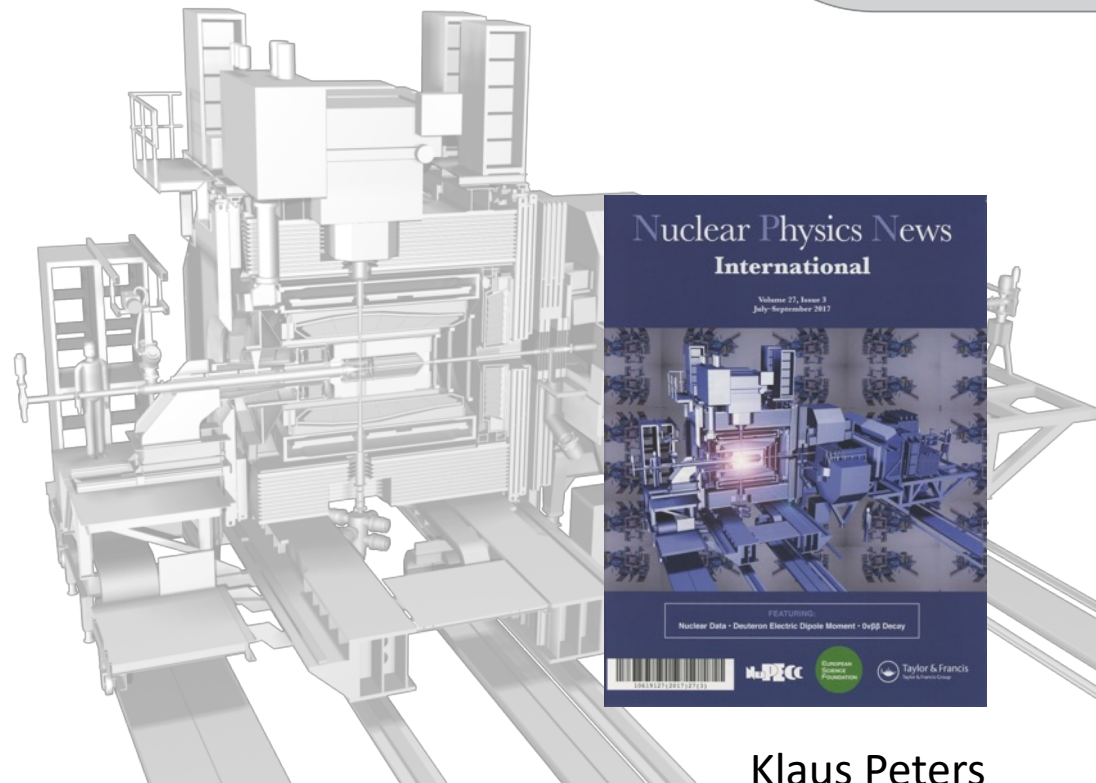
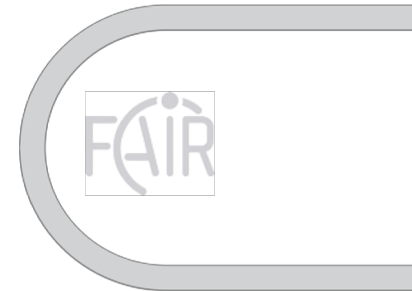


PANDA

KHuK Jahrestagung

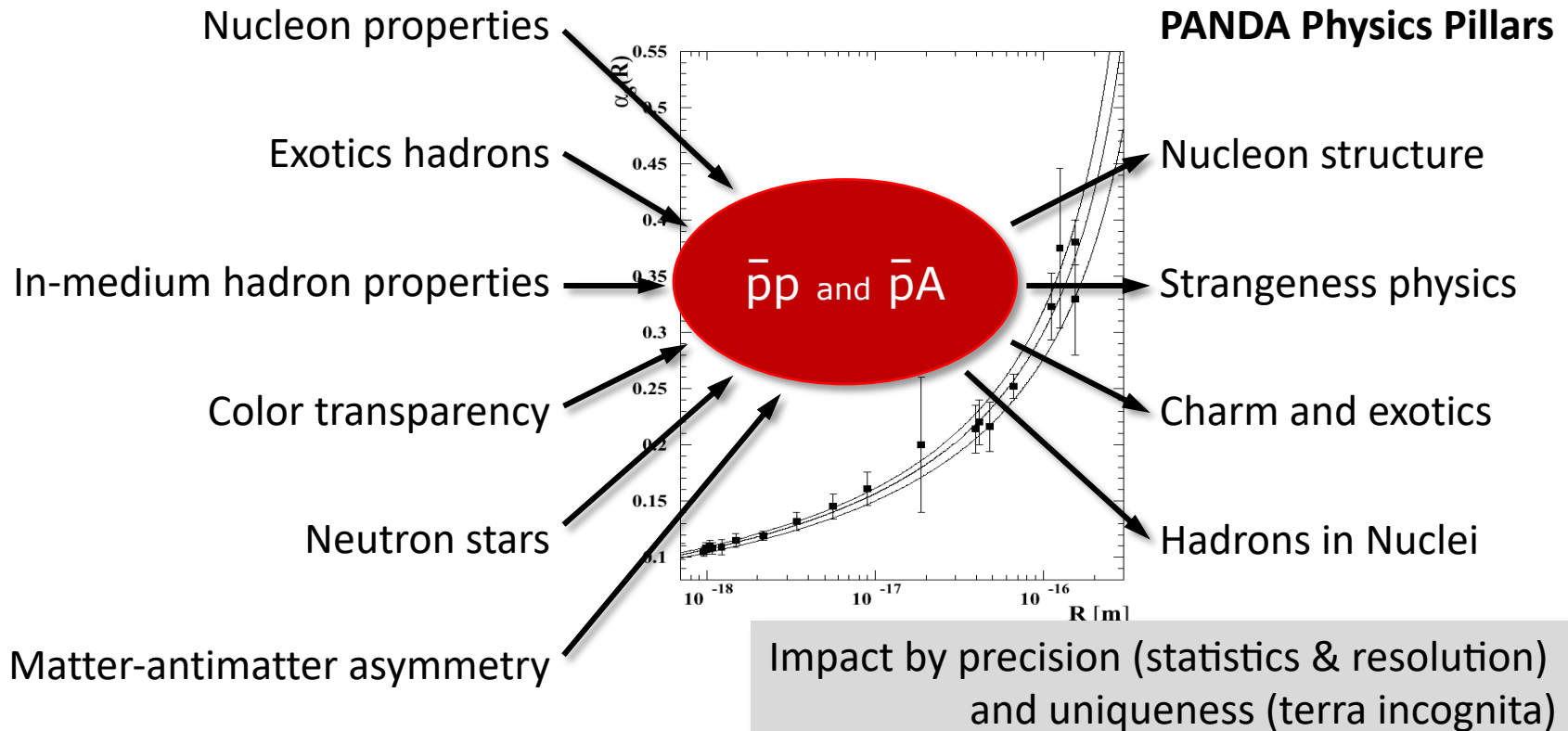
Bad Honnef, Dec 7, 2018



Klaus Peters
GSI/U Frankfurt

Key questions in “strong” QCD

No need for textbook motivations about the non-abelian structure of QCD and its problems



Why Antiprotons



Large mass-scale coverage

- creation of mass rather than momentum
- center-of-mass energies from 2 to 5.5 GeV
- from light, strange, to charm-rich hadrons

Mass scan experiments with beam-resolution

- unique linescans \rightarrow discovery by precision!

High hadronic production rates

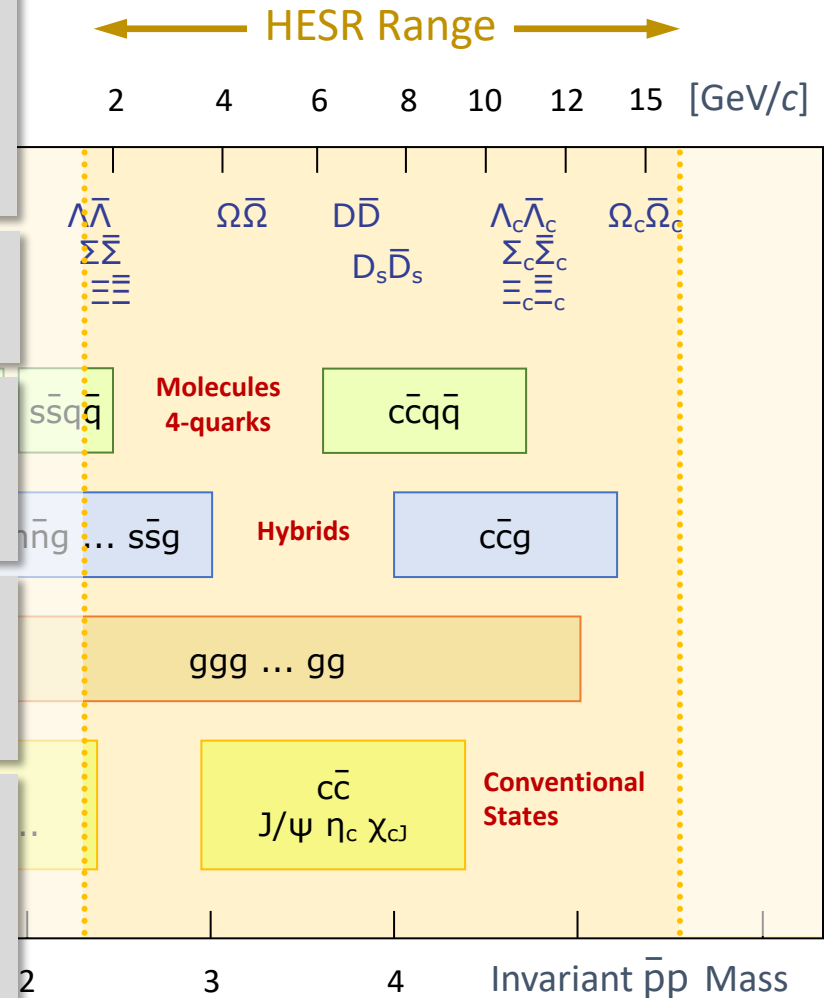
- charm+strange factory \rightarrow discovery by statistics!
- gluon-rich production \rightarrow potential for new exotics

Access to large spectrum of J^{PC} states

- direct formation of *all* conventional J^{PC} states
- large sensitivity to high spin states

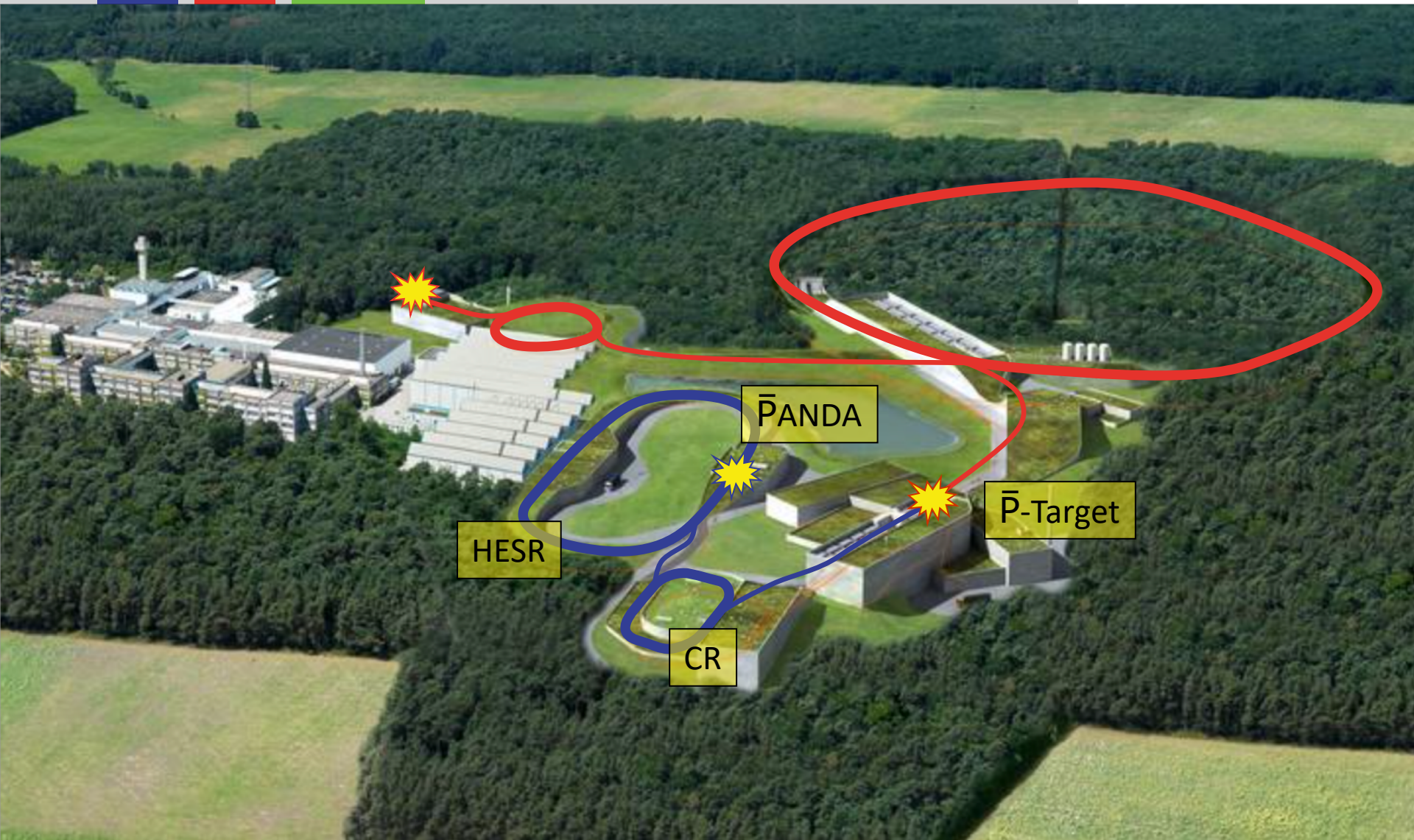
Associated hadron-pair production

- zero net quark content
- access to hidden-strange/charm hadrons
- tagging possibilities
- near threshold: good resolution and low background

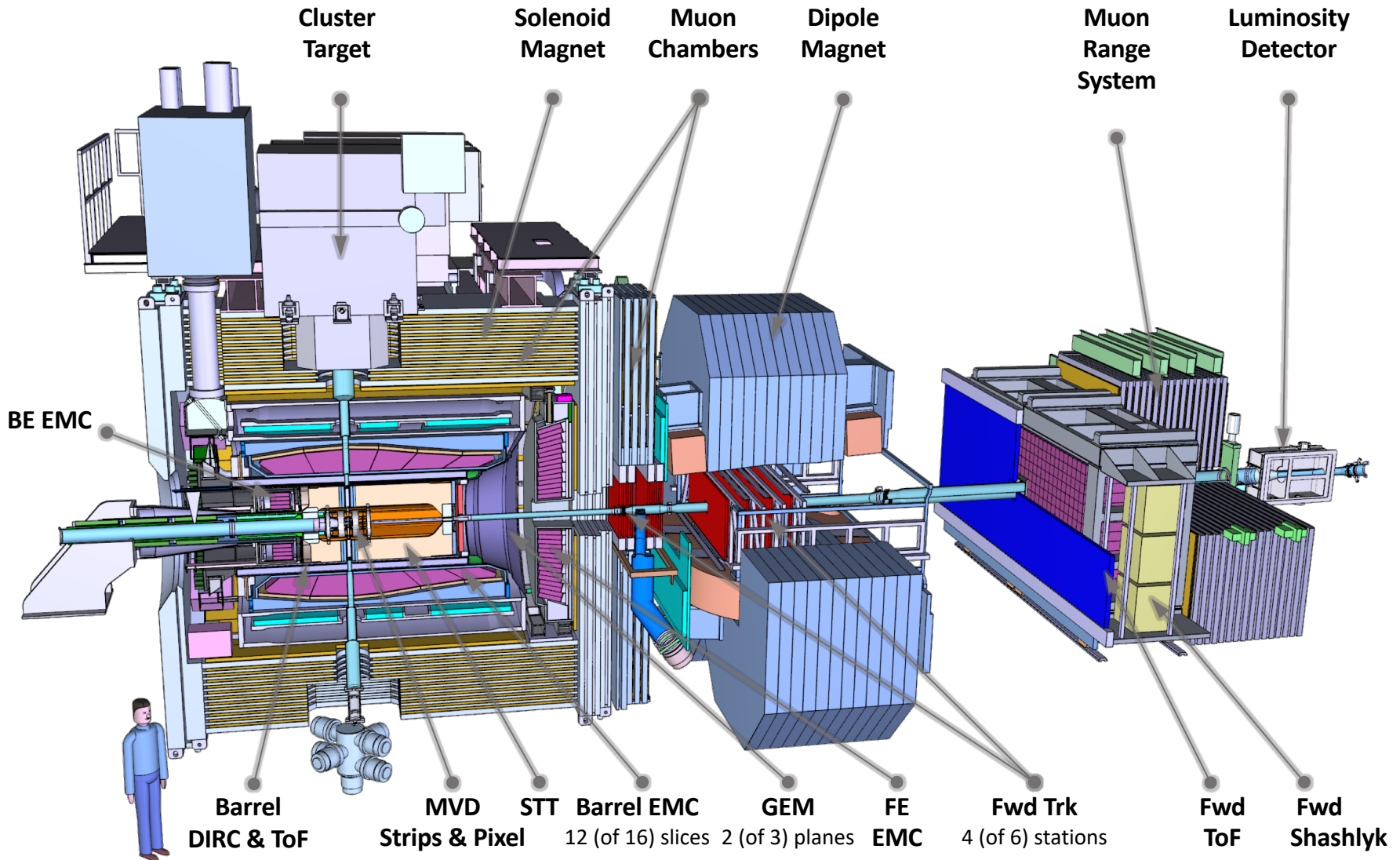


Systematic and precise tool to rigorously study the dynamics of QCD

Antiproton Chain: HESR & PANDA

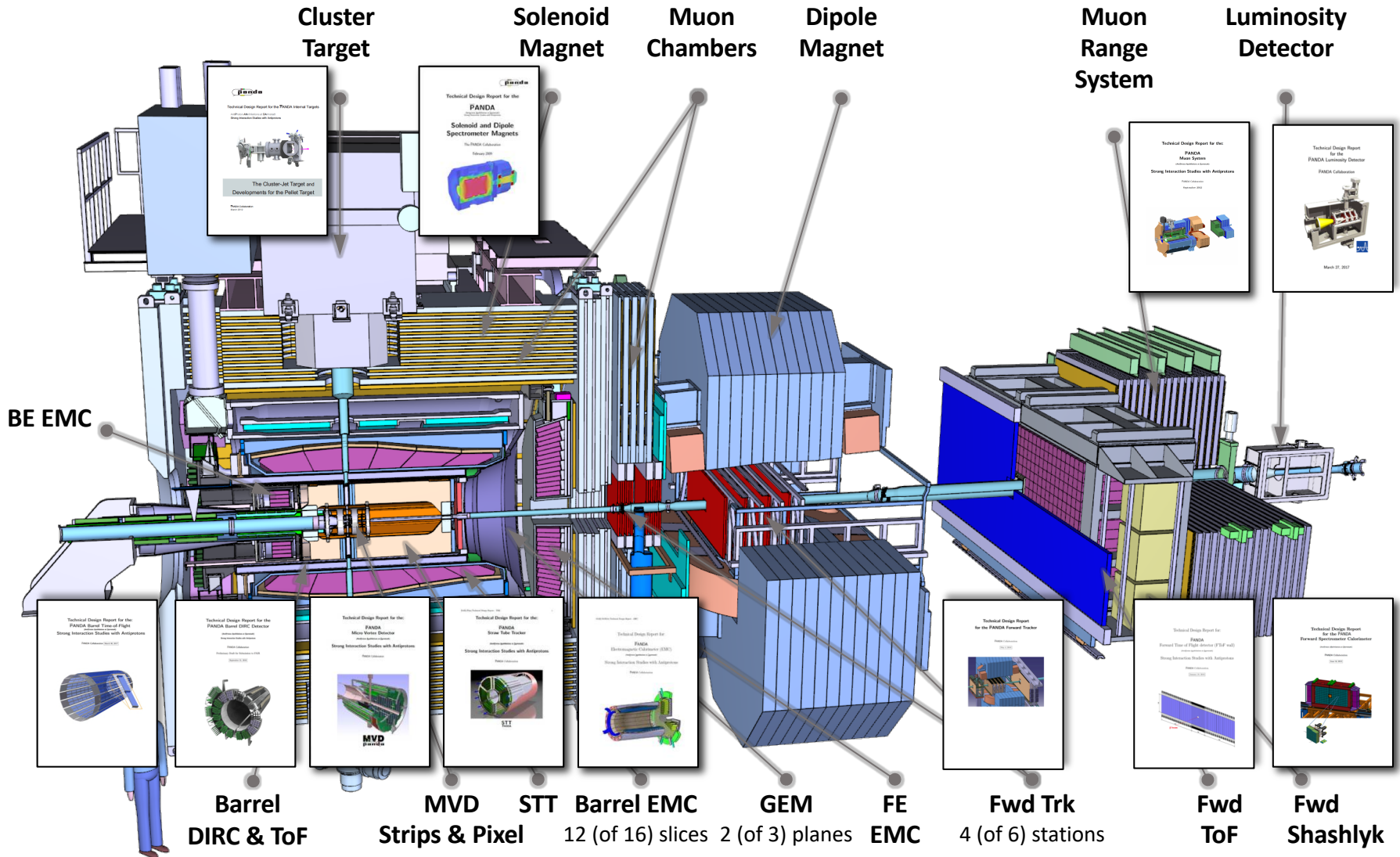


Day-1 Setup

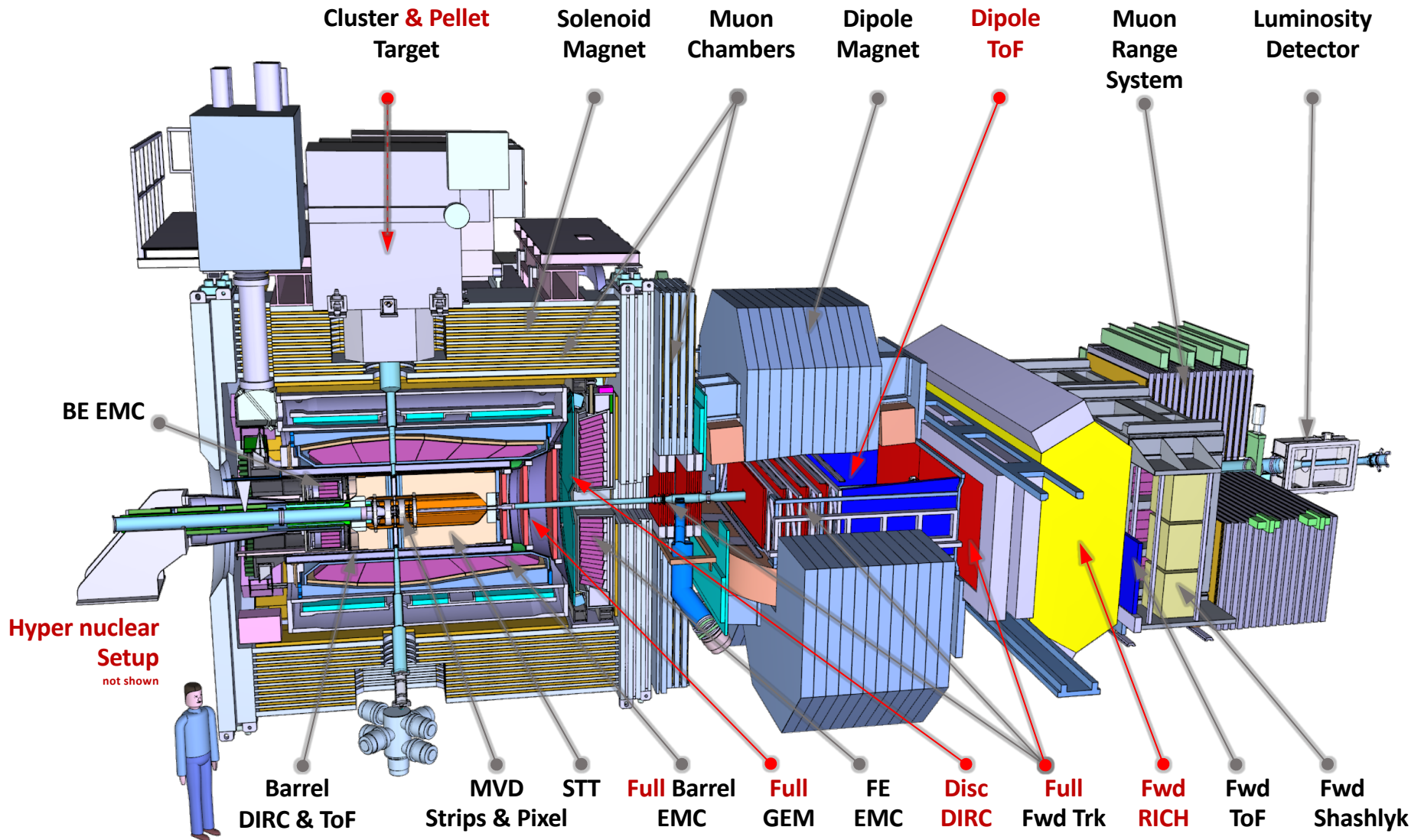


Day-1 Setup

TDRs approved for 87.3% of Day-1 funds



Full Setup



Technical Progress



Solenoid production progressing well

Dipole Design is contracted

Barrel DIRC Large Components in tendering

Barrel EMC Crystal Production resumed

Barrel EMC First Slice completed

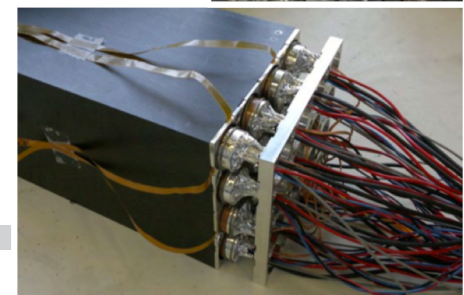
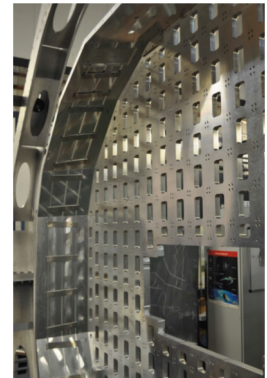
Fwd EMC all comp. delivered, construction advanced

STT all straws for the central tracker are produced

Barrel ToF TDR approved by FAIR Feb/2018

Forward Tracker TDR approved by FAIR in Oct/2018

Forward ToF TDR approved by FAIR in Oct/2018

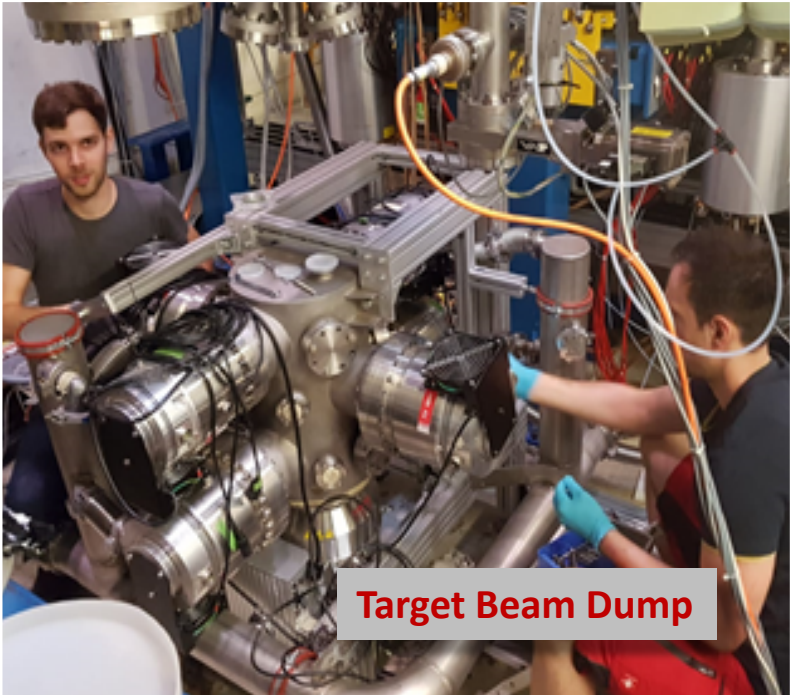




Cluster Jet Target



Muon Detector

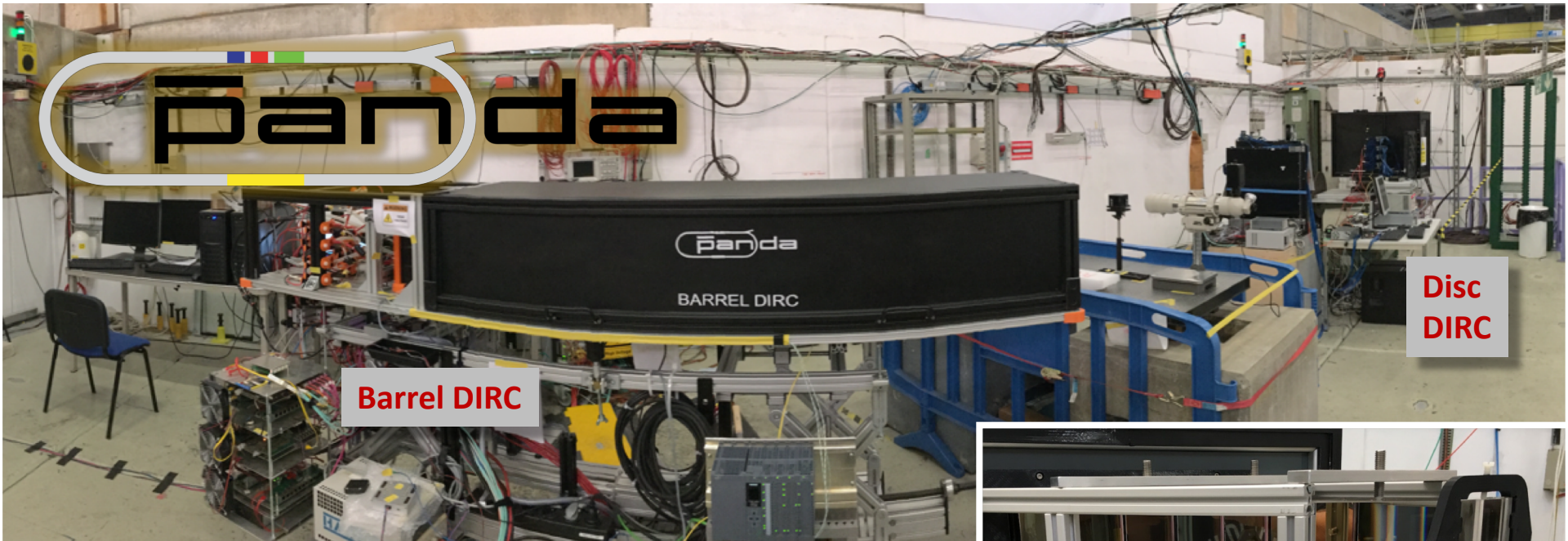


Target Beam Dump



Magnet Yoke Octant

panda

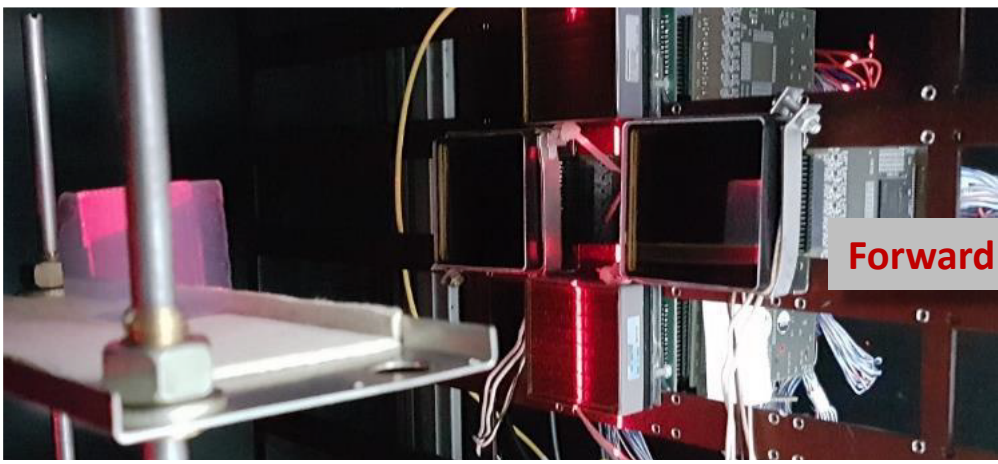
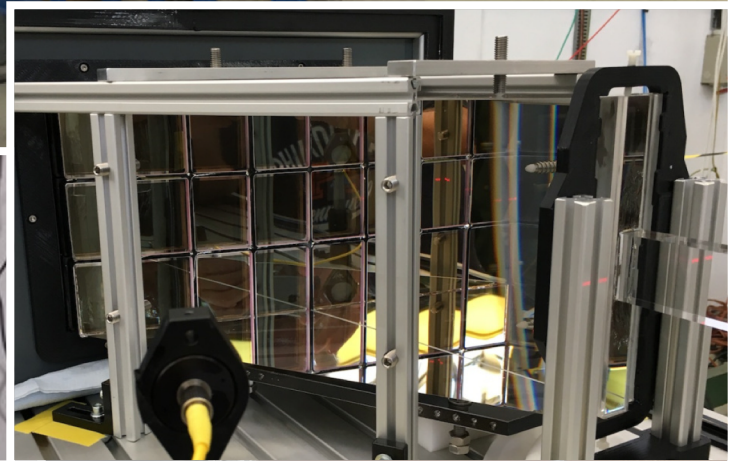


Barrel DIRC

Disc DIRC



Forward TOF



Forward RICH



Forward RICH



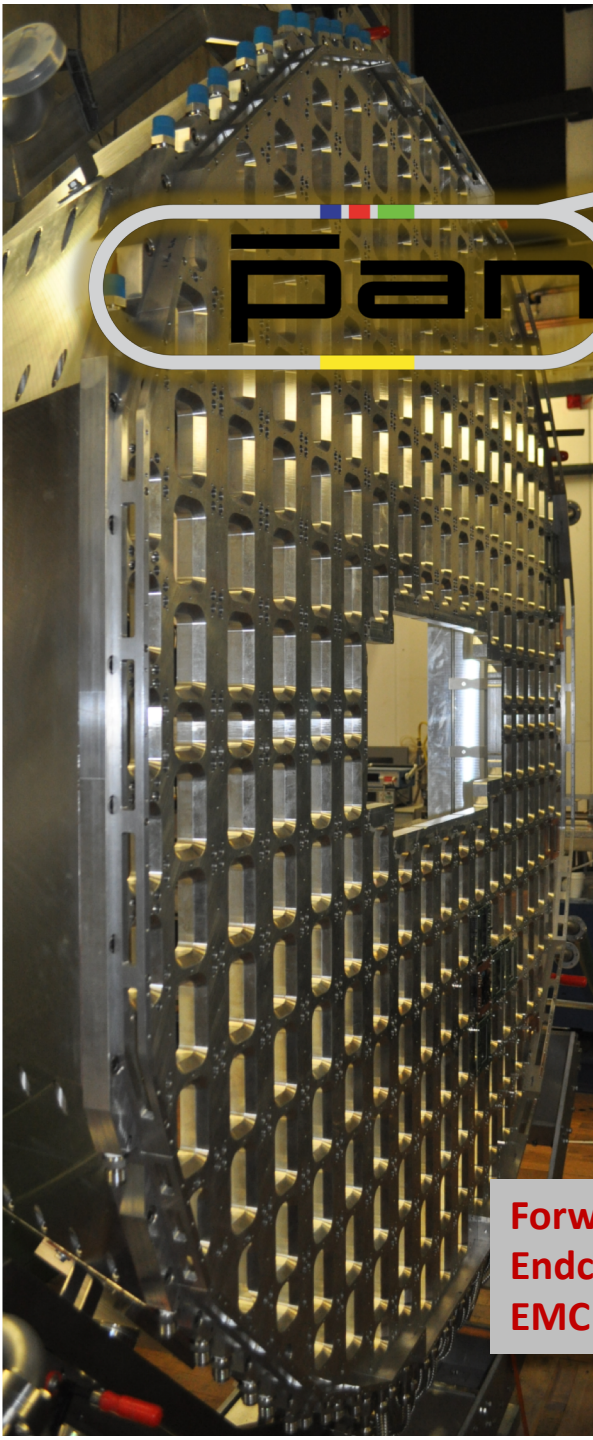
Panda



Luminosity
Detector



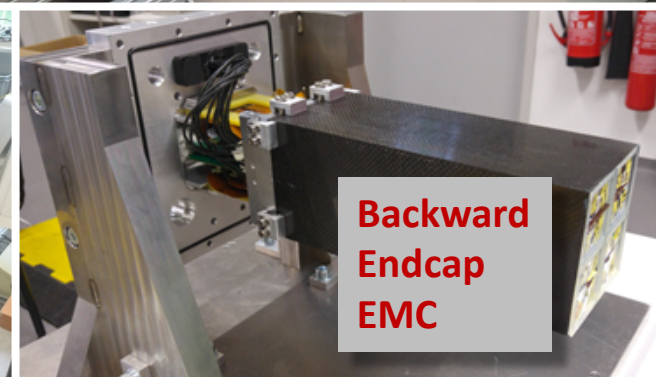
Forward Tracker



Forward
Endcap
EMC

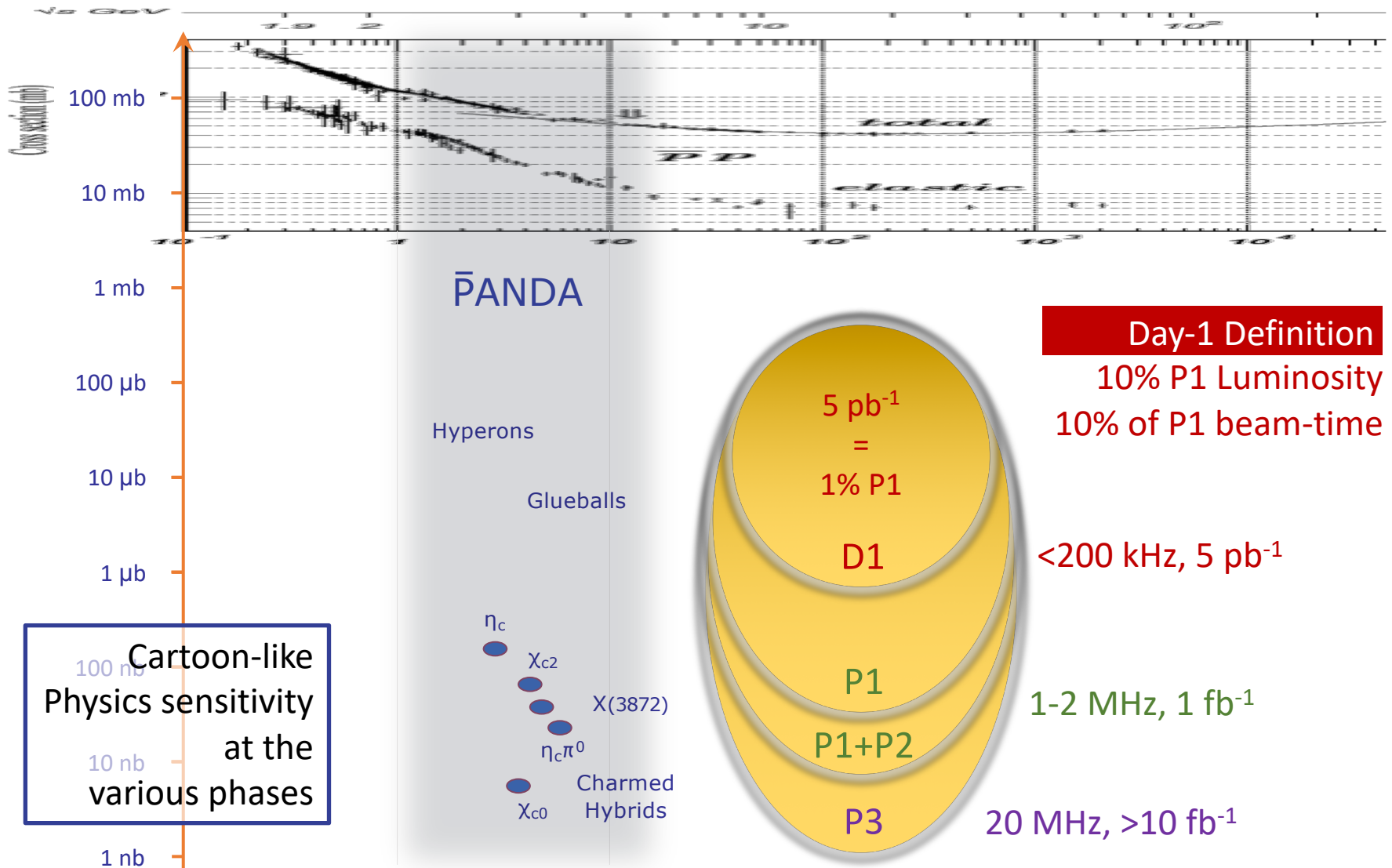


Barrel EMC



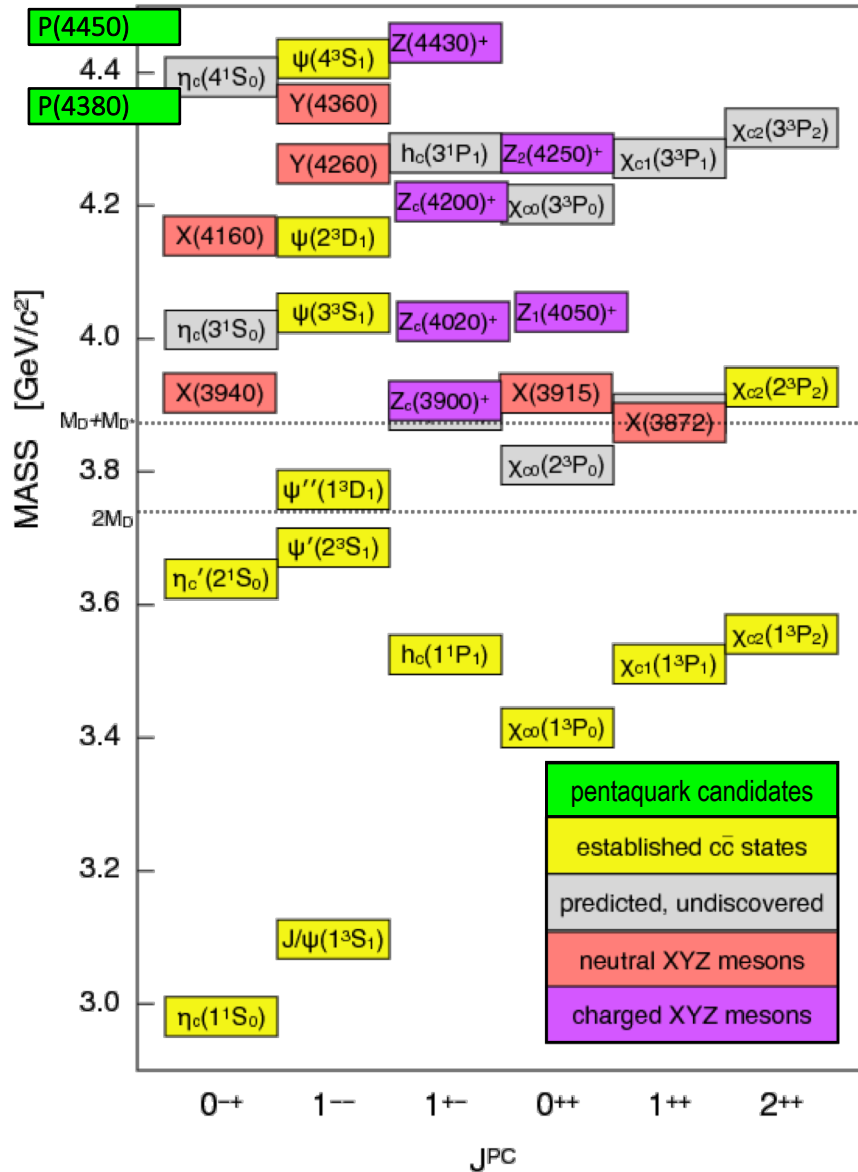
Backward
Endcap
EMC

Phases of PANDA – Sensitivities in a nutshell



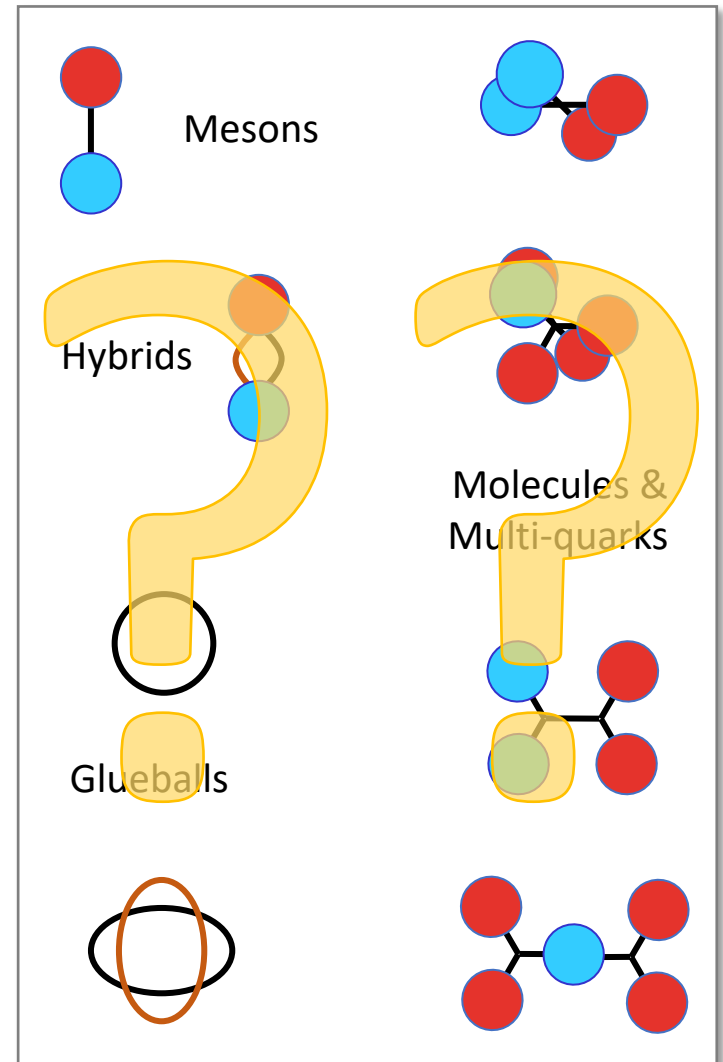
Cartoon-like
Physics sensitivity
at the
various phases

Charmonium-like particles – a mystery

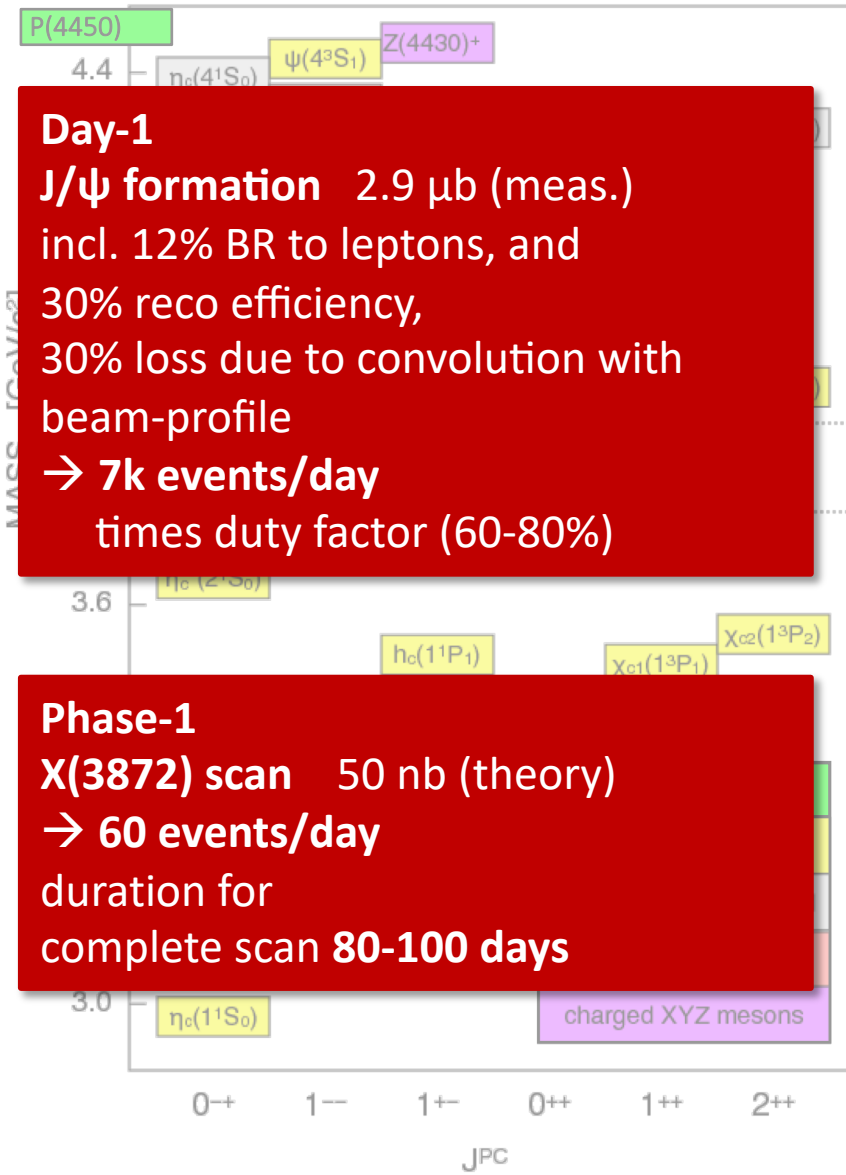


Discovery

Precision



Charmonium-like particles – a mystery



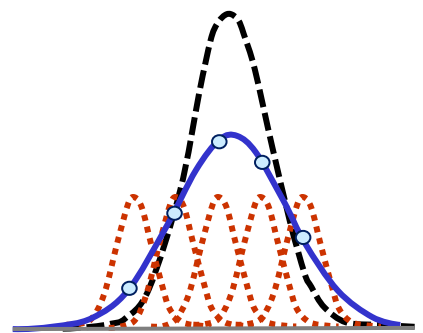
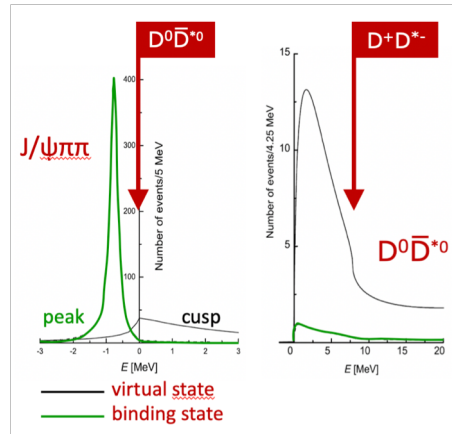
Day-1
J/ψ formation 2.9 μb (meas.)
 incl. 12% BR to leptons, and
 30% reco efficiency,
 30% loss due to convolution with
 beam-profile
→ 7k events/day
 times duty factor (60-80%)

Phase-1
X(3872) scan 50 nb (theory)
→ 60 events/day
 duration for
 complete scan **80-100 days**

Exploratory search of new Z states using
 direct formation in antiproton neutron

Line-scan proof-of-principle with narrow
 conventional charmonium

Day-1



Line-scan of “exotic” candidates
 such as X(3872)

Search for high-spin states with
 hidden-charm

Phase-1

Kaon spectrum

- every SU(3) meson nonet contains kaons but most of them have not been found
- their properties remain unclear and how well we really understand light mesons

(Strangeonium) hybrids

- predicted in the mass region
- spin-exotic quantum number scattering
- efforts will be continued and

Day-1

$> 500k \bar{p}p \rightarrow f_0(1500)\pi^0/\text{day} = >10x \text{ LEAR total}$

$> 100k \bar{p}p \rightarrow f_0(1500)\eta/\text{day}$

reconstructed, duty factor of 80% included

$\bar{p}p$ dominated by resonance production !!

LEAR: exotics yield is similar to ordinary mesons

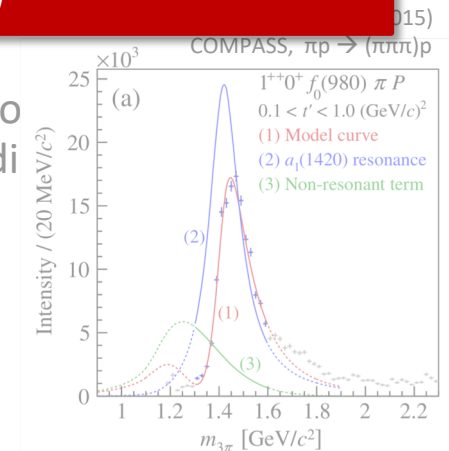
$f_0(1500) \sim O(f_2(1270))$

Glueballs

- $f_0(1500)$ discovered at LEAR/COMPASS
- LQCD predicts also $2^{++}, 0^{++}$ be
- mixing with $q\bar{q}$ states complicates clear identification
- BES III rad. J/ ψ for masses below $2.5 \text{ GeV}/c^2$ in (not conclusive so
- $4\text{-}5 \text{ GeV}/c^2$ region unexplored, where spin-exotic states are predi

Multiquarks/Molecules

- Where are the strange/strangeonium counterparts to the Zc's
- Is the recent $a_1(1420)$ finding by Compass a hint to that area?



$\phi\phi$ - Light Glueball Search



series of 2^{++} states with weak evidence by Etkin et al.

Jetset (1998):

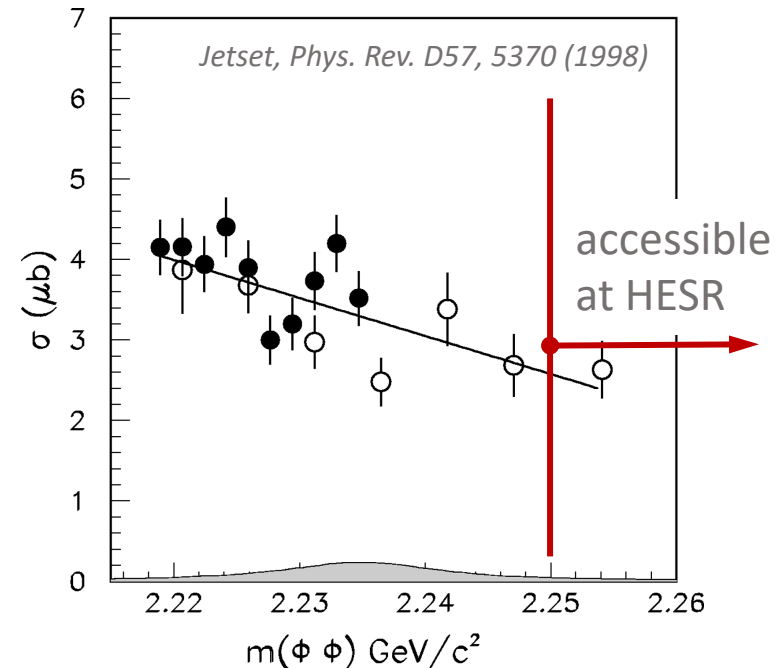
- cross section 100x larger than expected from OZI
- large gluonic component?
- glueball candidate?
- limited phase space, low rates

tensor states in this mass region seen by BESIII
in $J/\psi \rightarrow \gamma\phi\phi$ (13k events in 2^+ wave in 1.3B J/ψ)
 $\gamma\phi\phi$ lacks crossing interferences in Dalitz plot $\rightarrow J^{PC}$ biased

PANDA (2025):

- scan above 2.25 GeV: terra incognita
- physics studies at reduced luminosities feasible
- accesses 2^{++} and 0^+
- conventional mesons are suppressed due to OZI

$\bar{p}p \rightarrow \phi\phi$ cross section



Phase-1

> 500k $\bar{p}p \rightarrow \phi\phi$ /day

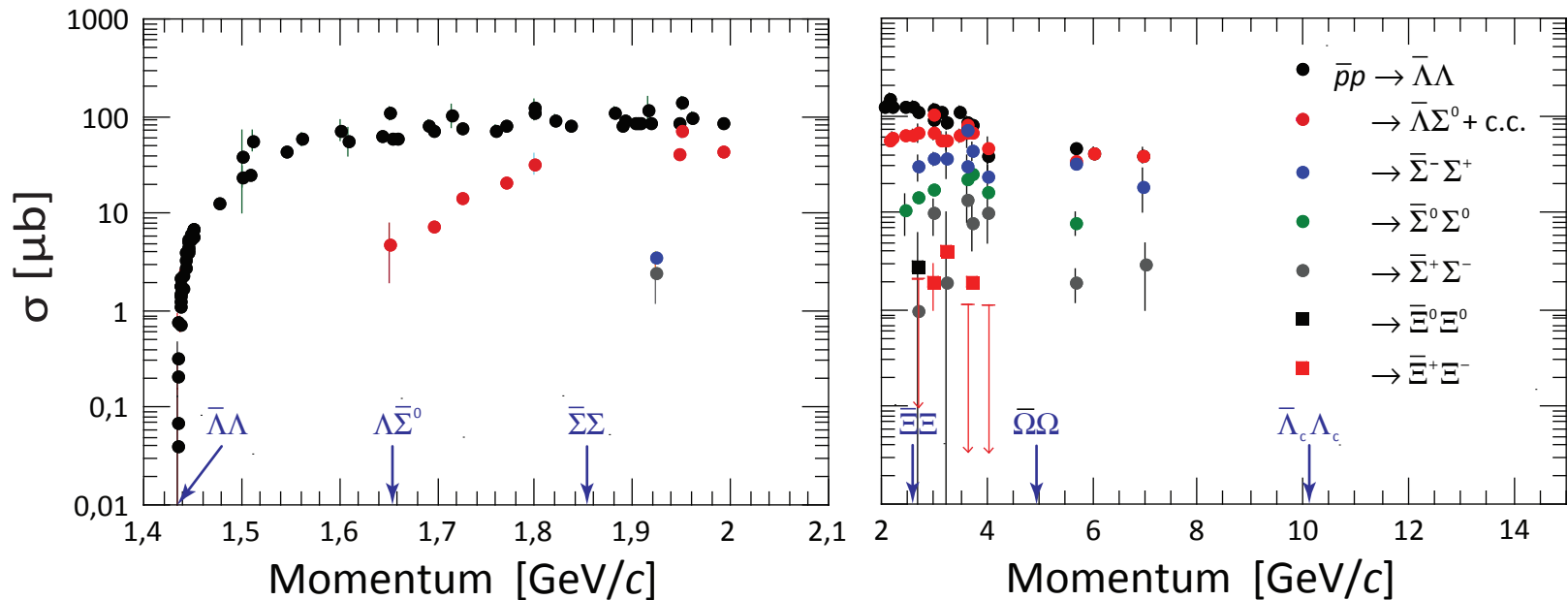
Day-1

> 50k $\bar{p}p \rightarrow \phi\phi$ /day

reconstructed

(duty factor of 80% included)

Previous measurements of $\bar{p}p \rightarrow \bar{Y}\Upsilon$



A lot of data on $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ near threshold, mainly from PS185 at LEAR

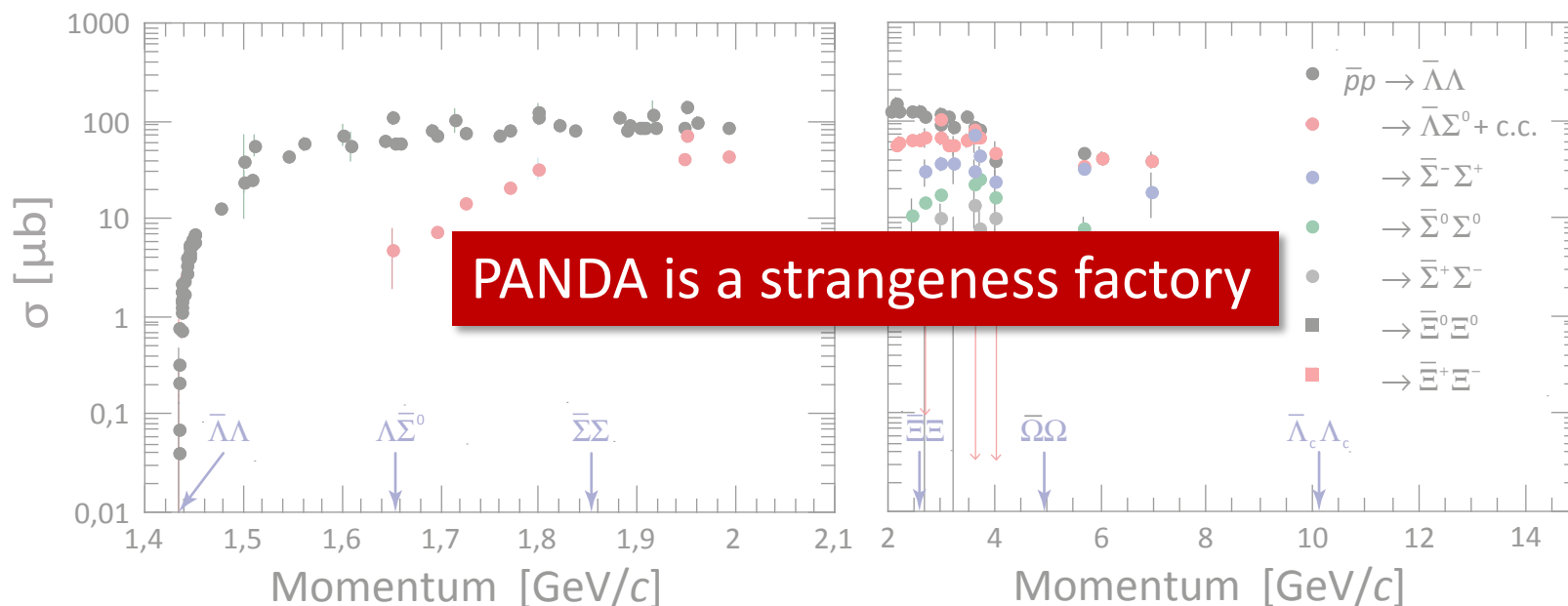
Very scarce data bank above 4 GeV/c

High event rates & low background for Λ and Σ

No data on $\bar{p}p \rightarrow \bar{\Omega}\Omega$ nor $\bar{p}p \rightarrow \bar{\Lambda}_c\Lambda_c$

Even with conservative cross section estimates, Ω / Λ_c channels are feasible

Previous measurements of $\bar{p}p \rightarrow \bar{Y}Y$



A lot of data
 Very scarce
 High event
 No data
 Even with

Phase-1

$|S| = 1 \quad \sim 7\text{M } \Lambda\bar{\Lambda}/\text{day}$
 $\quad \quad \quad \sim 4\text{M } \Lambda\bar{\Sigma}^0/\text{day}$
 $|S| = 2 \quad \sim 90\text{k } \Xi\bar{\Xi}/\text{day}$
 $|S| = 3 \quad \sim 100 \Omega\bar{\Omega}/\text{day}$
 duty factor of 80% included

Day-1

$|S| = 1 \quad \sim 700\text{k } \Lambda\bar{\Lambda}/\text{day}$
 $\quad \quad \quad \sim 400\text{k } \Lambda\bar{\Sigma}^0/\text{day}$
 $|S| = 2 \quad \sim 9\text{k } \Xi\bar{\Xi}/\text{day}$
 $|S| = 3 \quad \sim 10 \Omega\bar{\Omega}/\text{day excl.}$
 more w/incl. studies

Antihyperons in Nuclei



PANDA, NPA954, 323 (2016)

Antiprotons sensitive tool to study
antihyperon potential in nuclei !

Exploit abundantly produced
hyperon-antihyperon pairs near threshold

Benchmark data to test theoretical concepts to describe dynamics of (anti)hyperons in heavy-ion collisions

Important **first step** towards the $|S|=2$
hypernuclei program of PANDA

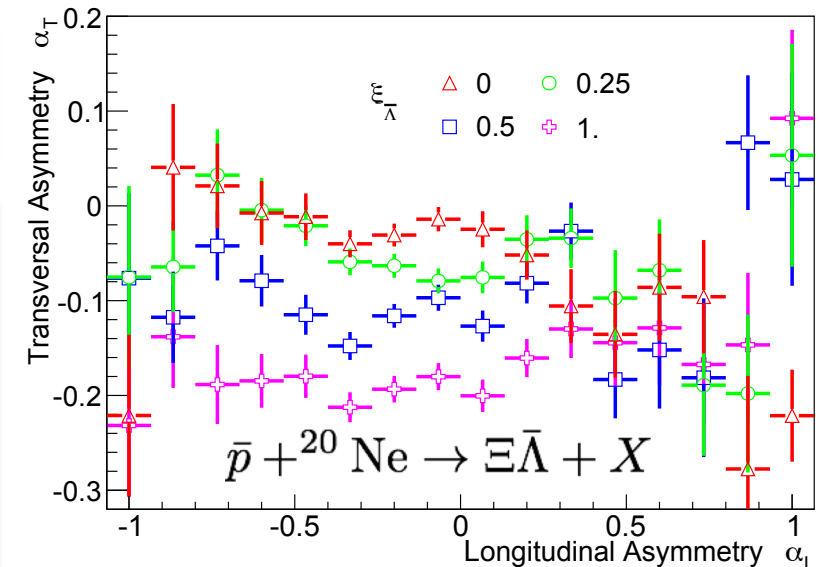
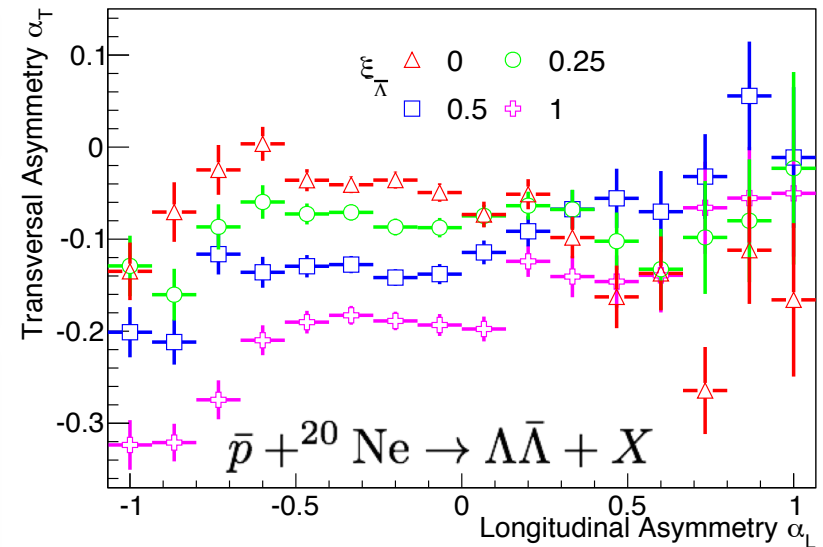
Need $\sim 10^6$ $Y\bar{Y}$ pairs for unique physics (polarization, planarity and everything)

Phase-1

→ ~ 10 d for $\bar{\Lambda}$ -Potential & ~ 75 d Ξ -Potential

Day-1

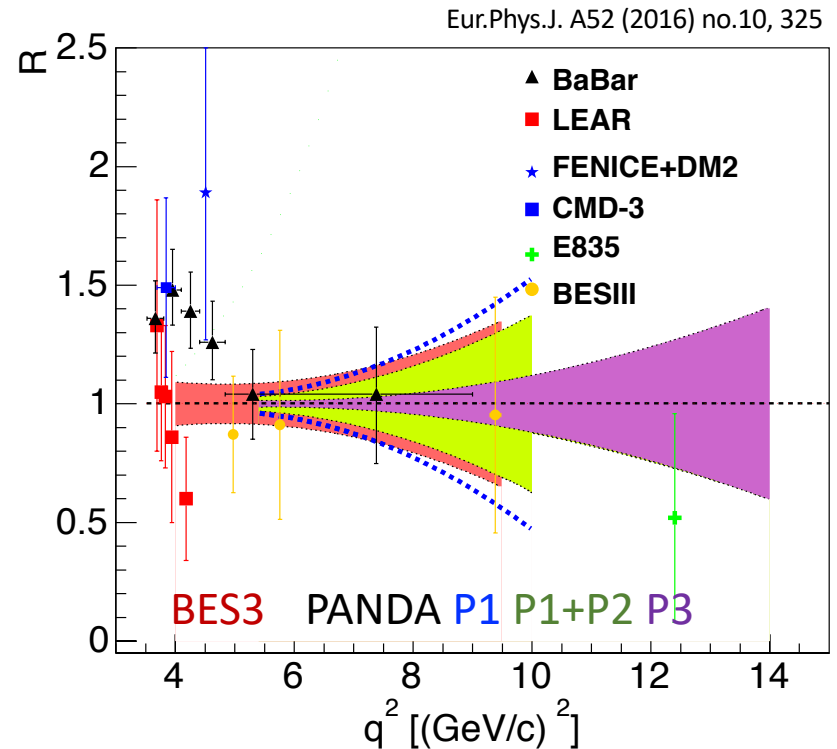
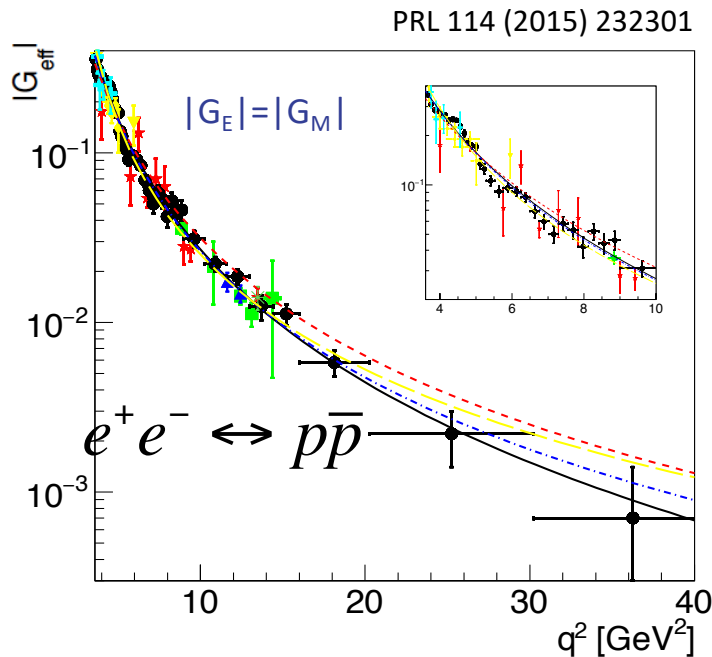
→ 1 day for 10^5 for $\bar{\Lambda}$ -Potential (12x simu)



Time-Like proton electromagnetic FFs



The **effective FF** can be measured
 up to $q^2 \sim 30 \text{ GeV}^2$
 no individual determination
 of G_E and G_M so far



Outlook with transversely polarized target

$$\left(\frac{d\sigma}{d\Omega}\right)_0 A_{1,y} \propto \sin 2\Theta \text{Im}(G_M G_E^*)$$

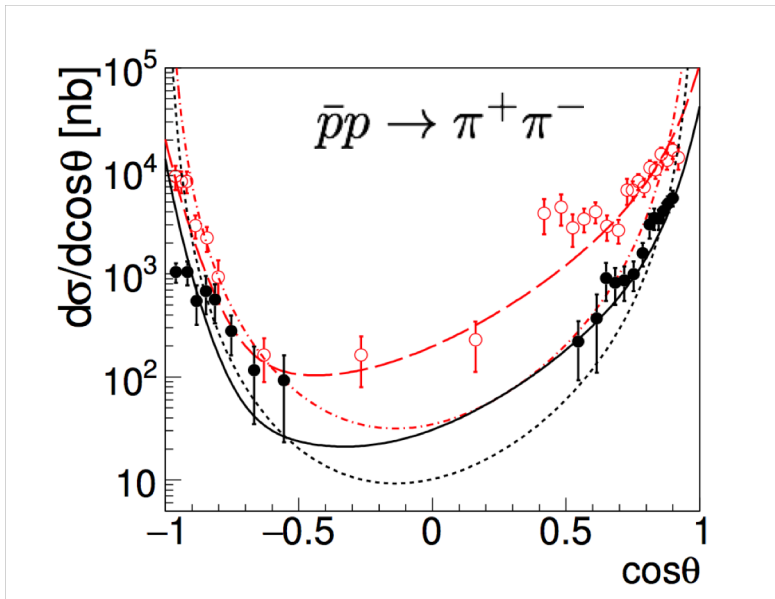
Analytical Structure of the Formfactor

Time-like Electromagnetic Form-factors
(lepton pair production)

Integrated luminosity (Phase-1)

$$L = 75 \text{ pb}^{-1} @ p_{\text{lab}} = 1.5 \text{ GeV}/c$$

$$L = 97 \text{ pb}^{-1} @ p_{\text{lab}} = 3.3 \text{ GeV}/c$$



Phase-1

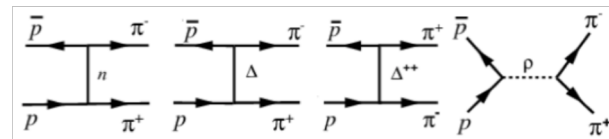
$\bar{p}p \rightarrow e^+e^-$ @1.5 GeV/c ~ 220/day

$\bar{p}p \rightarrow e^+e^-$ @3.3 GeV/c ~ 10/day

$\bar{p}p \rightarrow \mu^+\mu^-$ @1.5 GeV/c ~ 170/day

Day-1

$\bar{p}p \rightarrow e^+e^-\pi^0$ @1.5 GeV/c ~ 3'500/day



Day-1 activities:

Build **database** on **multi-pion production** in $\bar{p}p$ as input to QCD calculations

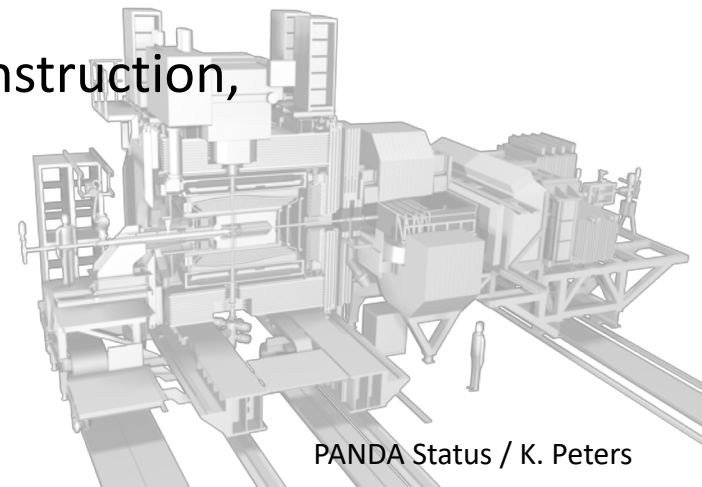
Demonstrate the feasibility to identify di-lepton (+ π^0) channels

QCD at large scales is extremely fascinating

- and PANDA is a **key tool** to challenge this field in all aspects
- the full setup covers the **broadest physics case ever** in hadron physics history
- already the start-setup addresses unique questions in **hyperon-, charm- and light-quark-physics**

PANDA is progressing very well

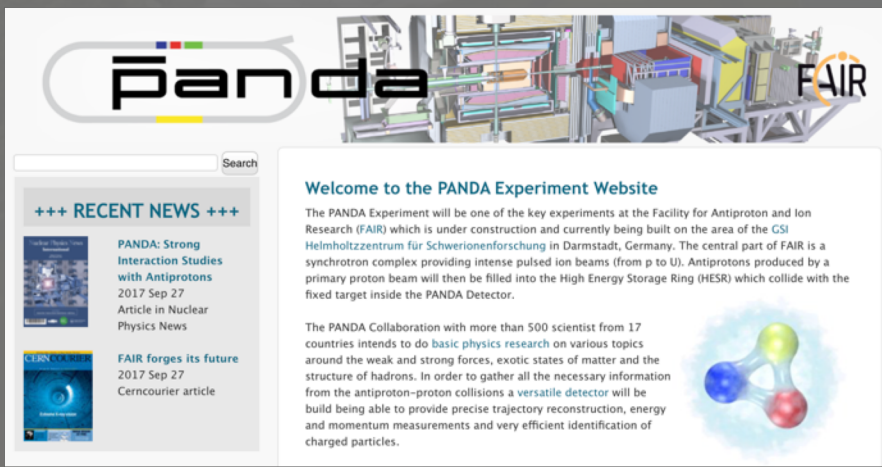
- in R&D and planning, contracting and construction,
- in physics,
- in attracting more man power
- Please stay tuned for start of **proton beam 2024** and **anti-proton beam 2025**



PANDA Status / K. Peters



panda.gsi.de



The screenshot shows the PANDA Experiment Website interface. At the top, there is a search bar and a navigation menu. Below the search bar, there is a section titled "+++ RECENT NEWS +++" with two news items:


- PANDA: Strong Interaction Studies with Antiprotons**
2017 Sep 27
Article in Nuclear Physics News
- FAIR forges its future**
2017 Sep 27
Cerncourier article

The main content area features a "Welcome to the PANDA Experiment Website" section. It includes a detailed 3D cutaway diagram of the PANDA detector and the FAIR logo. The text describes the experiment's location at GSI and its goals in studying strong interactions and exotic states of matter.

Welcome to the PANDA Experiment Website

The PANDA Experiment will be one of the key experiments at the Facility for Antiproton and Ion Research (FAIR) which is under construction and currently being built on the area of the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt, Germany. The central part of FAIR is a synchrotron complex providing intense pulsed ion beams (from p to U). Antiprotons produced by a primary proton beam will then be filled into the High Energy Storage Ring (HESR) which collide with the fixed target inside the PANDA Detector.

The PANDA Collaboration with more than 500 scientist from 17 countries intends to do basic physics research on various topics around the weak and strong forces, exotic states of matter and the structure of hadrons. In order to gather all the necessary information from the antiproton-proton collisions a versatile detector will be build being able to provide precise trajectory reconstruction, energy and momentum measurements and very efficient identification of charged particles.



Thank you