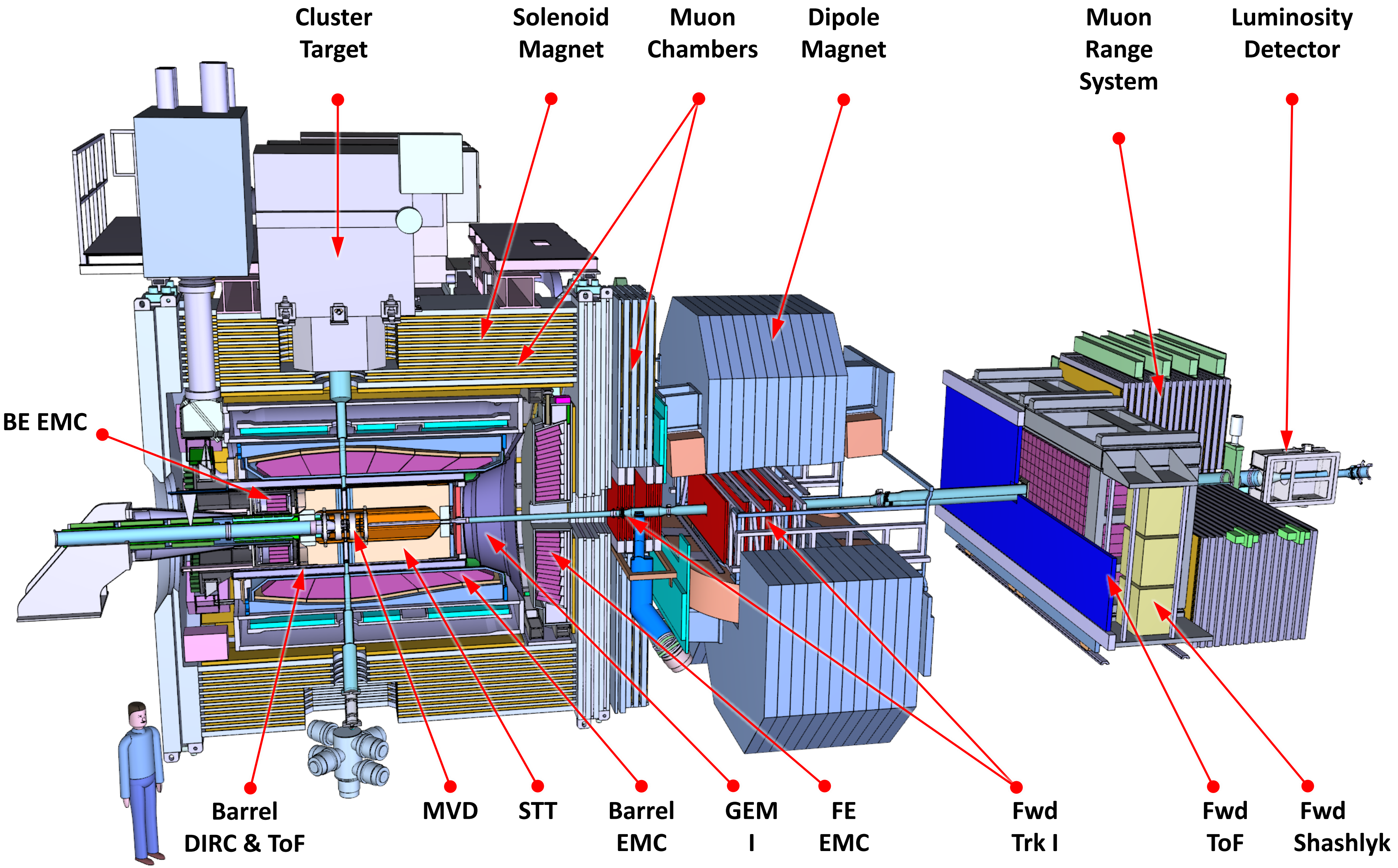
Phase 0
Currently PANDA detectors are being built.
They will be used in other excellent experiments until the experimental hall is available.

Phase 1
First physics experiments with the PANDA start setup using antiprotons

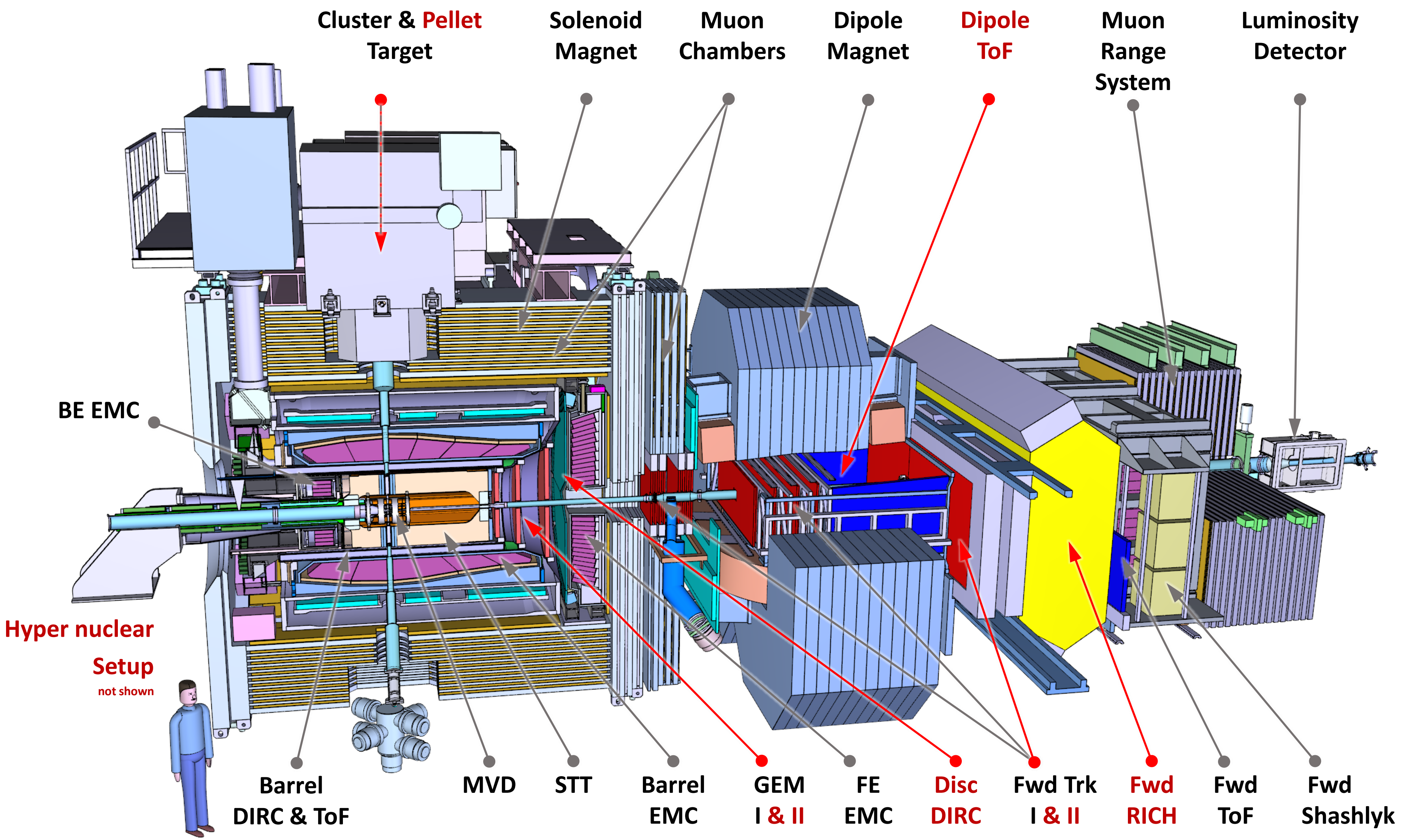
Phase 2
Experiments using the full setup

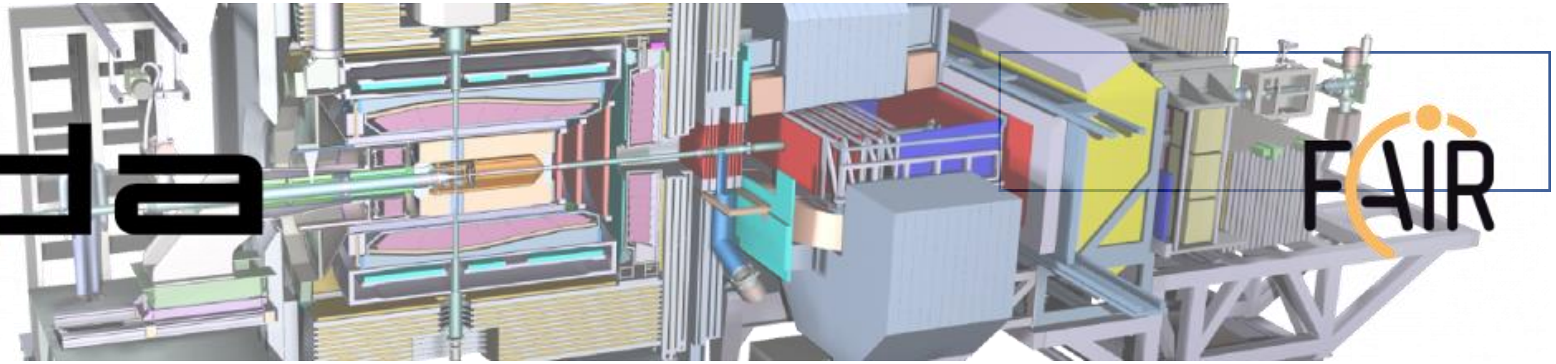
Phase 3
Experiments beyond MSV (needs RESR)

Start Setup (Phase 1)



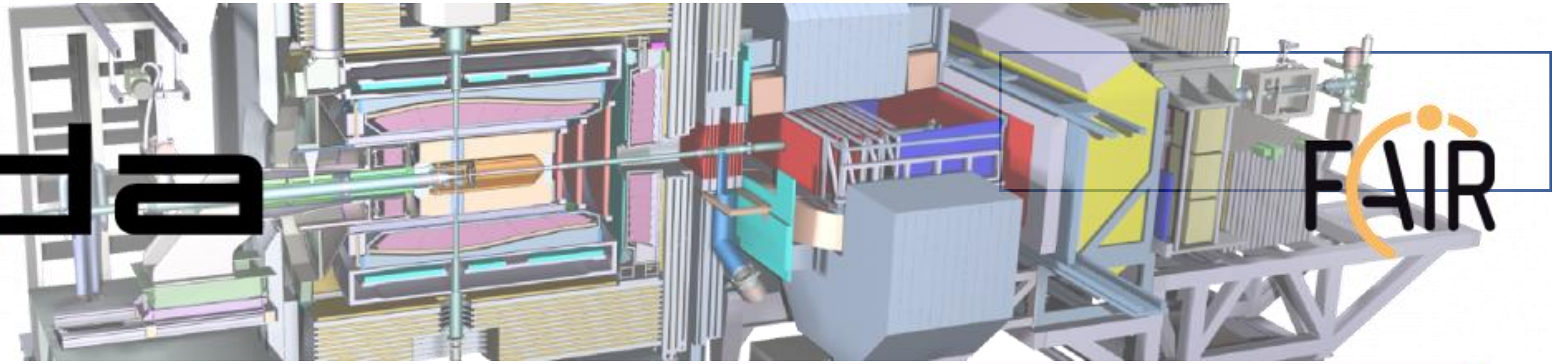
Full Setup (Phase 2)





Opportunities for significant contributions in PANDA at various stages

- Scope for detector R&D
  - phased schedule allows for R&D
  - systems with TDR pending
  - for high Luminosity running
- Readout, controls, monitor
  - Readout electronics - analog /digital
  - DAQ - FPGA , H/w, F/w, S/w
  - Detector Controls
  - Data quality monitoring
- First-of-Series Modules
  - System integration
  - Characterization in-beam
  - Calibration & Operations
- Detector assembly
  - Series production
  - QA/QC processes
  - Mechanic & cooling integration
  - Detector tests



PANDA is making excellent progress

- Most Phase 1 detector TDRs complete
- Preparation for Construction MoU ongoing
- Sharpened physics focus and detector start sequence

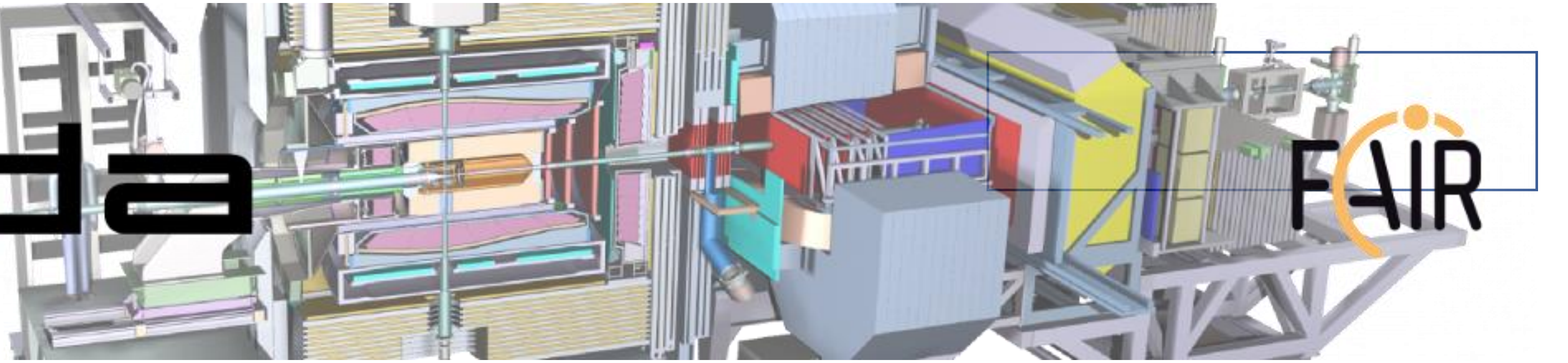
Timeline for PANDA Construction

- Construction of detector systems has started
- Pre-assembly of first components has started
- Installation schedules in-line with FAIR planning
- Commissioning start with cosmics and proton beam

PANDA physics with antiproton beam

- Versatile physics machine with full detection capabilities

Opportunities for significant contributions in PANDA



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PANDA physics with antiproton beam

- Versatile physics machine with full detection cap

Opportunities for significant contributions in P

On behalf of

Collaboration

UniVPM Ancona
U Basel
IHEP Beijing
U Bochum
U Bonn
U Brescia
IFIN-HH Bucharest
AGH UST Cracow
IFJ PAN Cracow
JU Cracow
U Cracow
FAIR Darmstadt
GSI Darmstadt
JINR Dubna
U Edinburgh
U Erlangen
NWU Evanston
U & INFN Ferrara

FIAS Frankfurt
U Frankfurt
LNF-INFN Frascati
U & INFN Genova
U Gießen
U Glasgow
BITS Pilani KKBGC, Goa
KVI Groningen
Sadar Patel U, Gujart
Gauhati U, Guwahati
USTC Hefei
URZ Heidelberg
FH Iserlohn
FZ Jülich
IMP Lanzhou
INFN Legnaro
U Lund
HI Mainz

U Mainz
INP Minsk
ITEP Moscow
MPEI Moscow
BARC Mumbai
U Münster
Nankai U
BINP Novosibirsk
Novosibirsk State U
IPN Orsay
U Wisconsin, Oshkosh
U & INFN Pavia
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Czech TU, Prague
IHEP Protvino
Irfu Saclay
U of Sidney

PNPI St. Petersburg
West Bohemian U, Pilzen
KTH Stockholm
U Stockholm
SUT, Nakhon Ratchasima
SVNIT Surat-Gujarat
S Gujarat U, Surat-Gujarat
FSU Tallahassee
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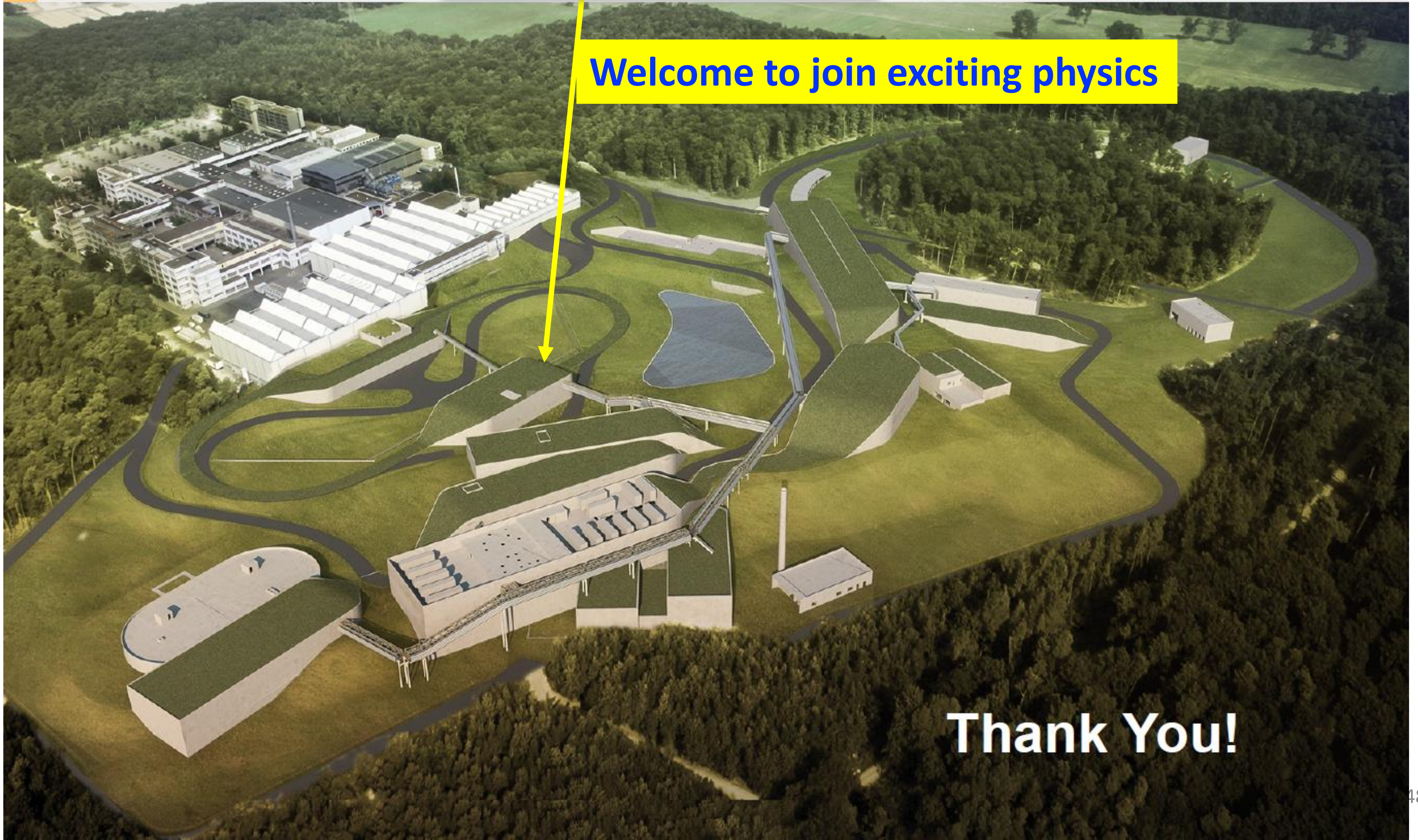
SMI Vienna
U Visva-Bharati
SINS Warsaw

more than 460 physicists from
from 75 institutions in 19 countries

Thank you all for your attention.


Welcome to join exciting physics
Thank You!