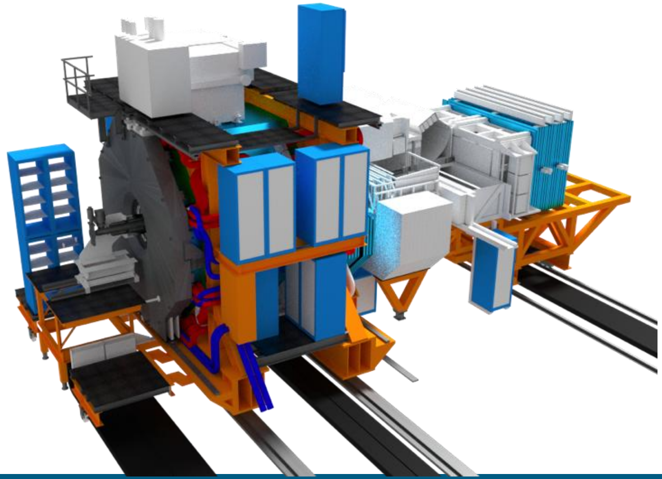


Exploring Excited Hyperon Spectroscopy with Antiproton Beams at PANDA

Jim Ritman Forschungszentrum Juelich

Outline

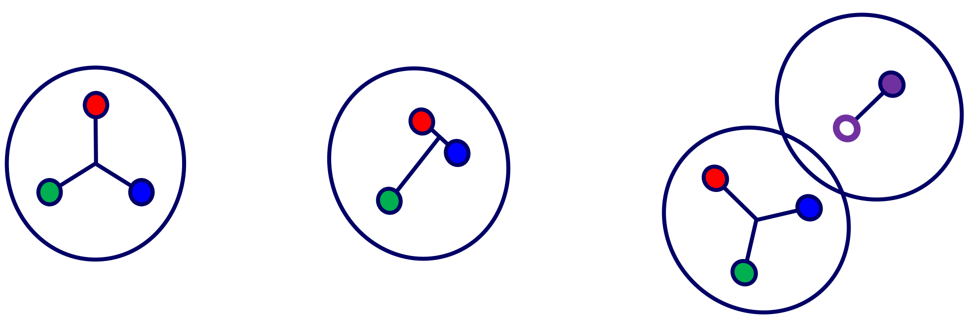
- Why measure Hyperon Spectroscopy?
- PANDA Phase 1 Experiments with Excited Hyperons
- PANDA Phase 0 @HADES: Excited Hyperon Dalitz decays
- Summary & Outlook

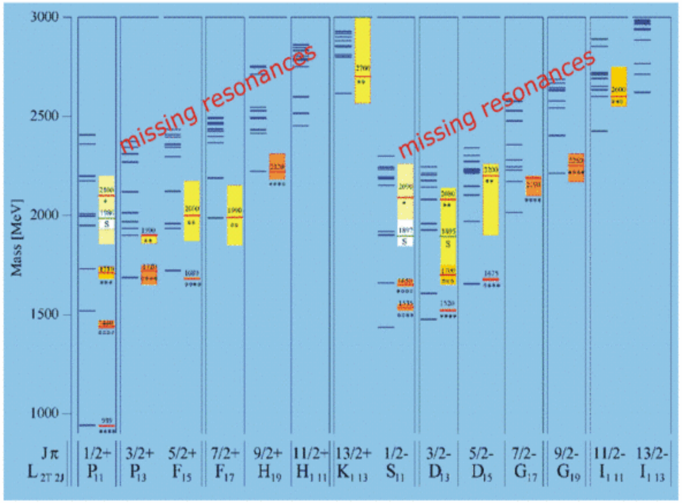
Hyperon Spectroscopy

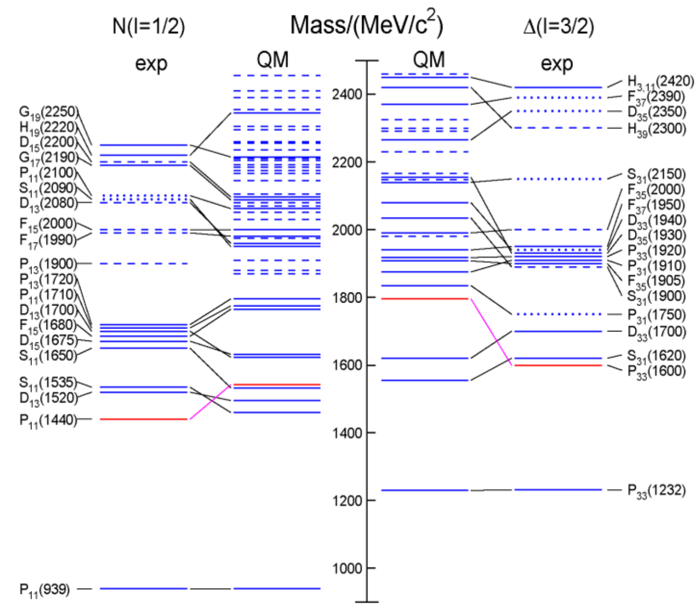
Jim Ritman

Open Questions

- Missing resonances
- Wrong masses, wrong sequence
- Relevant degrees of freedom?
  - 3-quark?
  - quark-diquark?
  - meson-baryon dynamics



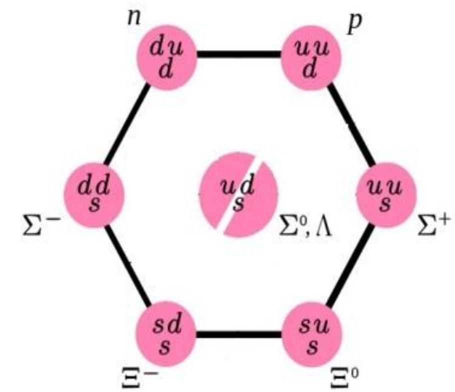


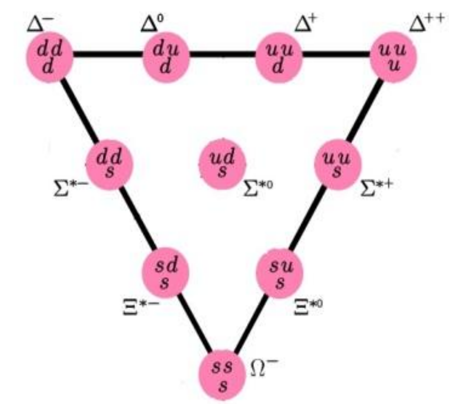


from RPP 2014 / QM: S. Capstick, W. Roberts

Strange Partners

- Approximate SU(3) flavor symmetry
- N* & Δ states have partners in the strange sector
- focus on Ξ and Ω
  - Ξ: as many states as N* & Δ together
  - Ω: as many states as Δ
- scrutinize our understanding of the baryon excitation pattern





Status of Ξ^* Resonances: RPP 2014

Chin. Phys. C 38 (2014) 090001

$\Xi(1820)$:

Teodoro78 favors J = 3/2, but cannot make a parity discrimination. Biagi 87c is consistent with J = 3/2 and favors negative parity for this J value.

Table 1. The status of the Ξ resonances. Only those with an overall status of *** or **** are included in the Baryon Summary Table.

Particle	J^P	Overall status	Status as seen in — $\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	Other channels
$\Xi(1318)$	1/2+ ?	****					Decays weakly
$\Xi(1530)$	3/2+	****	****				
$\Xi(1620)$		*	*				
$\Xi(1690)$		***		***	**		
$\Xi(1820)$	3/2− ?	***	**	***	**	**	
$\Xi(1950)$		***	**	**		*	
$\Xi(2030)$		***		**	***		
$\Xi(2120)$		*		*			
$\Xi(2250)$		**					3-body decays
$\Xi(2370)$		**					3-body decays
$\Xi(2500)$		*		*	*		3-body decays

****	Existence is certain, and properties are at least fairly well explored.
***	Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, *etc.* are not well determined.
**	Evidence of existence is only fair.
*	Evidence of existence is poor.

SU(6) x O(3) Classification

RPP 2014: Chin. Phys. C 38 (2014) 090001

„Assignments for …

Ξ(1820) and Ξ(2030), are merely educated guesses.“

Ξ(1690), Ξ(1950): ?

T. Melde *et al.*, PRD 77 (2008) 114002

decuplet: no Ξ*, no Ω*

“… nothing of significance on Ξ resonances has been added since our 1988 edition.”

J^P	$(D, L^P_N)\, S$	Octet members				Singlets
$1/2^+$	$(56,0^+_0)$ 1/2	$N(939)$	$\Lambda(1116)$	$\Sigma(1193)$	$\Xi(1318)$	
$1/2^+$	$(56,0^+_2)$ 1/2	$N(1440)$	$\Lambda(1600)$	$\Sigma(1660)$	$\Xi(1690)^\dagger$	
$1/2^-$	$(70,1^-_1)$ 1/2	$N(1535)$	$\Lambda(1670)$	$\Sigma(1620)$ $\Sigma(1560)^\dagger$	$\Xi(?)$	$\Lambda(1405)$
$3/2^-$	$(70,1^-_1)$ 1/2	$N(1520)$	$\Lambda(1690)$	$\Sigma(1670)$	$\Xi(1820)$	$\Lambda(1520)$
$1/2^-$	$(70,1^-_1)$ 3/2	$N(1650)$	$\Lambda(1800)$	$\Sigma(1750)$ $\Sigma(1620)^\dagger$	$\Xi(?)$	
$3/2^-$	$(70,1^-_1)$ 3/2	$N(1700)$	$\Lambda(?)$	$\Sigma(1940)^\dagger$	$\Xi(?)$	
$5/2^-$	$(70,1^-_1)$ 3/2	$N(1675)$	$\Lambda(1830)$	$\Sigma(1775)$	$\Xi(1950)^\dagger$	
$1/2^+$	$(70,0^+_2)$ 1/2	$N(1710)$	$\Lambda(1810)$	$\Sigma(1880)$	$\Xi(?)$	$\Lambda(1810)^\dagger$
$3/2^+$	$(56,2^+_2)$ 1/2	$N(1720)$	$\Lambda(1890)$	$\Sigma(?)$	$\Xi(?)$	
$5/2^+$	$(56,2^+_2)$ 1/2	$N(1680)$	$\Lambda(1820)$	$\Sigma(1915)$	$\Xi(2030)$	
$7/2^-$	$(70,3^-_3)$ 1/2	$N(2190)$	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	$\Lambda(2100)$
$9/2^-$	$(70,3^-_3)$ 3/2	$N(2250)$	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	
$9/2^+$	$(56,4^+_4)$ 1/2	$N(2220)$	$\Lambda(2350)$	$\Sigma(?)$	$\Xi(?)$	

		Decuplet members			
$3/2^+$	$(56,0^+_0)$ 3/2	$\Delta(1232)$	$\Sigma(1385)$	$\Xi(1530)$	$\Omega(1672)$
$3/2^+$	$(56,0^+_2)$ 3/2	$\Delta(1600)$	$\Sigma(1690)^\dagger$	$\Xi(?)$	$\Omega(?)$
$1/2^-$	$(70,1^-_1)$ 1/2	$\Delta(1620)$	$\Sigma(1750)^\dagger$	$\Xi(?)$	$\Omega(?)$
$3/2^-$	$(70,1^-_1)$ 1/2	$\Delta(1700)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$
$5/2^+$	$(56,2^+_2)$ 3/2	$\Delta(1905)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$
$7/2^+$	$(56,2^+_2)$ 3/2	$\Delta(1950)$	$\Sigma(2030)$	$\Xi(?)$	$\Omega(?)$
$11/2^+$	$(56,4^+_4)$ 3/2	$\Delta(2420)$	$\Sigma(?)$	$\Xi(?)$	$\Omega(?)$

PANDA Objectives

HEP: interference
of coupled channels

Spectroscopy

New narrow XYZ:
Search for partner
states

**Production of
exotic QCD states:**
Glueballs & hybrids

HEP: underlying
elementary processes

Nucleon Structure

**Generalized parton
distributions:**
Orbital angular momentum

Drell Yan process:
Transverse structure,
valence anti-quarks

Timelike formfactors:
Low and high E,
e and μ pairs

**Bound
States of
Strong
Interaction**

Astro physics:
Strange n-stars

Strangeness

Strange baryons:
Spectroscopy
Polarisation

HI collisions:
comparing QGP
to elementary
reactions

Nuclear Physics

Hypernuclear physics:
Double Λ hypernuclei
Hyperon interaction

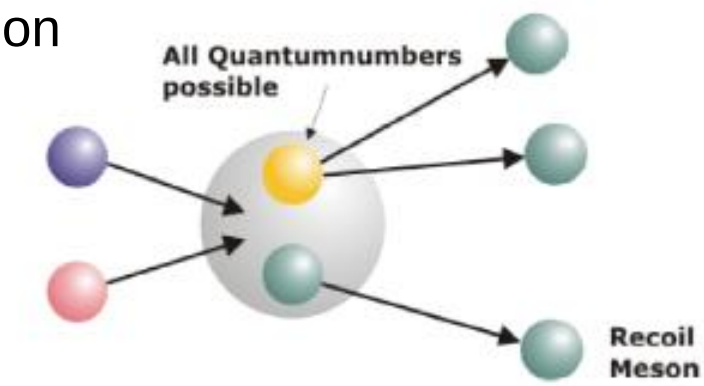
Hadrons in nuclei:
Charm and strangeness
in the medium

Nuclear physics:
Hypernuclear
spectroscopy

Antiproton Annihilations: Gluon Rich Environment

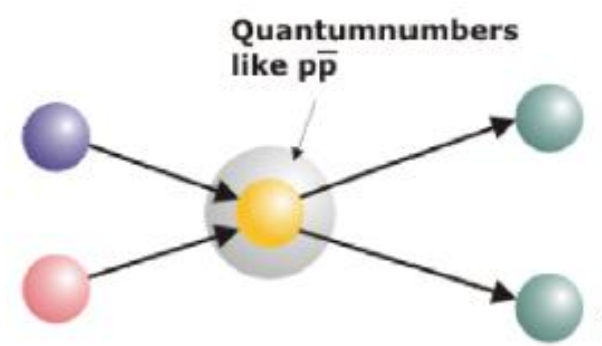
Production: all states with exotic and non-exotic quantum numbers accessible via associated production

- high discovery potential



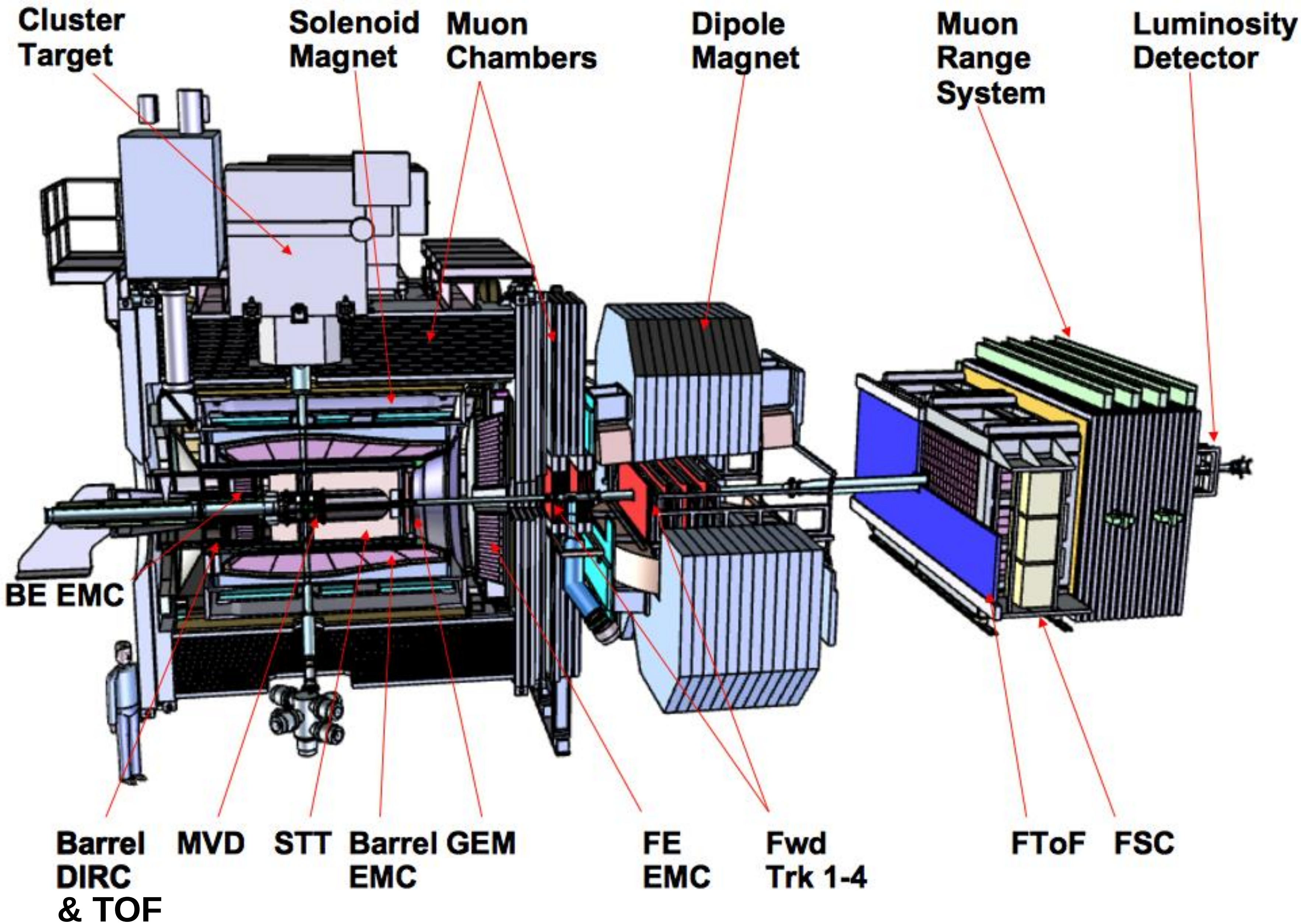
Formation: all states with non-exotic quantum numbers accessible

- not only limited to 1^{--} as e^+e^- colliders
- precision physics of known states
- resonant, high statistics, extremely good precision in mass and width



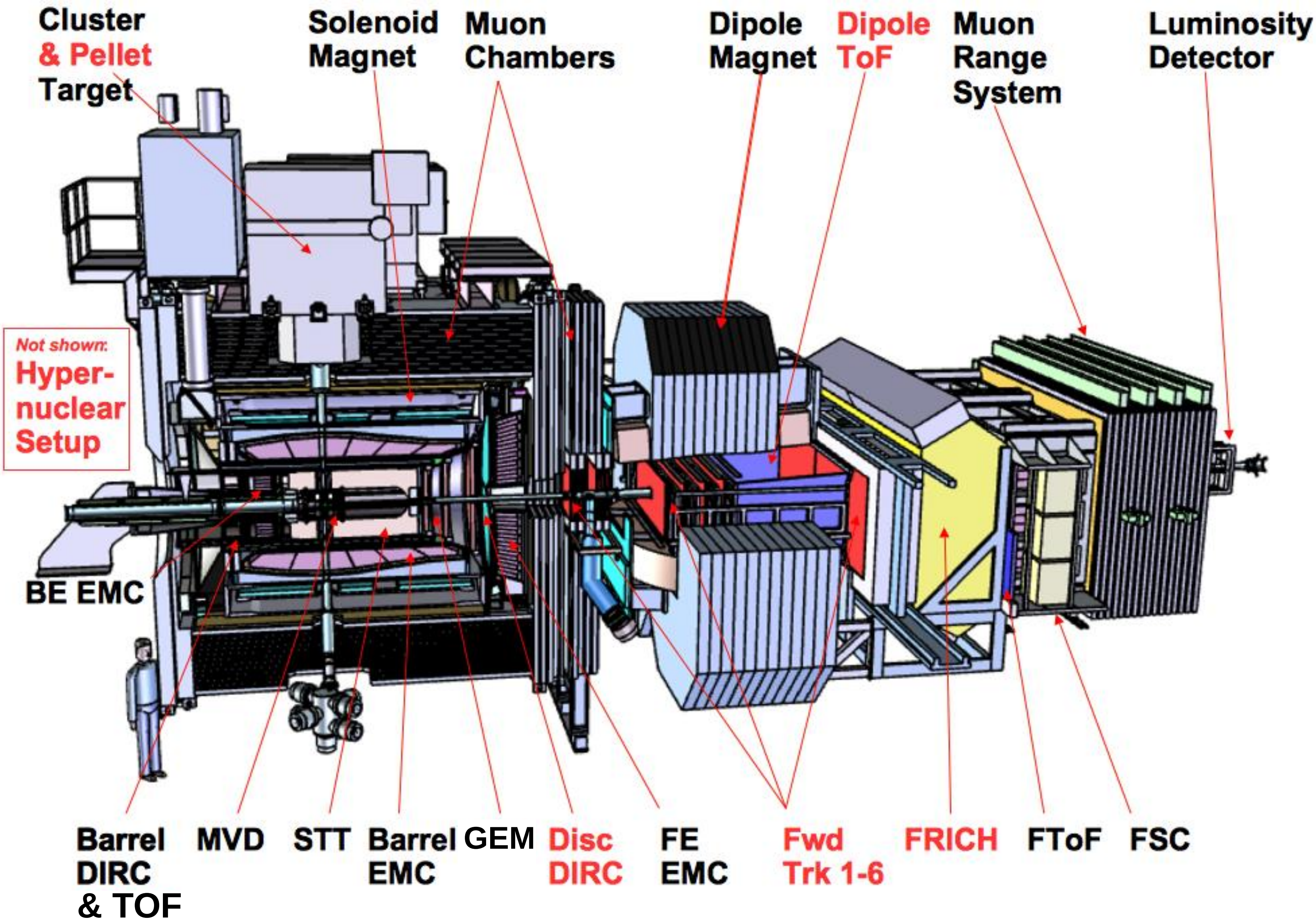
antiproton probe unique: large coupling to $B\bar{B}$

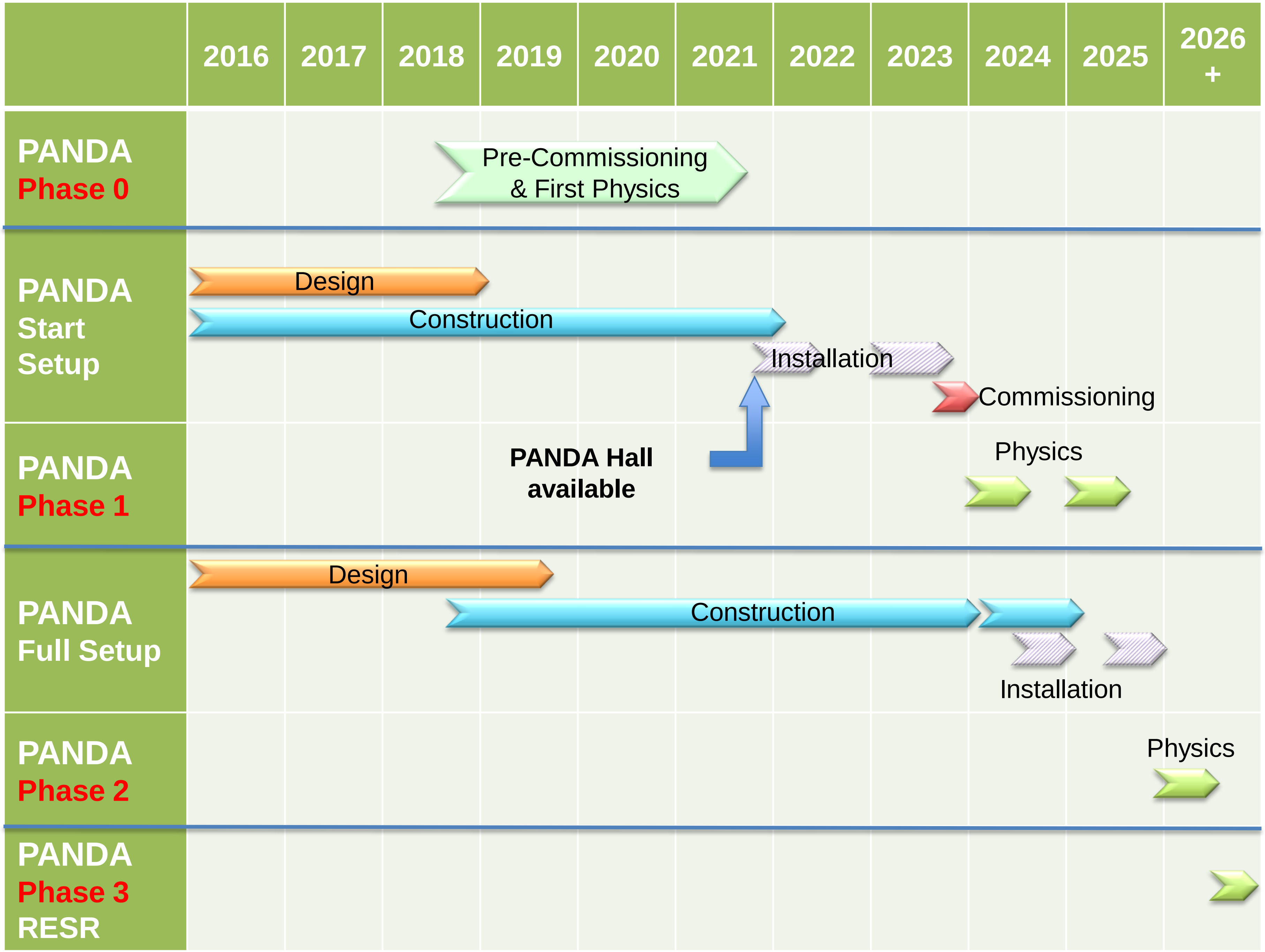
Start Setup



Cluster Target
Solenoid Magnet
Muon Chambers
Dipole Magnet
Muon Range System
Luminosity Detector
BE EMC
Barrel DIRC & TOF
MVD
STT
Barrel EMC
GEM
FE EMC
Fwd Trk 1-4
FToF
FSC

Full Setup


Cluster
& Pellet
Target
Solenoid
Magnet
Muon
Chambers
Dipole
Magnet
Dipole
ToF
Muon
Range
System
Luminosity
Detector
Not shown:
Hyper-
nuclear
Setup
BE EMC
Barrel
DIRC
& TOF
MVD
STT
Barrel
EMC
GEM
Disc
DIRC
FE
EMC
Fwd
Trk 1-6
FRICH
FToF
FSC


2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026 +
PANDA Phase 0
Pre-Commissioning & First Physics
PANDA Start Setup
Design
Construction
Installation
Commissioning
PANDA Phase 1
PANDA Hall available
Physics
PANDA Full Setup
Design
Construction
Installation
PANDA Phase 2
Physics
PANDA Phase 3 RESR

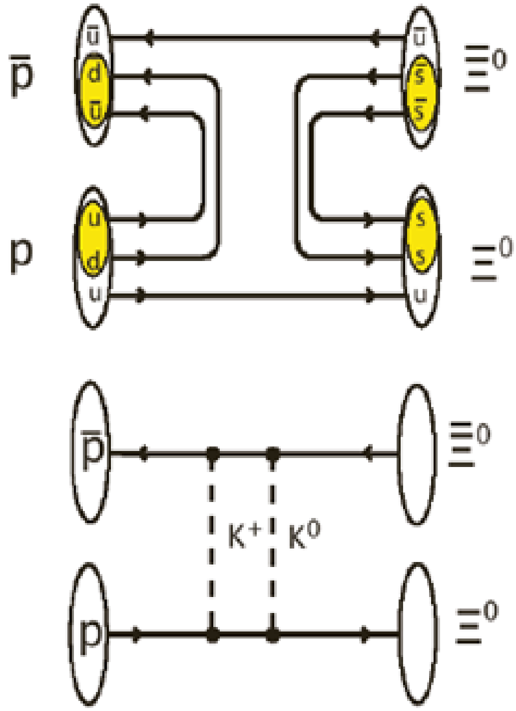
Multi-Strangeness Baryon Spectroscopy

Jim Ritman

Baryon Spectroscopy

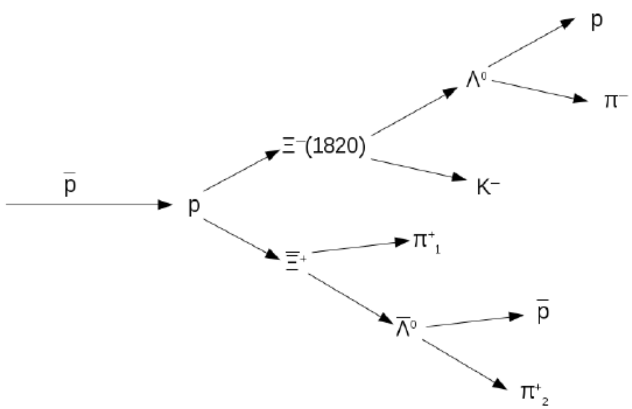
- Production of multi-strangeness baryons
  (unexplored, new territory, „Strangeness-Factory“)

Momentum (GeV/c)	Reaction	σ (μb)	Efficiency (%)	Rate at $0.5 \times 10^{31}/cm^2/s$
1.64	$\bar{p}p \to \bar{\Lambda}\Lambda$	64	10	$28\ s^{-1}$
4	$\bar{p}p \to \bar{\Lambda}\Sigma^o$	~40	30	$30\ s^{-1}$
4	$\bar{p}p \to \bar{\Xi}^+\Xi^-$	~2	20	$1.5\ s^{-1}$
12	$\bar{p}p \to \bar{\Omega}^+\Omega^-$	~0.002	30	$\sim 4\ h^{-1}$
12	$\bar{p}p \to \bar{\Lambda}_c^-\Lambda_c^+$	~0.1	35	$\sim 2\ day^{-1}$

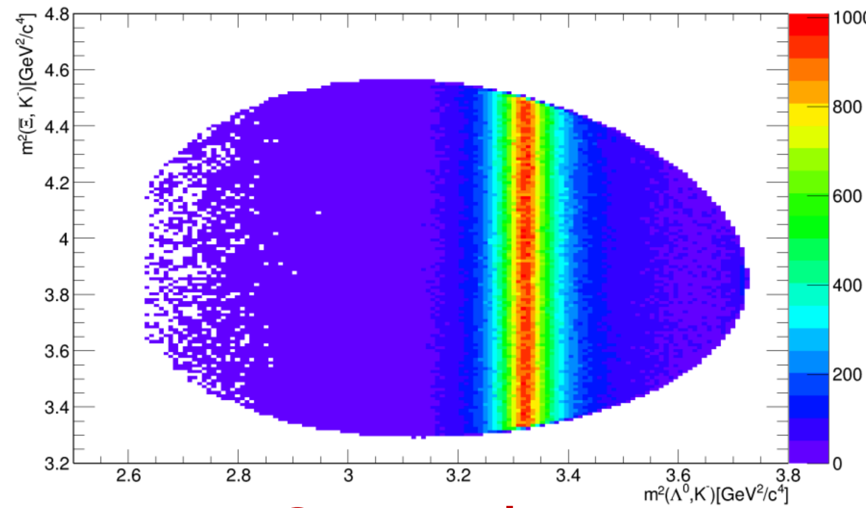


Example: $\Xi(1820)$

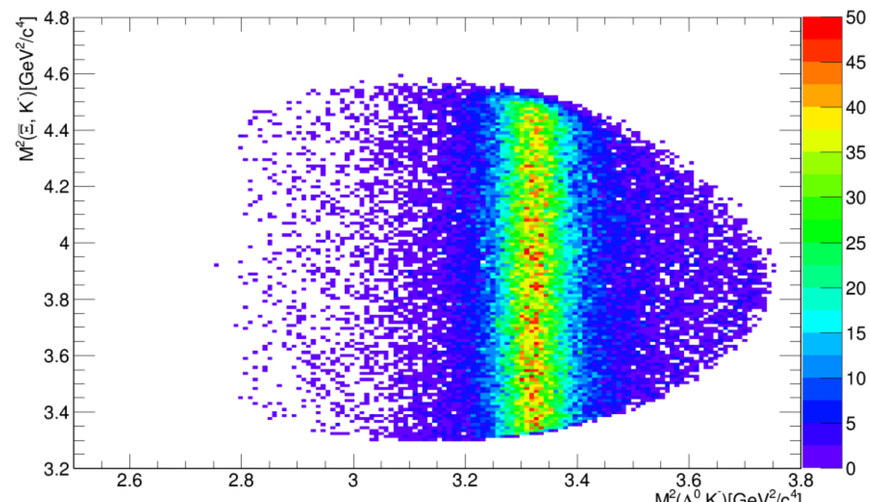
High signal rates and high background rejection for excited double strange baryons



Particle	N_{sig}	$N_{\text{bg}} \cdot B$	S
Λ	786,243	$1.321 \cdot 10^9$	467.68
$\bar{\Lambda}$	711,820	$620.341 \cdot 10^6$	815.85
$\bar{\Xi}+$	302,681	$15.31 \cdot 10^6$	5,868.03
$\Xi\,(1820)^-$	490,672	$1.49 \cdot 10^6$	121,544.21
$\Xi\,(1820)^-\ \bar{\Xi}+$	74,523	0	$>$ 69,837.37



Generated



Reconstructed

PANDA Phase 0 Projects

Already 2018++ PANDA detector components can be used for physics

PANDA Phase 0 Experiments with HADES

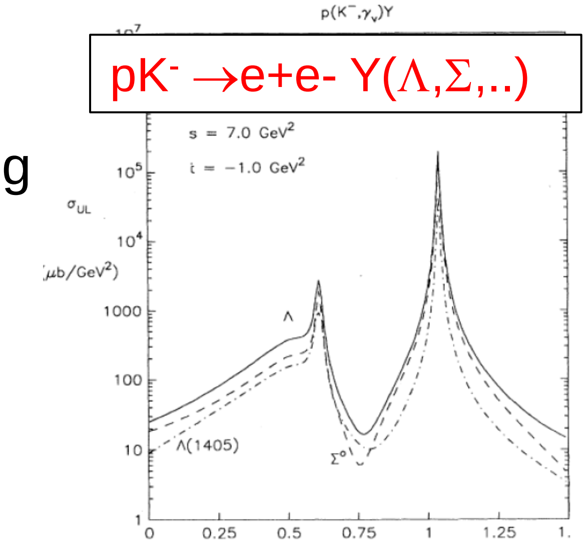
Physics Motivation

Goal: Hyperon structure, extend our understanding of the nucleon

How: Hyperon Dalitz decay Transition FF

well connected to PANDA physics program

pK$^-$ $\rightarrow$e+e- Y(Λ,Σ,..)

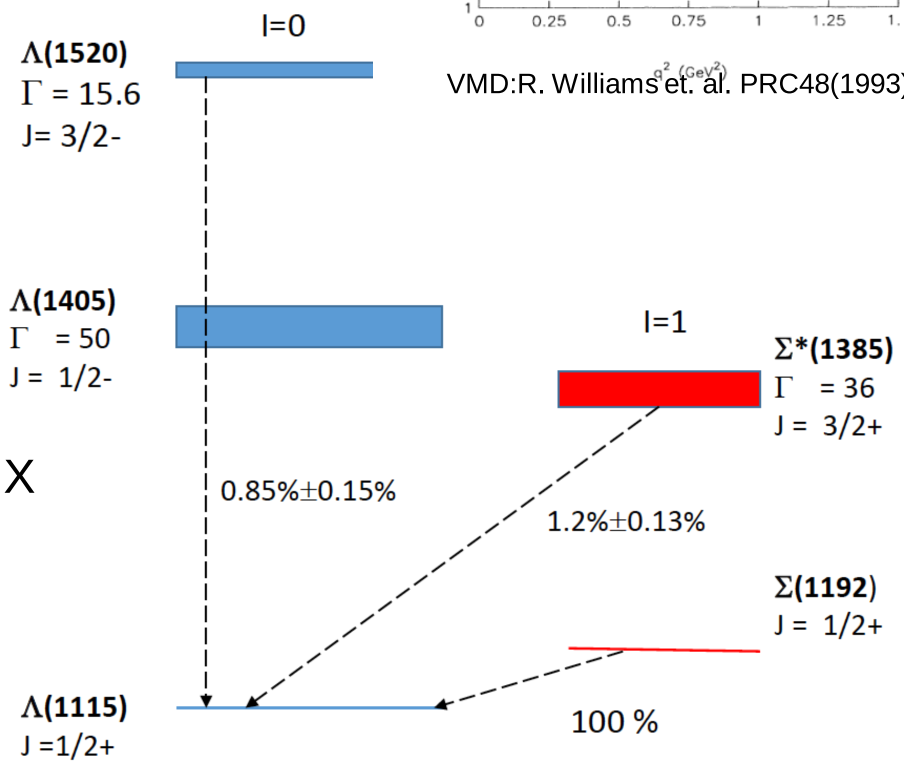


VMD:R. Williams et. al. PRC48(1993)

Role of ρ-baryon coupling (VMD?)

- Only few measurements of radiative decays:
  ($\Sigma^{0(*)} \rightarrow \Lambda\gamma$ $\Lambda(1520) \rightarrow \Lambda\gamma$)
- Y $\rightarrow \Lambda$e+e- never measured !
- Proposed reaction:
  p p(A) $\rightarrow$Y (any hyperon) X $\rightarrow \Lambda$e+e- X

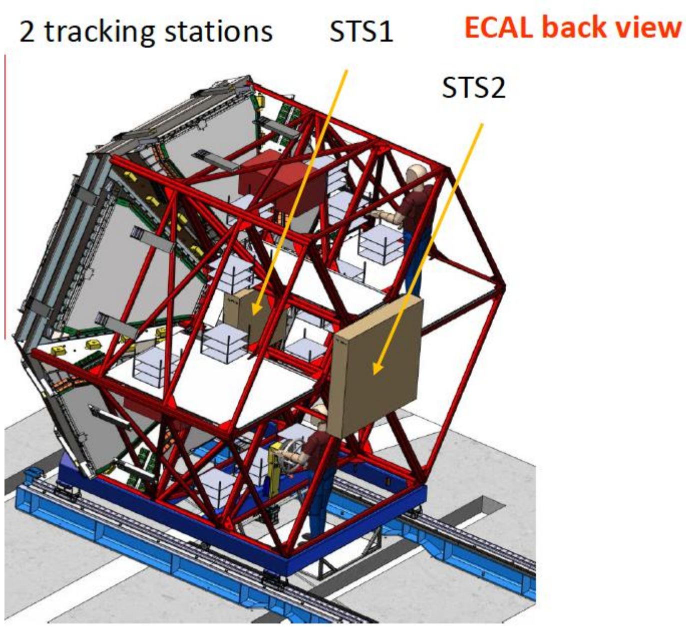
  tag with $\Lambda \rightarrow \pi^- p$
  BR ~ 10^{-5}

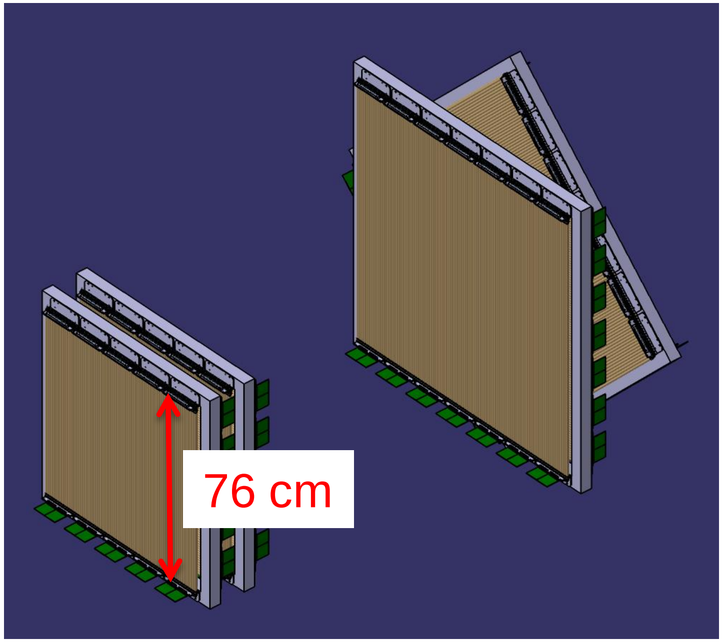


PANDA Phase 0 Experiments with HADES *Detectors*

PANDA pre-series and prototype detectors for STS1/2

- HADES measures the dileptons & mesons
- PANDA Straw Trackers for the baryon (Θ<7˚)
  STS1: 640 tubes (use later as FT3/4)
  STS2: 900 tubes (use later as FT5/6)
  (4 double layers each)





PANDA Phase 0 Experiments with HADES

Simulations

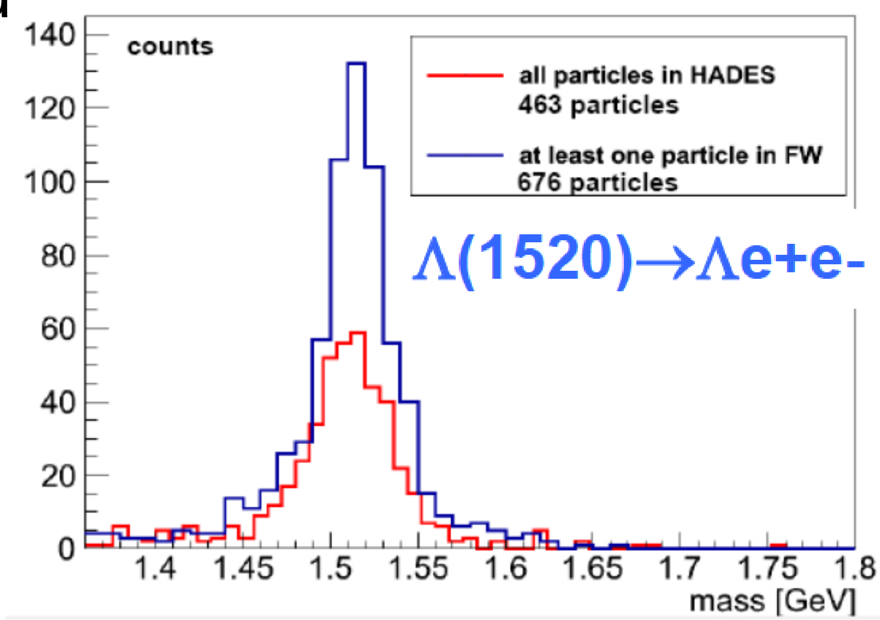
p+(p/C) → pKΛ(1520) → pK Λee
Max. SIS18 energy
10^8 /s
σ = 40 μb (assumed)

10^8 p/s $5*10^5$ π/s

	Proton Beam	Pion Beam
HADES only		
Carbon Target	52/day	0.2/day
Hydrogen Target	13.2/day	0.2/day
HADES and FW		
Carbon Target	128.3/day	0.5/day
Hydrogen Target	32.6/day	0.7/day

→128 evts/day reconstructed
And furthermore
Increase by x5-10
Due to upgraded RICH
and DAQ

9 days run with C target



Summary

Excellent Physics from the Start

- Clear strategy for a strong PANDA physics case with high impact for the start phase

- PANDA detector for the start phase defined in line with FAIR high level time schedule

- Start of Physics from 2018 with the *Phase 0 measurements* :
  Hyperon Dalitz decays together with HADES

PANDA Phase 1 Program

Jim Ritman

Key-Experiments of the Start Phase

Concentration on unique and forefront physics topics

- Production of multi-strangeness baryons
  (unexplored, new territory, „Strangeness-Factory“)

- Precise measurement of the line shape of narrow XYZ-states, e.g. X(3872)
  (only possible in proton–antiproton, counting experiment, clarification of the nature of the states)

- Resonant formation of the negative and uncharged partners of the Z-States
  (only possible in proton–antiproton, clarification of the nature of the states)

- Measurement of the electromagnetic form factors of the proton in the time-like
  domain with electrons and muons in the final state

- Production of high spin charmonia (only possible in proton–antiproton)
  light mesons, baryons and production of hybrids und glueballs

$\boxed{\text{XYZ-, hyperon factory}}$