PANDA

KHuK Jahrstagung

Bad Honnef, Dec 7, 2018

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GSI/U Frankfurt

PANDA physics: light, strange, charm

Key questions in “strong” QCD

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

Nucleon properties

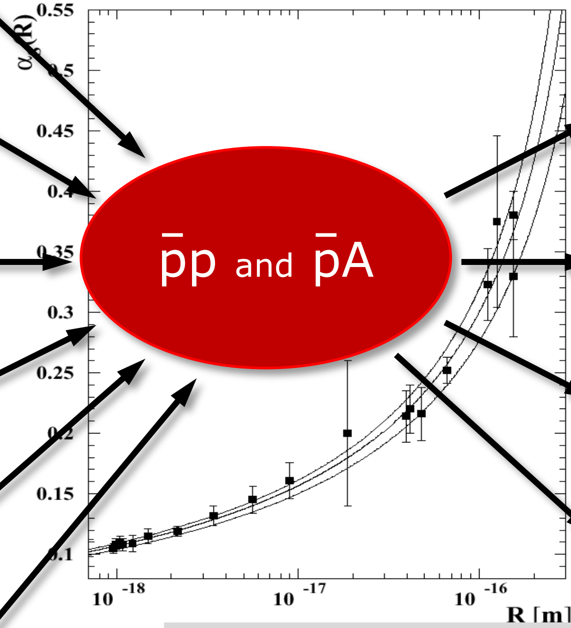
Exotics hadrons

In-medium hadron properties

Color transparency

Neutron stars

Matter-antimatter asymmetry



PANDA Physics Pillars

Nucleon structure

Strangeness physics

Charm and exotics

Hadrons in Nuclei

Impact by precision (statistics & resolution) and uniqueness (terra incognita)

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 → discovery by precision!

High hadronic production rates

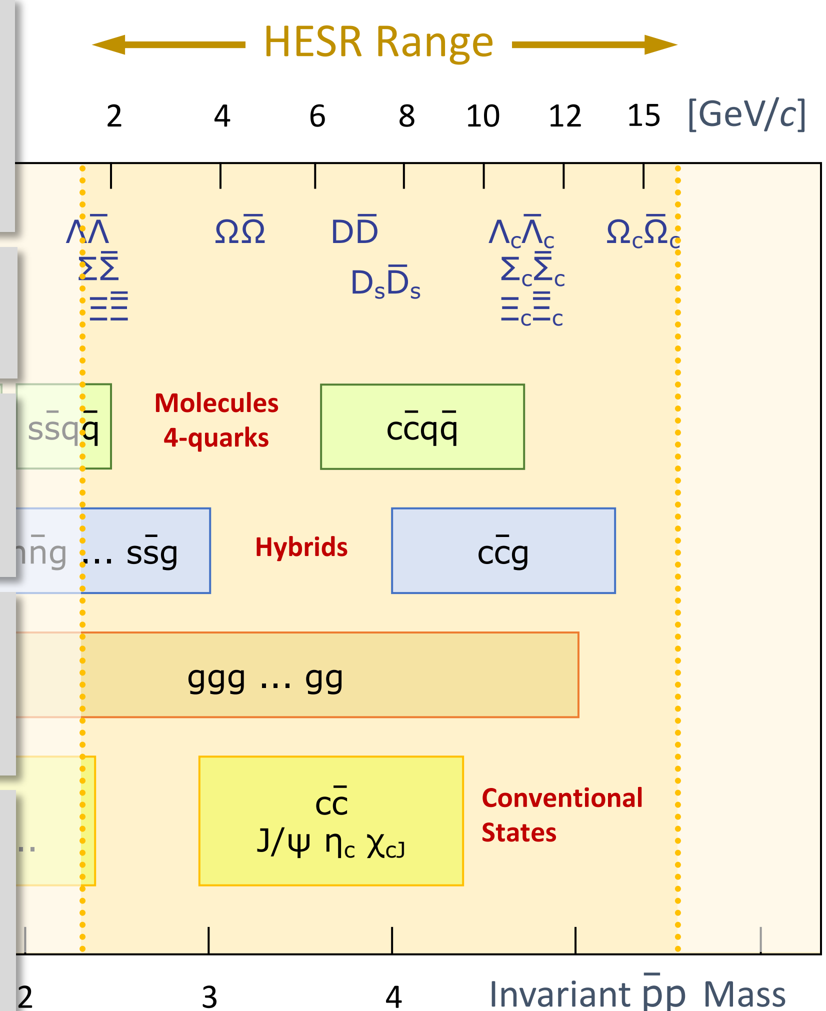
- charm+strange factory → discovery by statistics!
- gluon-rich production → potential for new exotics

Access to large spectrum of J^{PC} states

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

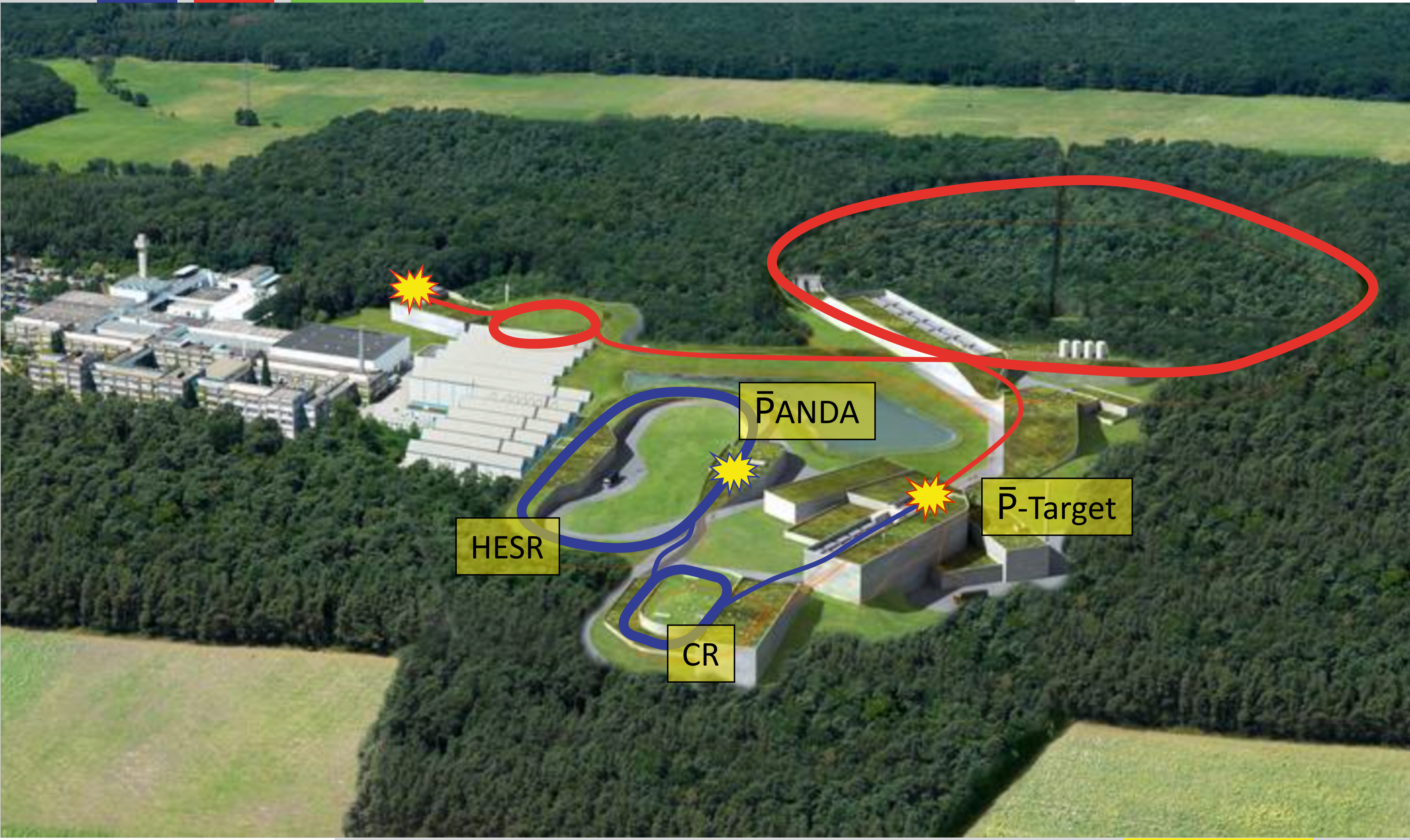
Associated hadron-pair production

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

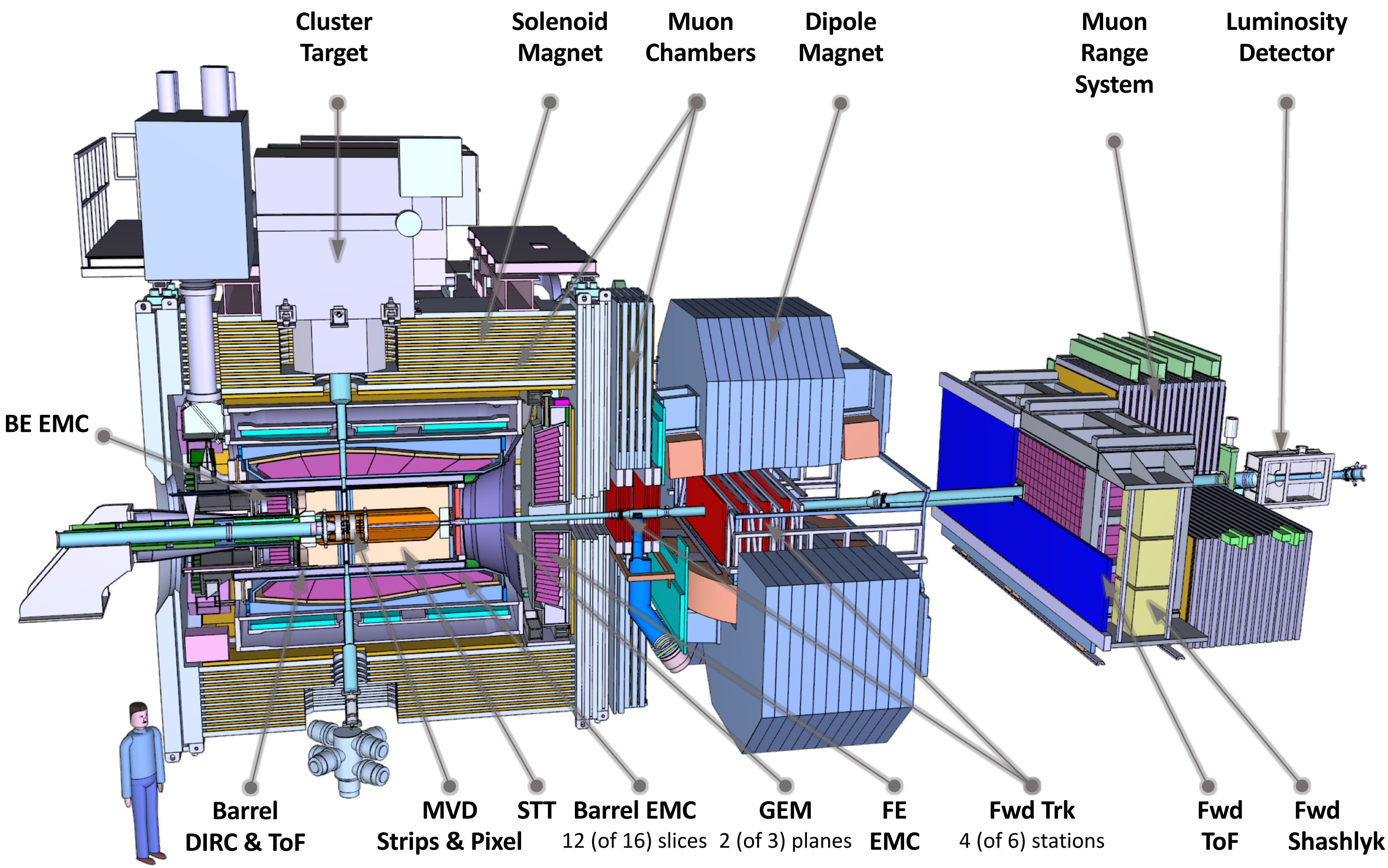


Systematic and precise tool to rigorously study the dynamics of QCD

Antiproton Chain: HESR & PANDA



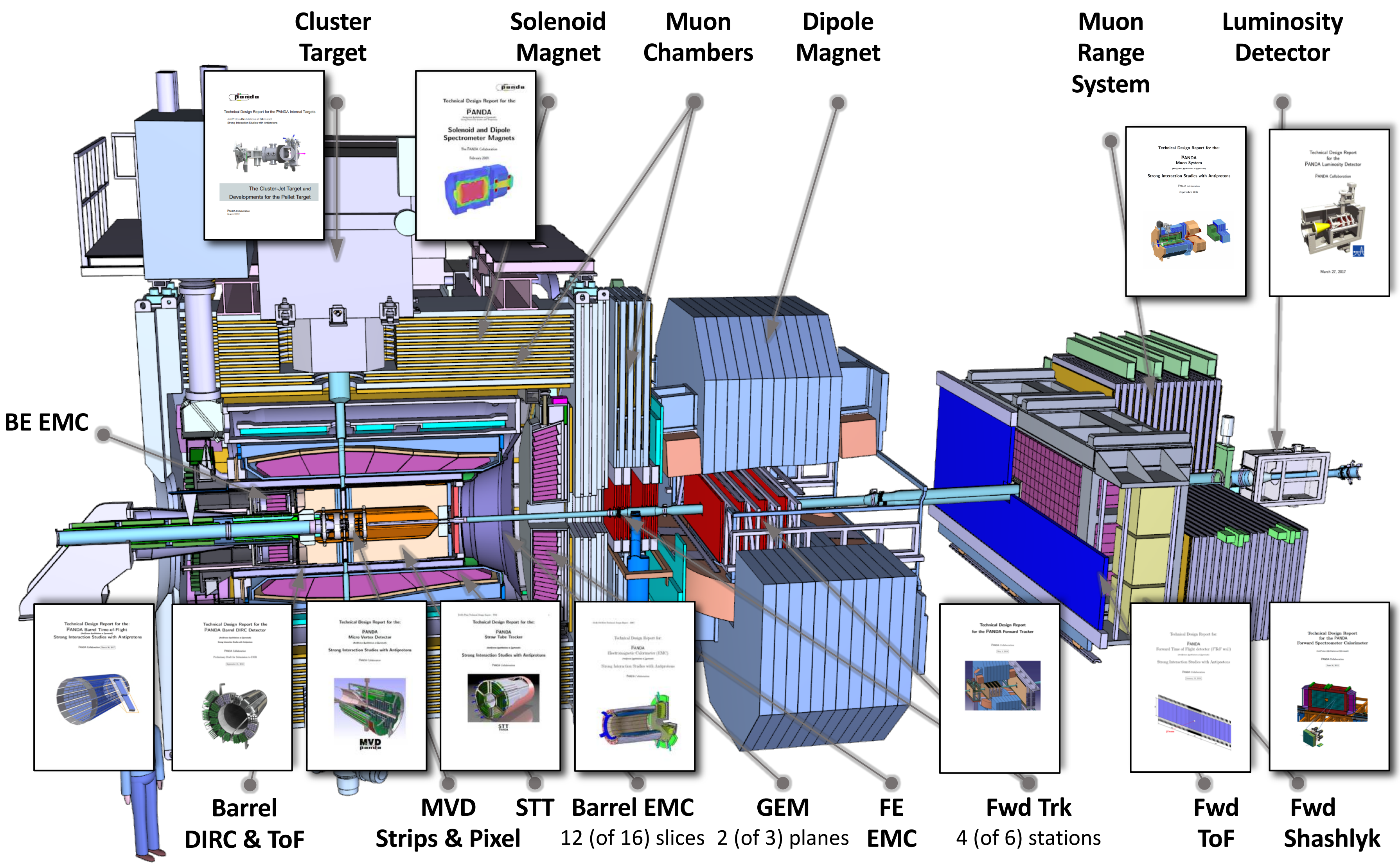
Day-1 Setup



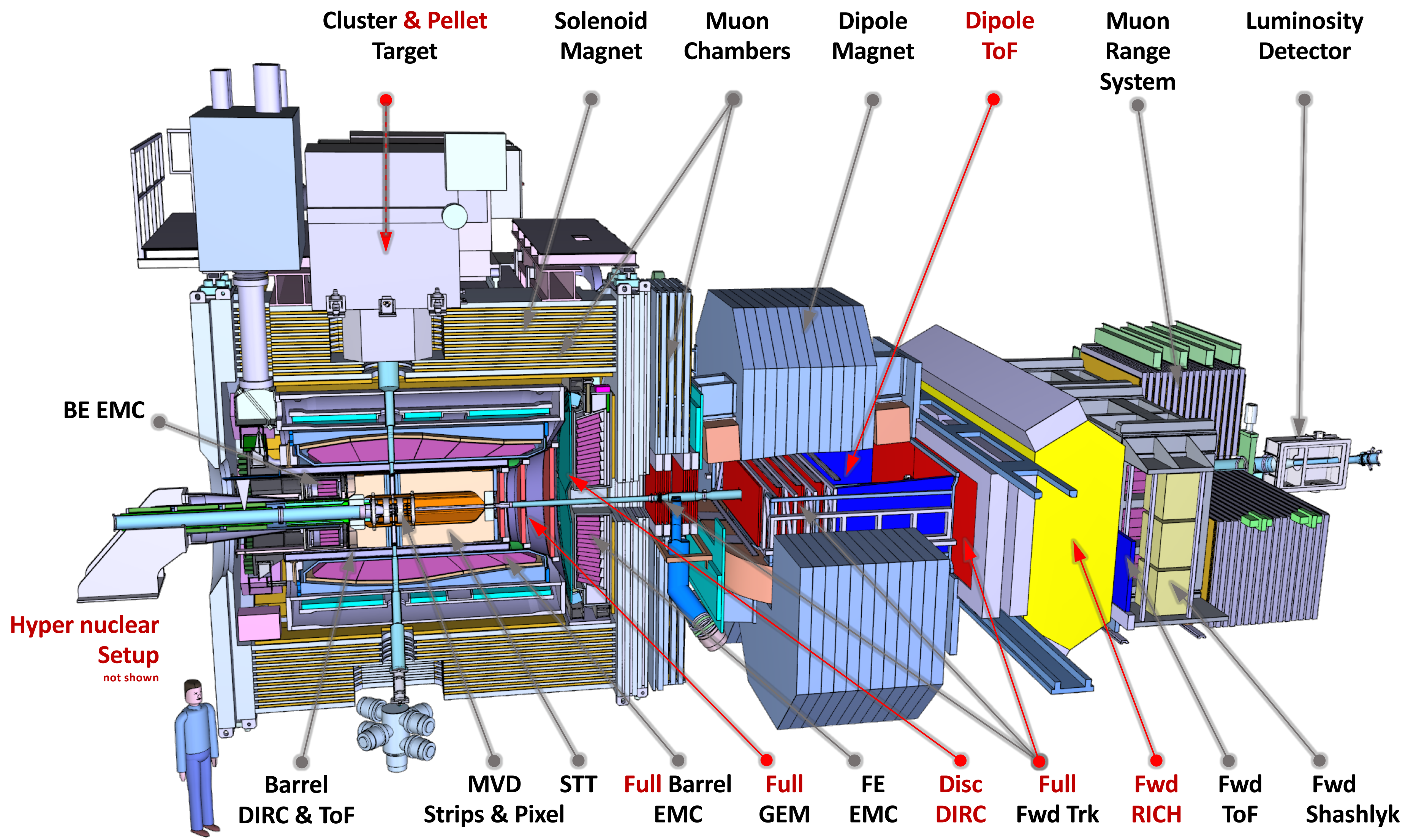
Cluster Target
Solenoid Magnet
Muon Chambers
Dipole Magnet
Muon Range System
Luminosity Detector
BE EMC
Barrel DIRC & ToF
MVD Strips & Pixel
STT
Barrel EMC 12 (of 16) slices
GEM 2 (of 3) planes
FE EMC
Fwd Trk 4 (of 6) stations
Fwd ToF
Fwd Shashlyk

Day-1 Setup

TDRs approved for 87.3% of Day-1 funds



Full Setup



Cluster & Pellet Target
Solenoid Magnet
Muon Chambers
Dipole Magnet
Dipole ToF
Muon Range System
Luminosity Detector
BE EMC
Hyper nuclear Setup
not shown
Barrel DIRC & ToF
MVD Strips & Pixel
STT
Full Barrel EMC
Full GEM
FE EMC
Disc DIRC
Full Fwd Trk
Fwd RICH
Fwd ToF
Fwd Shashlyk

Important Progress

Major Milestones

- FAIR Construction progressing well
- Solenoid production progressing well
- Dipole Design is contracted
- Super-conducting cable R&D on track for the Solenoid
- 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

2 TDRs in the ECE Queue

- LMD TDR finalization of internal ECE report
- Disk DIRC TDR assessment pending

2 TDRs approved by FAIR

- Forward TOF submitted
- Forward Tracker submitted, both will be considers in Fall 2018

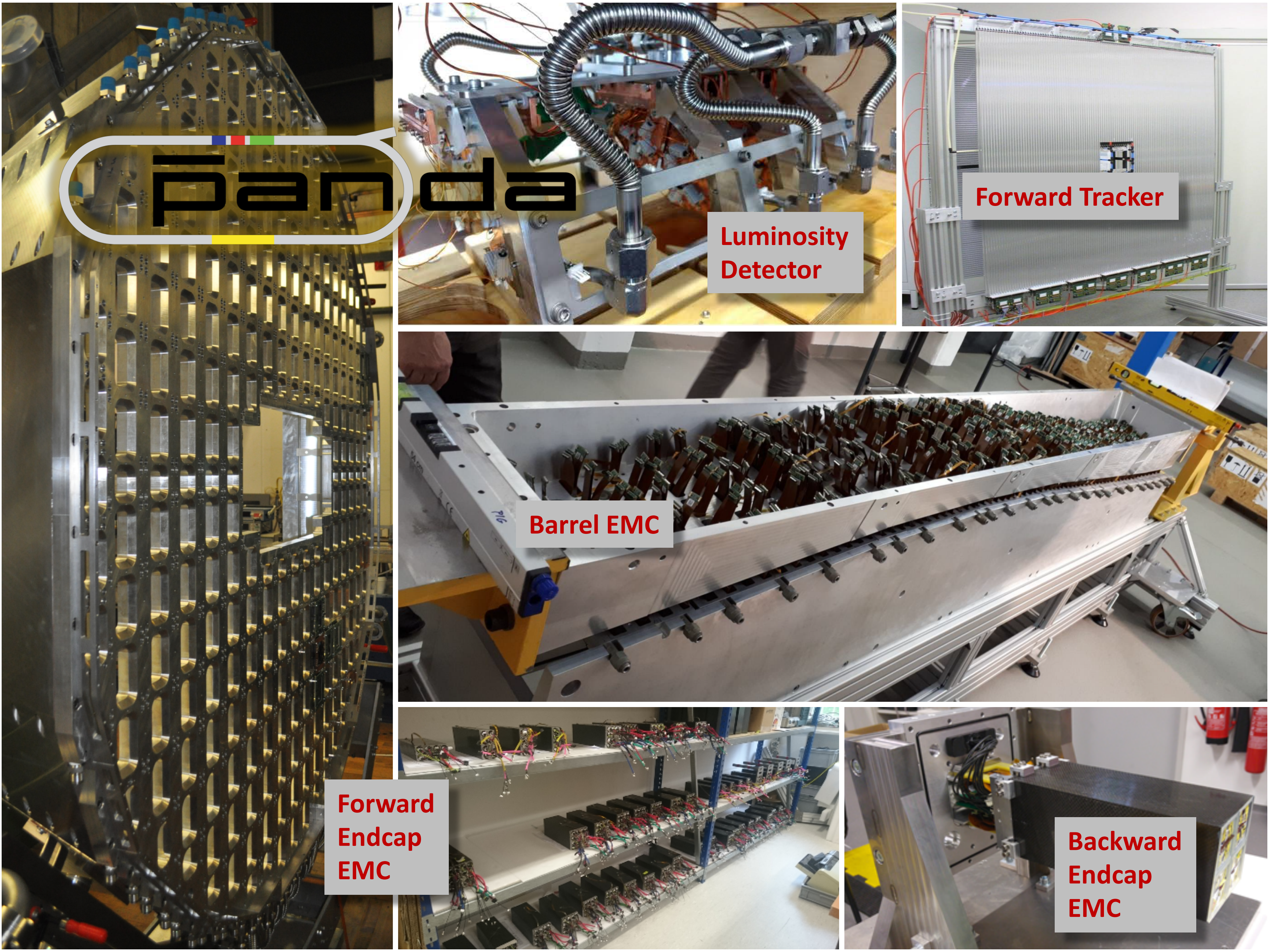
In the pipeline

- DCS presented this meeting
- DAQ status report this week
- GEM (end of 2019)

Infrastructure planning and detector integration well under way ...

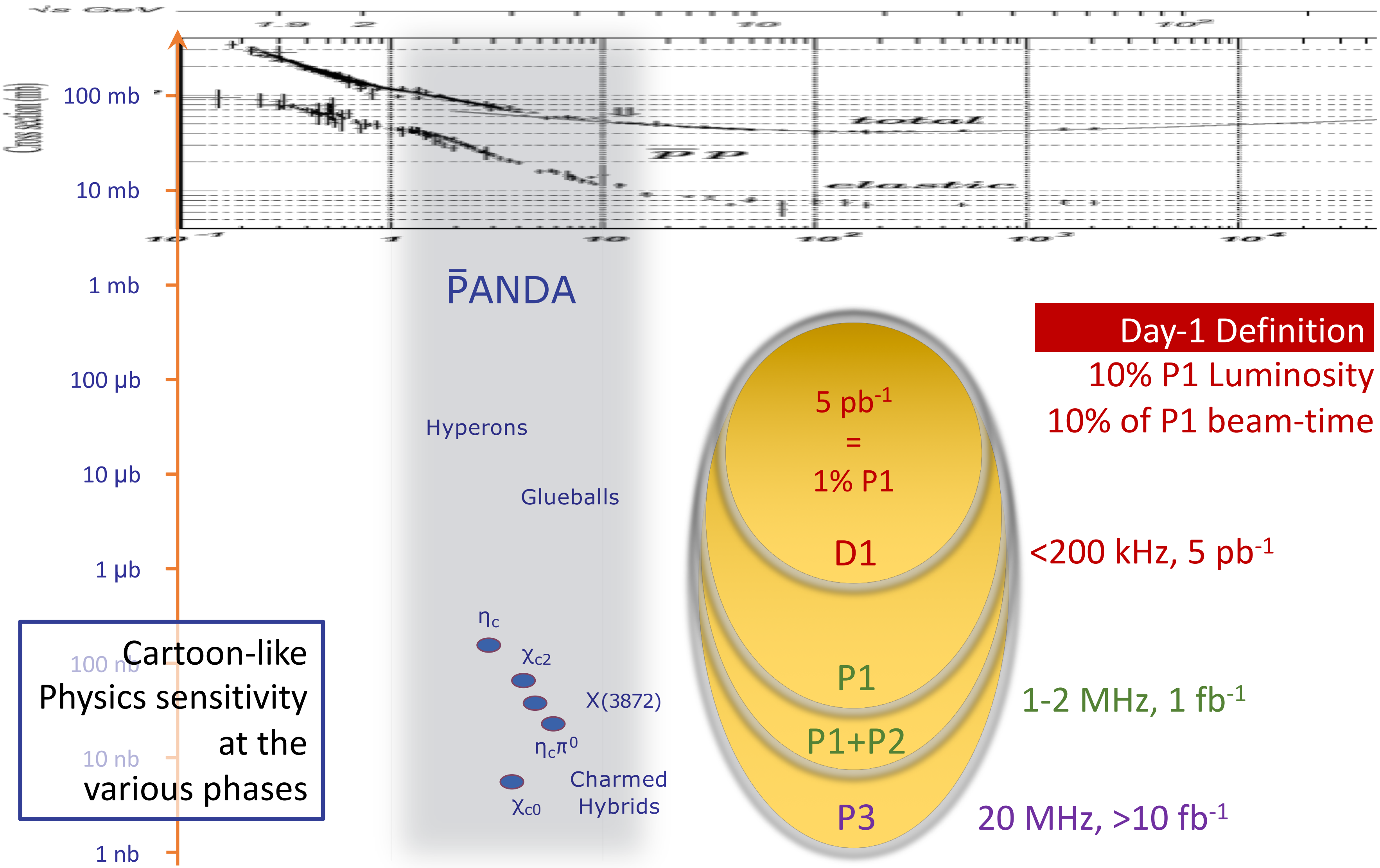

Cluster Jet Target
Muon Detector
Target Beam Dump
Magnet Yoke Octant

panda
BARREL DIRC
Barrel DIRC
Disc DIRC
Forward TOF
Forward RICH

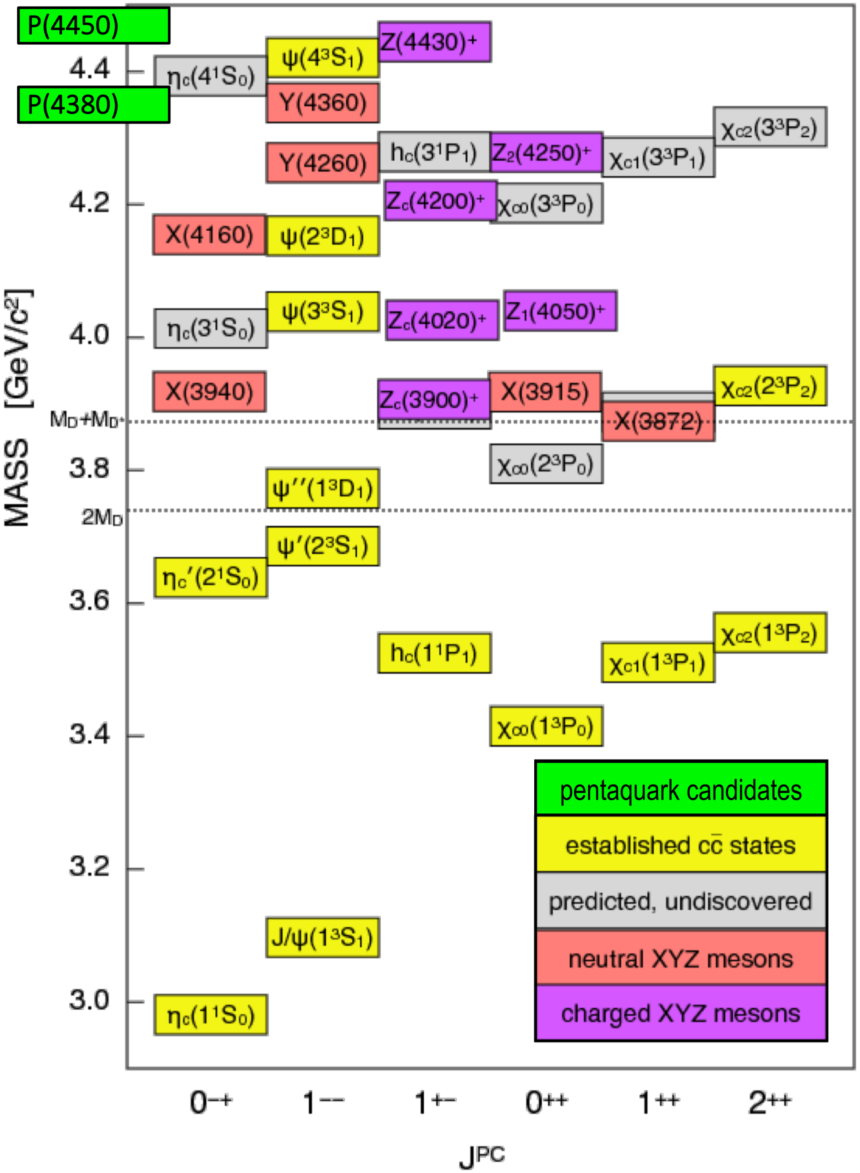


Luminosity Detector
Forward Tracker
Barrel EMC
Forward Endcap EMC
Backward Endcap EMC

Phases of PANDA – Sensitivities in a nutshell

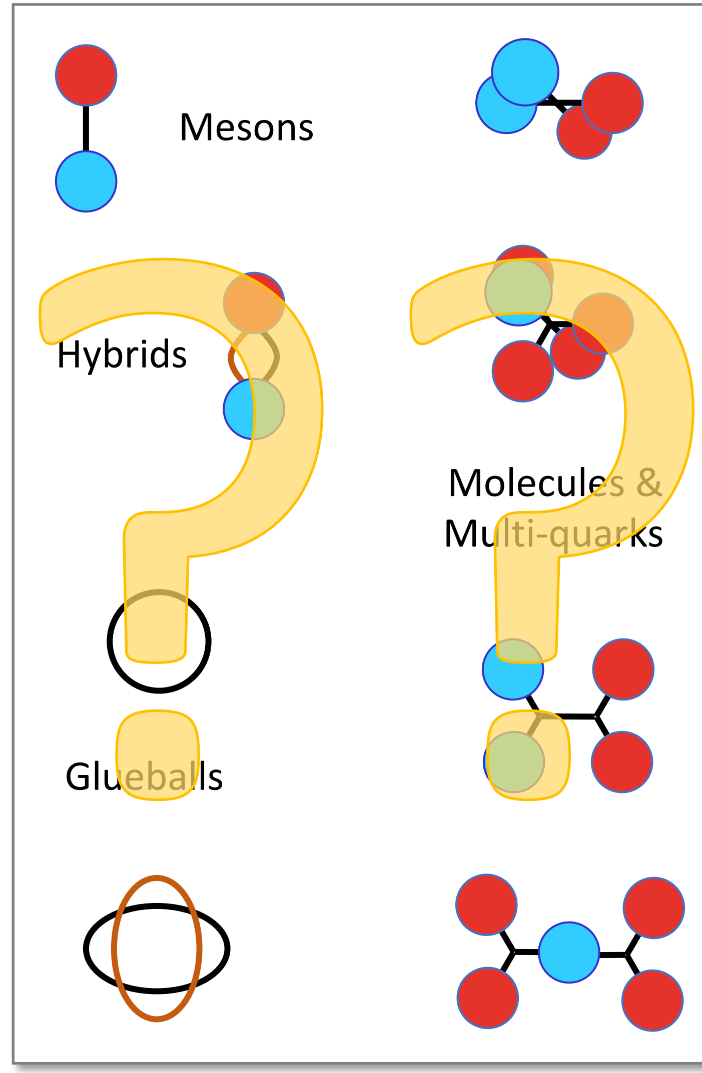


Charmonium-like particles – a mystery

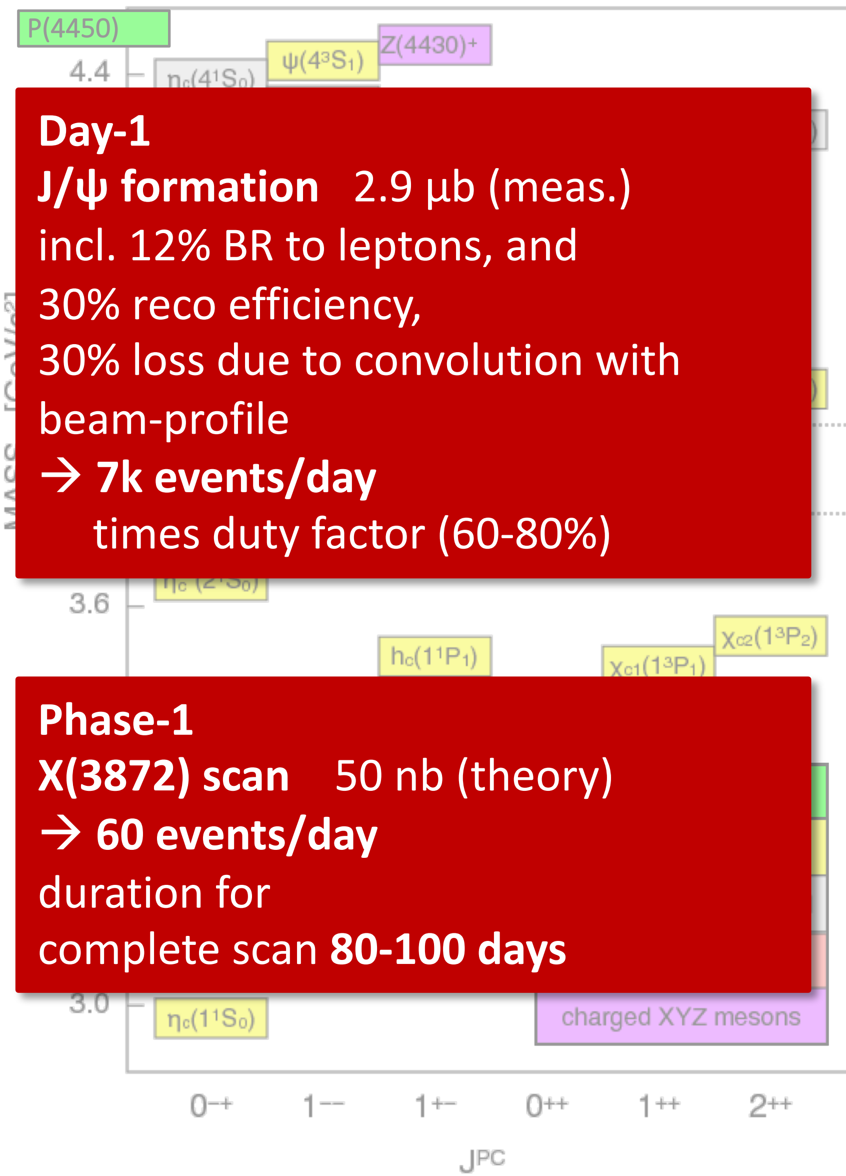


Discovery

Precision



Charmonium-like particles – a mystery

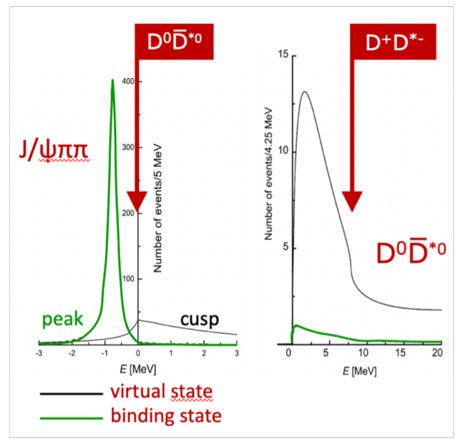


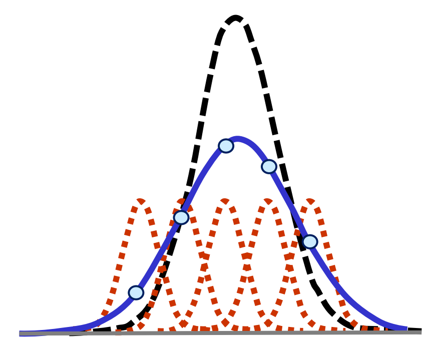
Day-1
J/ψ formation 2.9 μb (meas.)
incl. 12% BR to leptons, and
30% reco efficiency,
30% loss due to convolution with beam-profile
→ **7k events/day**
times duty factor (60-80%)

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

Day-1

- Exploratory search of new Z states using direct formation in antiproton neutron
- Line-scan proof-of-principle with narrow conventional charmonium





Phase-1

- Line-scan of “exotic” candidates such as X(3872)
- Search for high-spin states with hidden-charm

Light Quark/Meson Spectroscopy

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

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

reconstructed, duty factor of 80% included

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

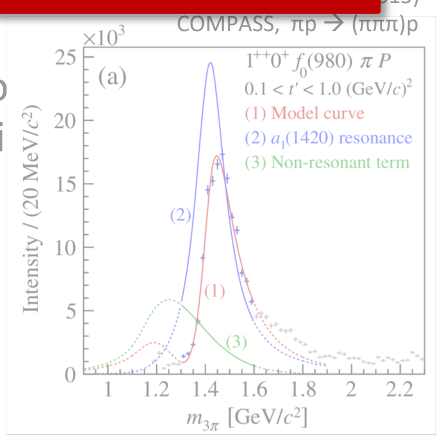
LEAR: exotics yield is similar to ordinary mesons

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

Glueballs

- $f_0(1500)$ discovered at LEAR/C
- 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 GeV/c^2 in (not conclusive so
- 4-5 GeV/c^2 region unexplored, where spin-exotic states are predi

015)



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?

φφ - Light Glueball Search

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

Jetset (1998):

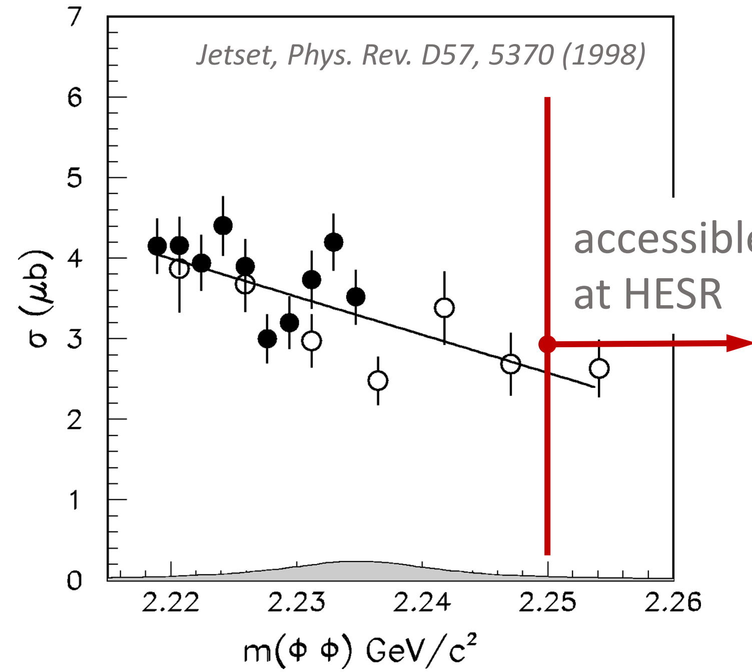
- cross section 100x larger than expected from OZI
- large gluonic component?
- glueball candidate?
- limited phase space, low rates

tensor states in this mass region seen by BESIII
in J/ψ → γφφ (13k events in 2^+ wave in 1.3B J/ψ)
γφφ lacks crossing interferences in Dalitz plot → 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

$\bar{p}p$ → φφ cross section

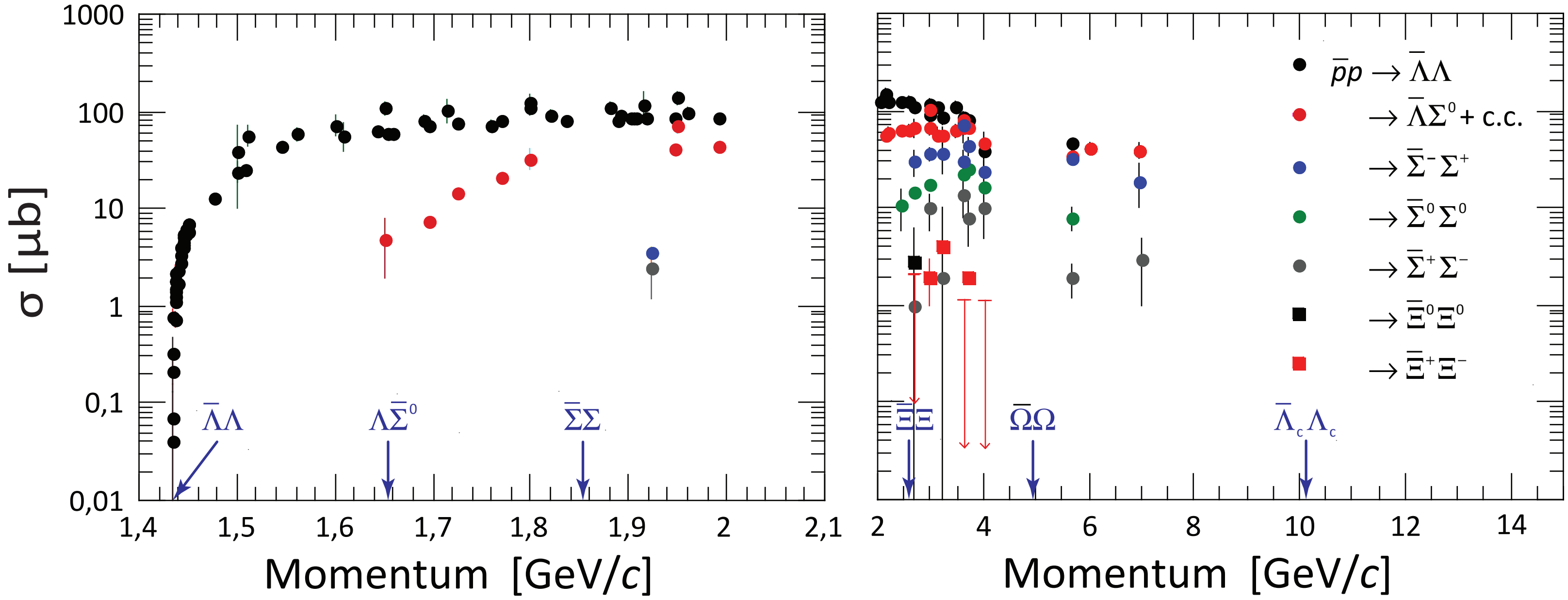


Phase-1
> 500k $\bar{p}p$ → φφ/day

Day-1
> 50k $\bar{p}p$ → φφ/day

reconstructed
(duty factor of 80% included)

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



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

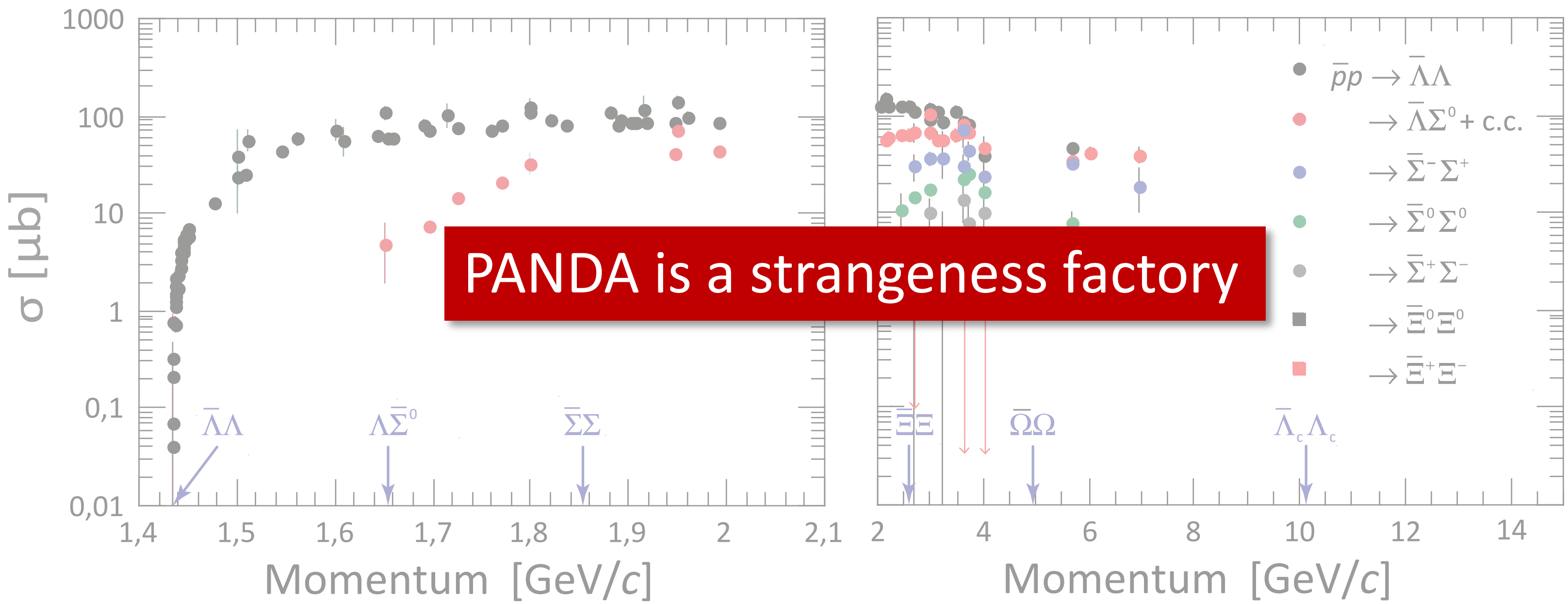
Very scarce data bank above 4 GeV/c

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 $\bar{p}p \rightarrow \bar{Y}Y$



PANDA is a strangeness factory

A lot of ... hold, ...
Very sca...
High eve... r Λ ar...
No data ... Λ_c
Even wit... estim... ...le

Phase-1

|S| = 1	~ 7M $\Lambda\bar{\Lambda}$/day
	~ 4M $\Lambda\bar{\Sigma}^0$/day
|S| = 2	~ 90k $\Xi\bar{\Xi}$/day
|S| = 3	~ 100 $\Omega\bar{\Omega}$/day

duty factor of 80% included

Day-1

|S| = 1	~ 700k $\Lambda\bar{\Lambda}$/day
	~ 400k $\Lambda\bar{\Sigma}^0$/day
|S| = 2	~ 9k $\Xi\bar{\Xi}$/day
|S| = 3	~ 10 $\Omega\bar{\Omega}$/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

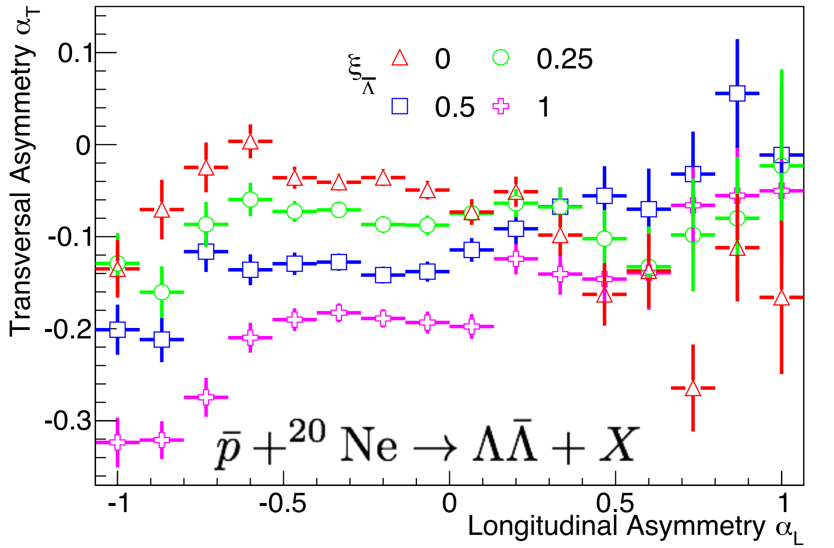
Benchmark data to test theoretical concepts to describe dynamics of (anti)hyperons in heavy-ion collisions

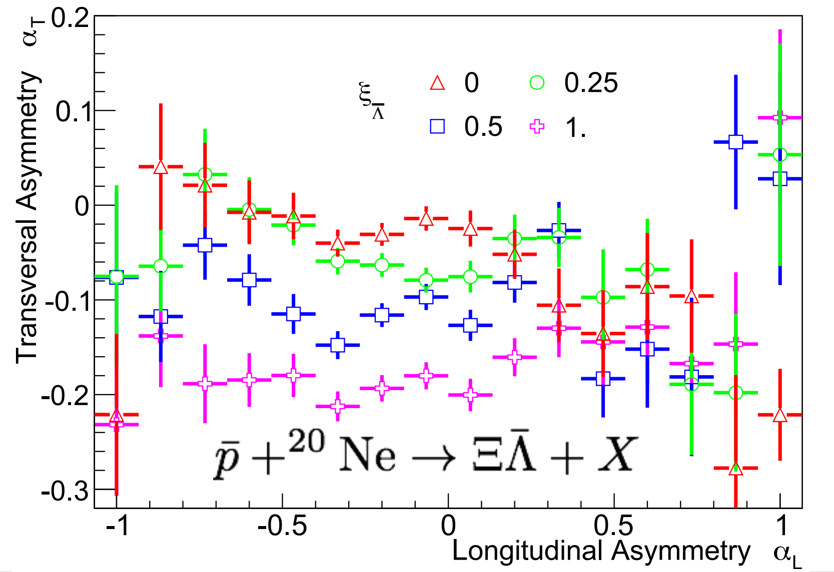
Important **first step** towards the |S|=2 **hypernuclei program** of PANDA

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

Phase-1
→ ~10 d for $\bar{\Lambda}$-Potential & ~75 d $\bar{\Xi}$-Potential

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



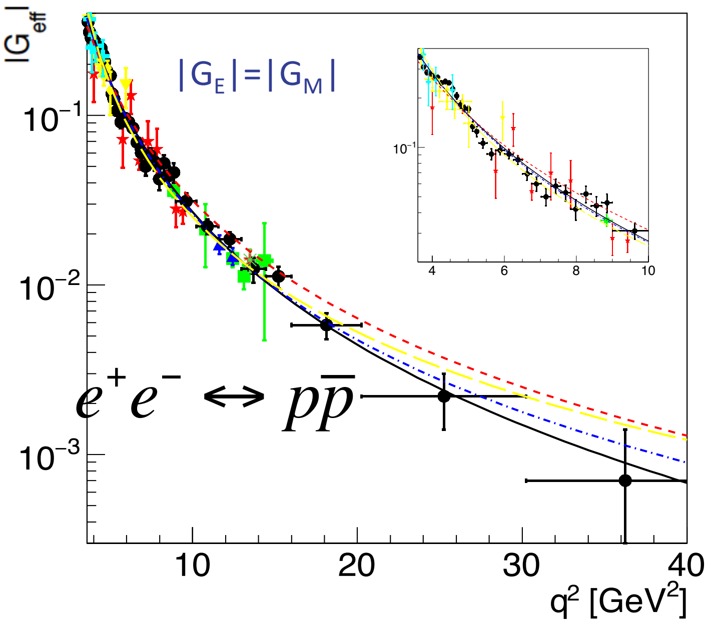


Time-Like proton electromagnetic FFs

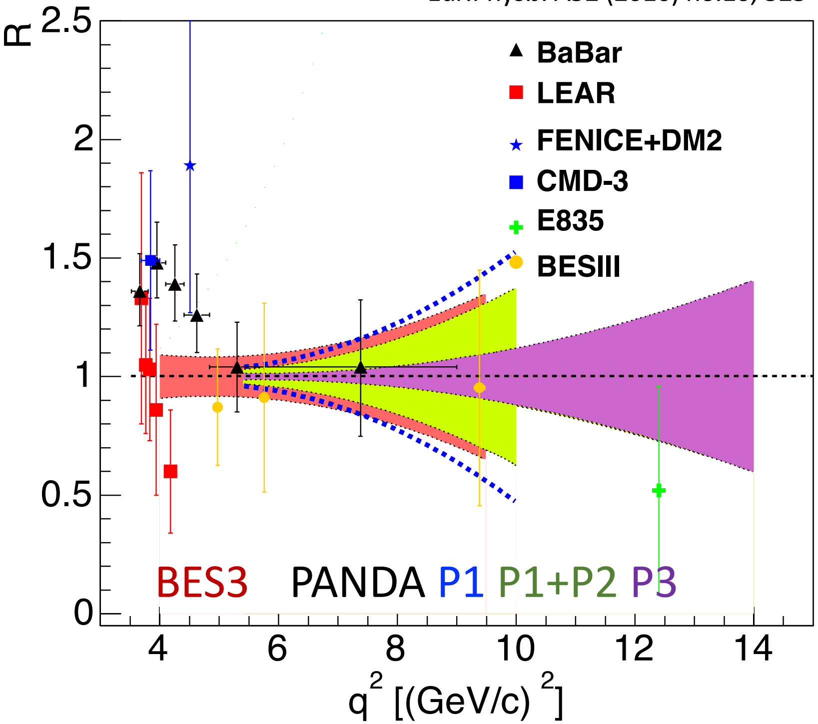
The effective FF can be measured up to $q^2 \sim 30\ GeV^2$

no individual determination of G_E and G_M so far

PRL 114 (2015) 232301



Eur.Phys.J. A52 (2016) no.10, 325



Outlook with transversely polarized target

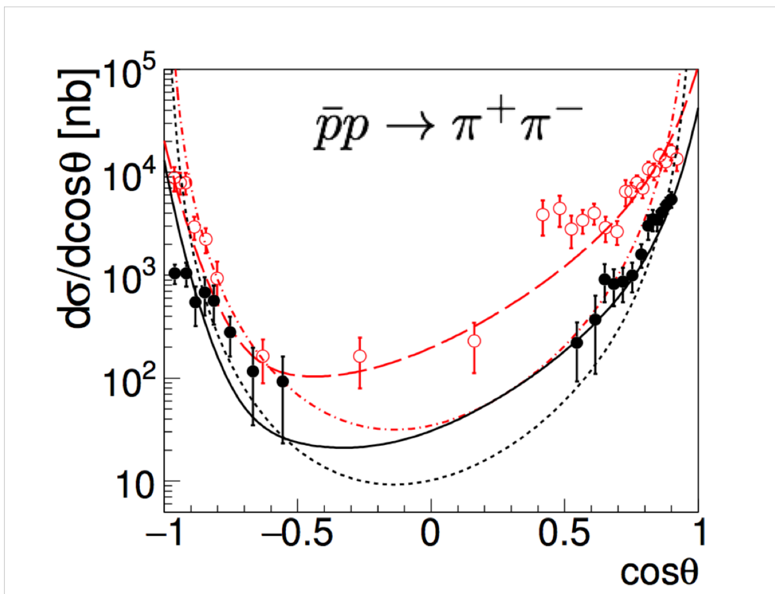
$$\left(\frac{d\sigma}{d\Omega}\right)_0 A_{1,y} \propto \sin 2\Theta \,\mathrm{Im}\left(G_M G_E^*\right)$$

Analytical Structure of the Formfactor

Time-like Electromagnetic Form-factors (lepton pair production)
Integrated luminosity (Phase-1)

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

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

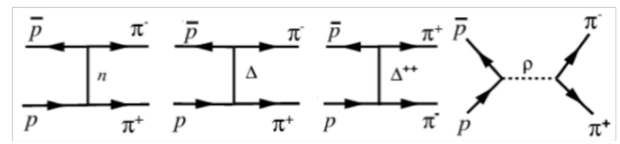


Phase-1

$\bar{p}p \to e^+e^-$	@1.5 GeV/c	~ 220/day
$\bar{p}p \to e^+e^-$	@3.3 GeV/c	~ 10/day
$\bar{p}p \to \mu^+\mu^-$	@1.5 GeV/c	~ 170/day

Day-1

$\bar{p}p \to e^+e^-\pi^0$	@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 ($+\pi^0$) channels

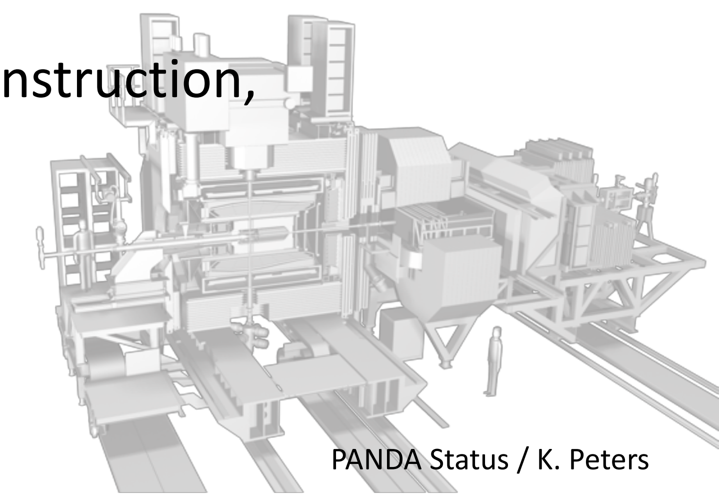
Summary and Outlook

QCD at large scales is extremely fascinating

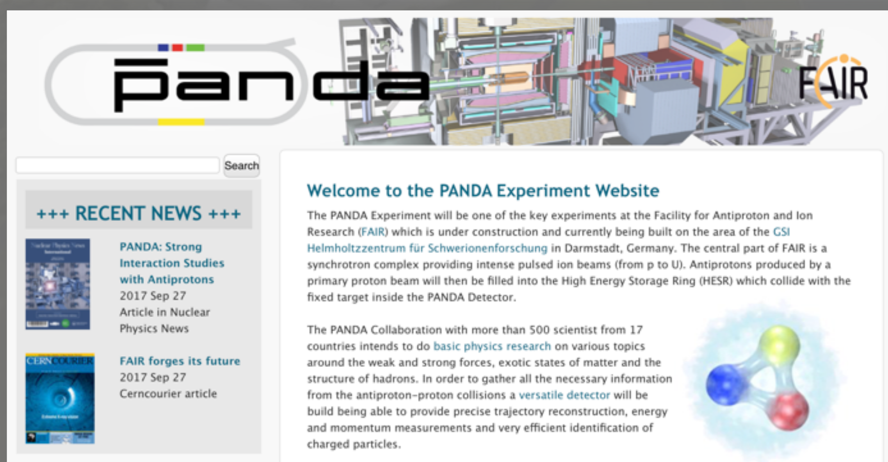
- and PANDA is a key tool to challenge this field in all aspects
- the full setup covers the
  broadest physics case ever
  in hadron physics history
- already the start-setup addresses unique questions
  in hyperon-, charm- and light-quark-physics

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.gsi.de



Thank you