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Physics prospects for first experiments at $\bar{\mathrm{P}}$ANDA

FRRC
FAIR-Russia Research Center
FAIR

PANDA Russia Workshop
FRRC Moscow, Russia 25-27 May 2015

Outline

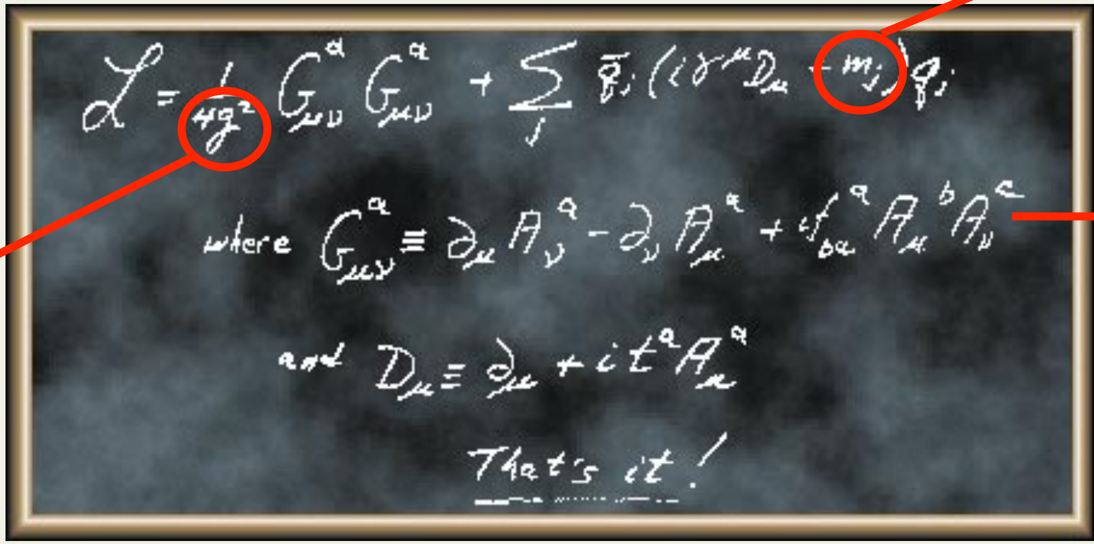
- Hadron spectroscopy with antiprotons;
- The FAIR accelerator complex;
- Low energy sector;
- Open-Charm and Charmonium spectroscopy;
- Exotic states;
- Baryonic states.

Quantum Chromodynamics

Quantum ChromoDynamics (QCD) is the theory of strong interactions that bind quarks and gluons together to form hadrons.

QCD is a nonlinear theory that is not analytically solvable

masses of the 6 quark flavours



gluon field

g
coupling constant

From F.A. Wilczek QCD Lecture

For the equivalent quantum field theory of weak force and electromagnetism, approximations using perturbation expansions in the interaction strength give very accurate results. However, since the QCD interaction is "so strong", perturbative approximations often fail.

Hadron structure

The quark flavors can be divided into two categories, depending on their masses: the light flavors *(u, d, s)*, and the heavy flavors *(c, b, t)*

The study of the light hadron sector has led to the creation of the ***Chiral Symmetry Breaking*** picture in which the ground state mesons and baryons can be explained well with the constituent (valence) quarks and the sum of the quark masses roughly gives the hadron mass.

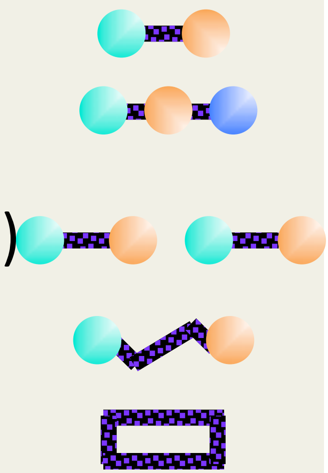
At very high energy, in the heavy quark sector asymptotic freedom allows accurate calculations at high energy with perturbation theory.

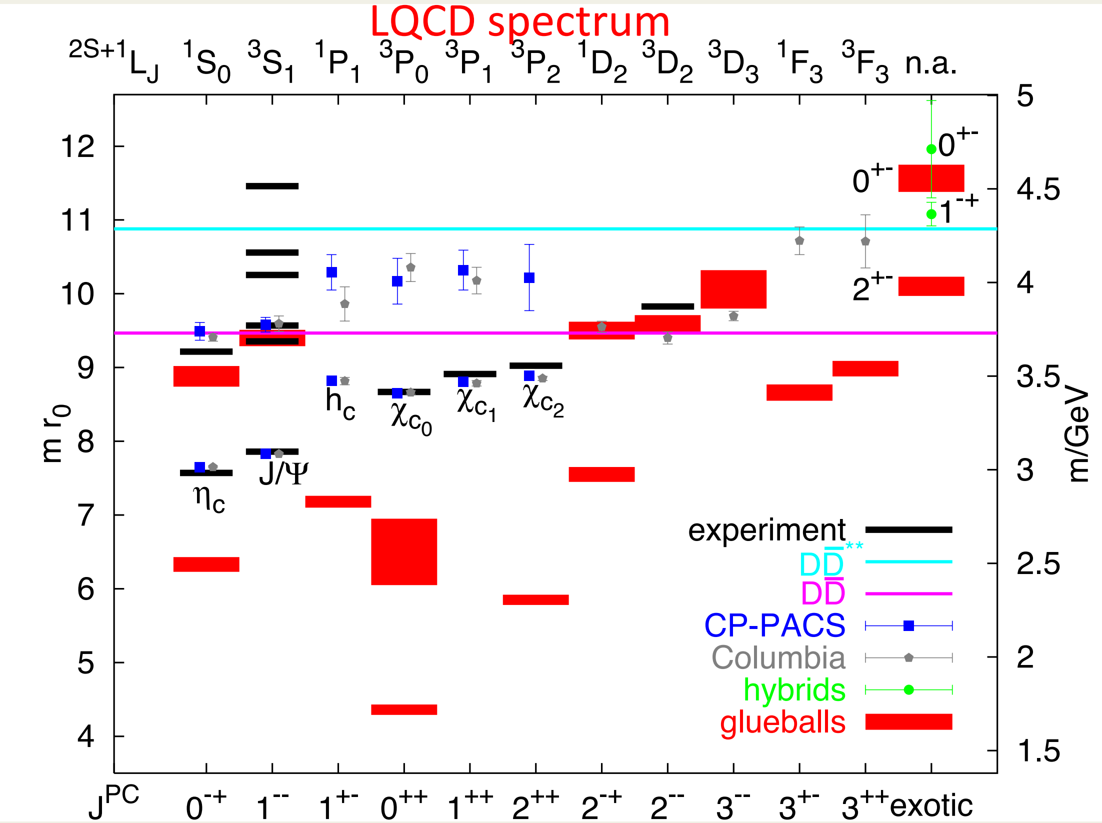
Charm sits between heavy and light quarks ➔ it allow a test of theory methods and physics phenomena it is then the best playground to understand QCD.

The hadron spectrum

The whole set of theoretical approaches rely on approximations and/or free parameters that must be constrained. Furthermore, They all predict states with explicit gluon content.

Mesons	$q\bar{q}$
Baryons	qqq
Multiquarks	$(q\bar{q})(q\bar{q})$
Hybrids	$(q\bar{q})$ g
Glueballs	gg





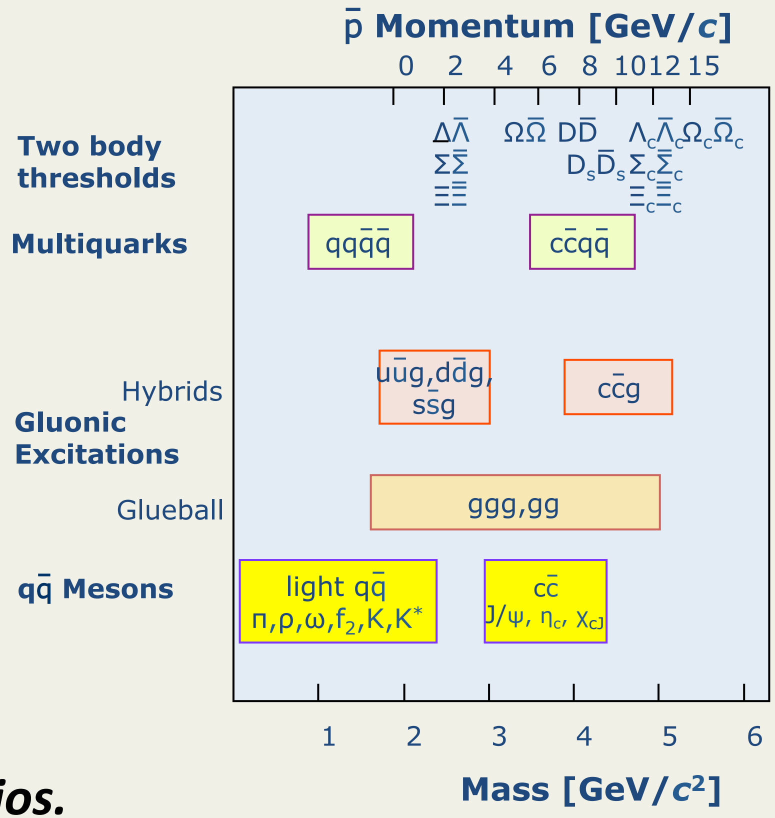
G. S. Bali, Int.J.Mod.Phys. A21 (2006) 5610-5617

The experimental point of view

- Can we observe experimentally gluonic degrees of freedom?
- How would these manifest themselves in terms of the excitation spectrum and also in the strong decays of hadrons?

Three are the main goals of hadron spectroscopy:

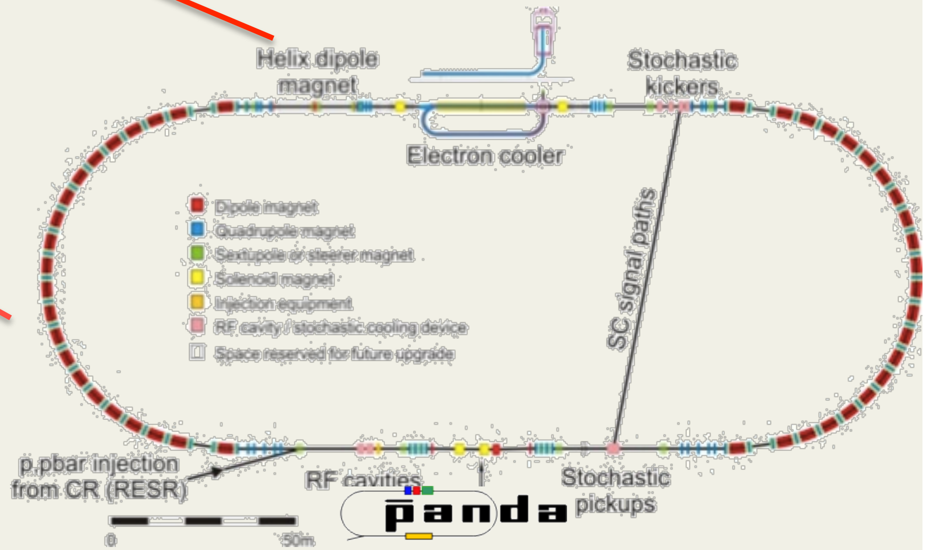
- *Identify the physical states and their quantum numbers, and measure their **masses and widths.***
- *Determine their **decay modes and branching ratios.***
- *Study the underlying **dynamics of production and decay.***



Facility for Antiproton and Ion Research

Antiproton production

- Proton Linac 70 MeV
- Accelerate p in SIS18 / 100
- Produce $\bar{p}$ on Cu target
- Collection in CR, fast cooling
- Accumulation in RESR
- Storage and usage in HESR



HESR: Storage ring for $\bar{p}$

- Injection of $\bar{p}$ at 3.7 GeV/*c*
- Slow synchrotron (1.5-15 GeV/*c*)
- Luminosity up to L~ 2×10^{32} $cm^{-2}s^{-1}$
- Beam cooling (stochastic & electron)

Antiproton power

- e^+e^- interactions:

- $p\bar{p}$ reactions:

Antiproton power

- e^+e^- interactions:

  - Only 1^{--} states are formed
  - Other states only by secondary decays (moderate mass resolution related to the detector 5÷10 MeV)

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- $p\bar{p}$ reactions:

  - Most states directly formed (very good mass resolution; $\bar{p}$-beam can be efficiently cooled $\Delta p/p \sim 10^{-5}$)

Antiproton power

$e^+e^- \rightarrow \psi(2S) \rightarrow \gamma\chi_{1,2} \rightarrow \gamma\gamma J/\psi \rightarrow \gamma\gamma e^+e^-$

$\bar{p}\,p \rightarrow \chi_{1,2} \rightarrow \gamma J/\psi \rightarrow \gamma e^+e^-$

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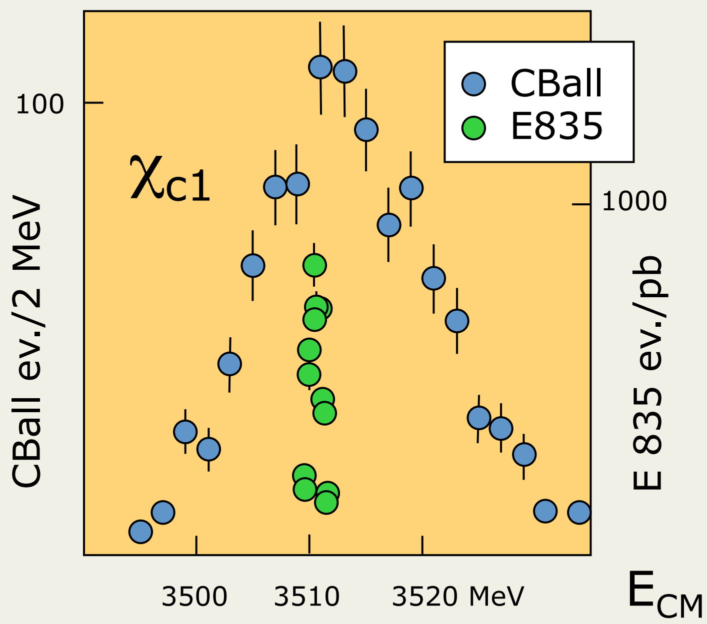

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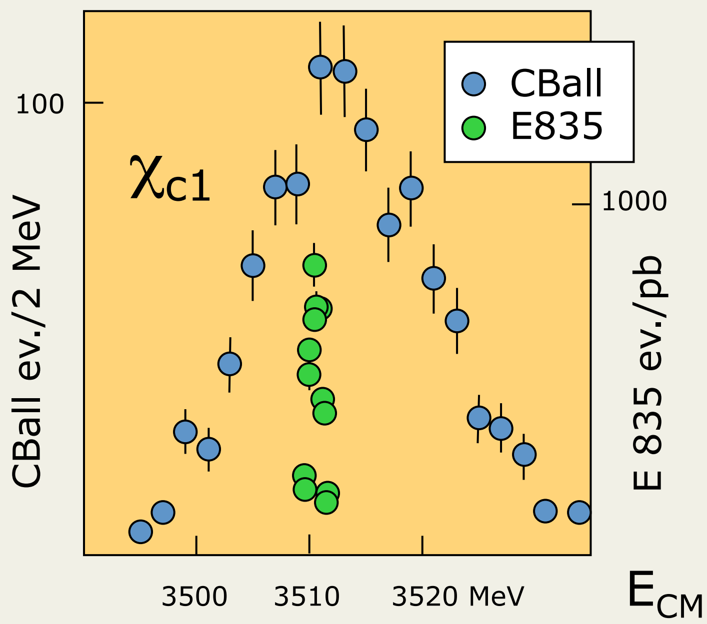
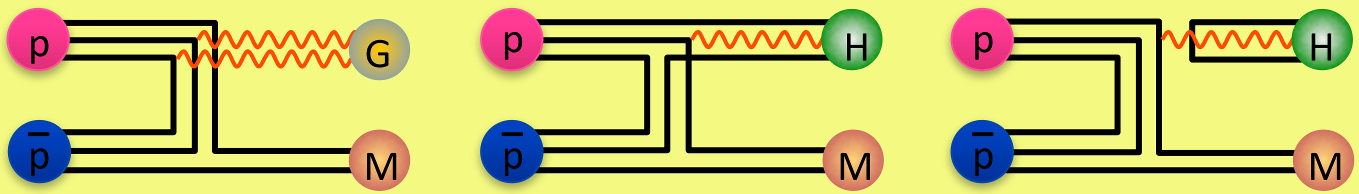


$Br(\bar{p}p \to \eta_c) = 1.2\ 10^{-3}$

$Br(e^+e^- \to \psi') \cdot Br(\psi' \to \gamma\eta_c) = 2.5\ 10^{-5}$

Spectroscopy with antiprotons

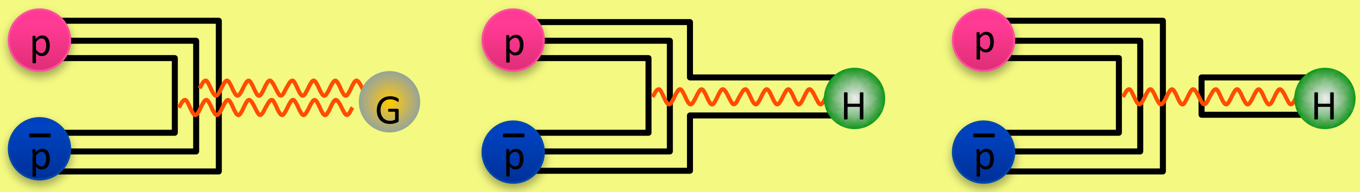
Two are the mechanisms to access particular final states:



Even exotic quantum numbers can be reached σ ~100 pb

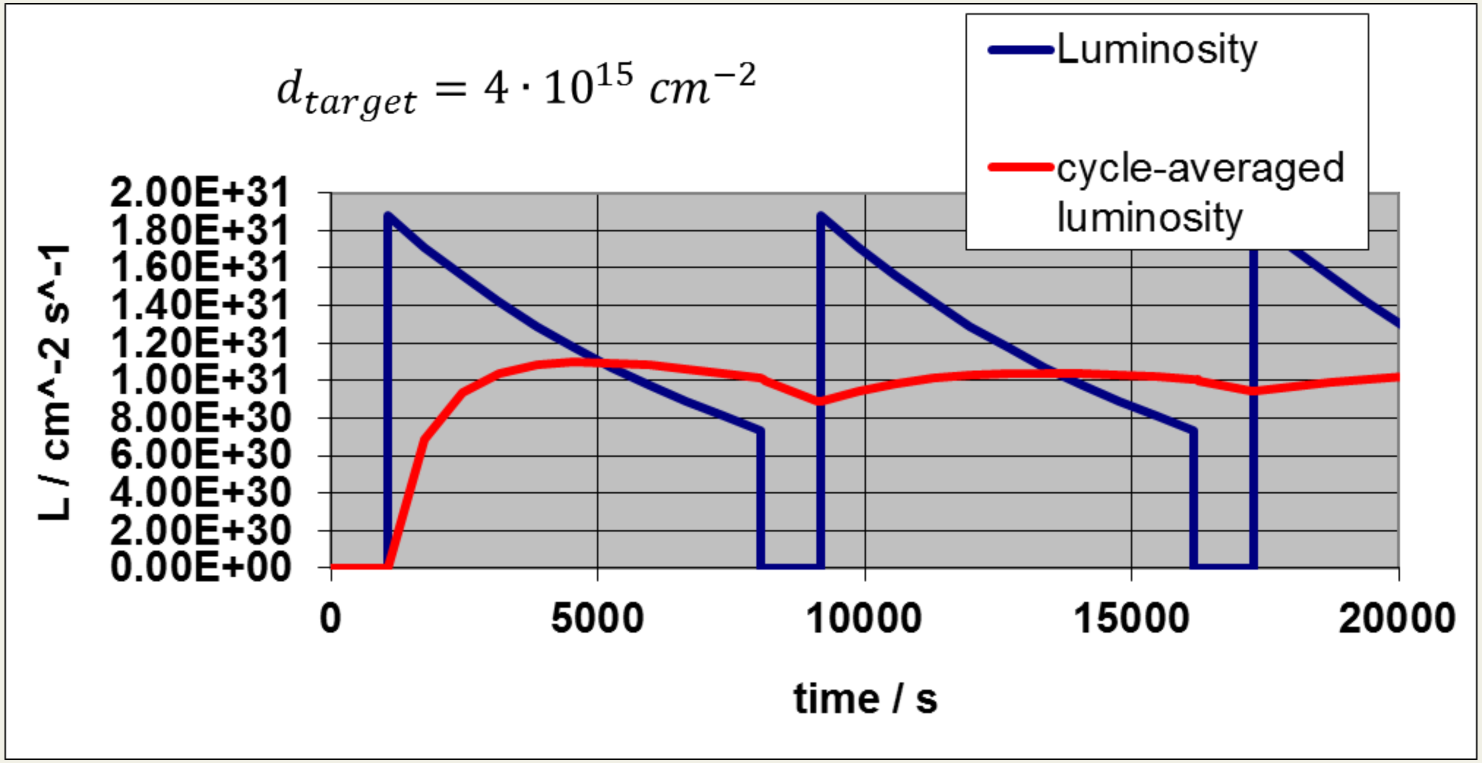
We can play with the two different mechanisms to determine quantum numbers

All ordinary quantum numbers can be reached σ ~1 μb



HESR in the MSV

- The intensity in the HESR in the MSV is limited to 10^{10} p-bars due to the cooling and injection efficiencies (RESR will not be present and is work will be done in the HESR).
- This means for PANDA:
  1. Less intensity (only high resolution mode)
  2. Worse duty cycle due to 20 minutes accumulation time



The low energy range

In the last 20 years many steps forward in the field were possible thanks to the variety of facilities available all over the world.

Main non-$q\bar{q}$ candidates	
$f_0(980)$	4q state, molecule
$f_0(1500)$	0^{++} glueball candidate
$f_0(1370)$	0^{++} glueball candidate
$f_0(1710)$	0^{++} glueball candidate
$\eta(1410)$; $\eta(1460)$	0^{-+} glueball candidate
$f_1(1420)$	hybrid, 4q state
$\pi_1(1400)$	hybrid candidate 1^{-+}
$\pi_1(1600)$	hybrid candidate 1^{-+}
π (1800)	hybrid candidate 0^{-+}
$\pi_2(1900)$	hybrid candidate 2^{-+}
$\pi_1(2000)$	hybrid candidate 1^{-+}
$a_2'(2100)$	hybrid candidate 1^{++}
$\phi(2170)$	hybrid candidate 1^{--}, 4q state

Nowadays confirmation of predictions, together with unexpected results, are still coming out mainly from $e^+ e^-$ collider.

$Y_S(2175)$

The Y_S [X](2175) [or ϕ(2170) on PDG] was first observed by BABAR in the process $e^+e^- \to \phi(1020) f_0(980)$ and identified as a 1^{--} state, M = (2.175±0.010±0.015) GeV, Γ = (58±16±20) MeV. Then was confirmed by BES in the decay $J/\Psi \to \eta\phi f_0(980)$ with M = (2.186±0.010±0.006) GeV and Γ = (65±25±17) MeV.

We performed a preliminary study for this channel looking to the following reaction: $\bar{p}p \to Y_S(2175) + X$ with X being a π^0 or $\pi^+\pi^-$

$$\hookrightarrow \phi\pi^+\pi^-, \phi\pi^0\pi^0$$

assuming different hypotheses for the signal cross-section and the decay B.R.

This is an example of "meson production" where we can investigate different decay channels.

Light meson spectroscopy

Assuming cross sections of about 10 nb for glueball/hybrid candidates important topics of the PANDA light hadron spectroscopy program can be addressed:

- with an integrated luminosity of about 2 pb^{-1} /channel;
- for new resonances, which do not require a Partial Wave Analysis, results can be obtained with data samples of 0.1 pb^{-1}.

Two data samples of 2 pb^{-1} recorded in the low and high energy region, will allow to start first spin-parity analyses for spectroscopy.
These corresponds to 5 days with a Luminosity of 10^{31} cm^{-2} s^{-1} that is foreseen for the PANDA Day-1.

Exotic hadrons

The identification of exotic states is an important key to understand hadron spectrum and the process of mass generation.

Mesons	$q\bar{q}$	
Baryons	qqq	
Multiquarks	$(q\bar{q})(q\bar{q})$	
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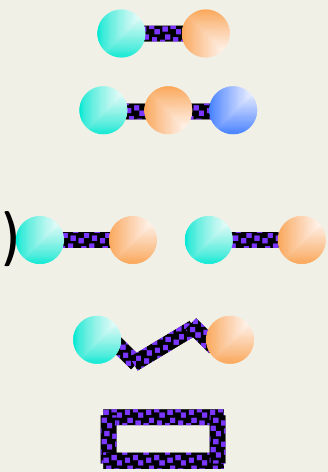

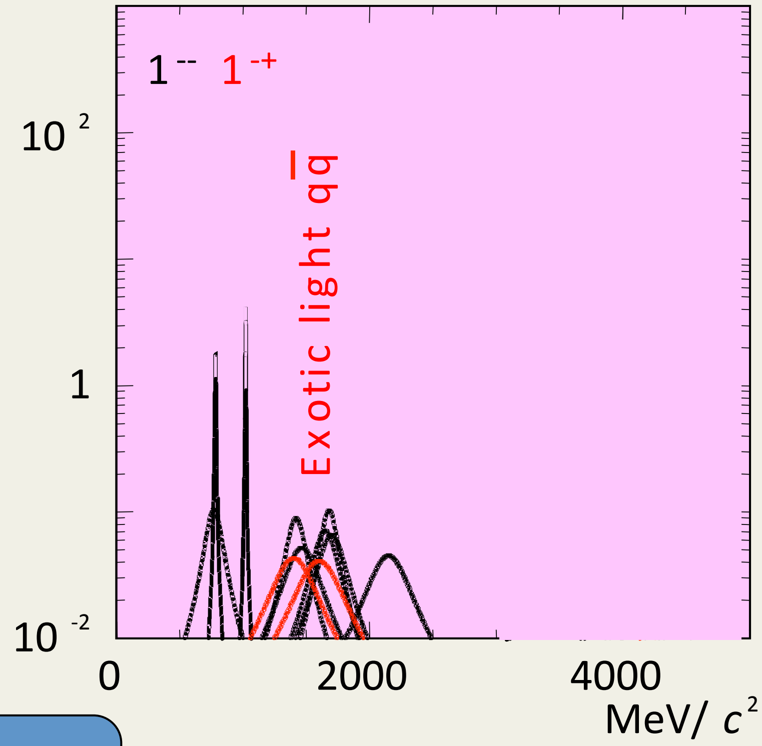

In the light meson energy range exotic states overlap with conventional states

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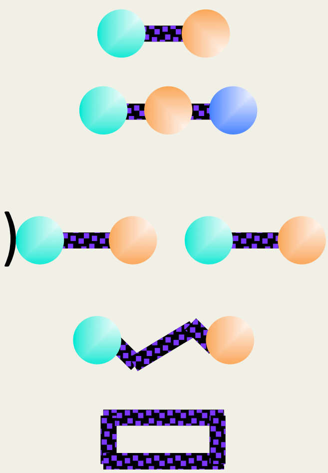
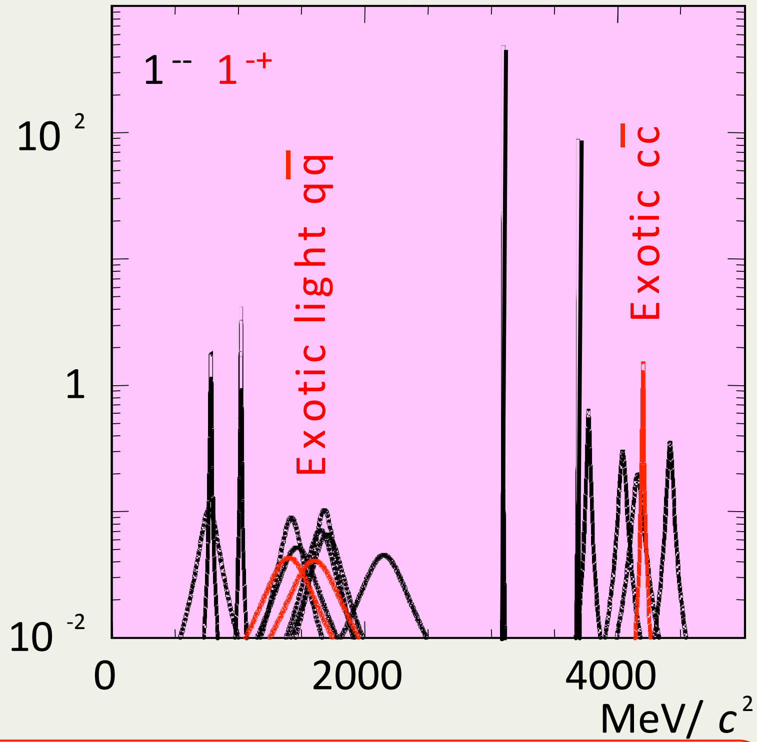


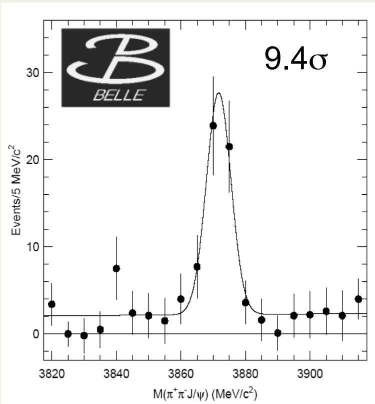


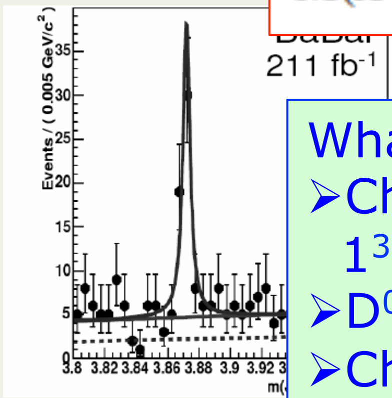
In the charmonium energy region the density of states is lower and also the overlap

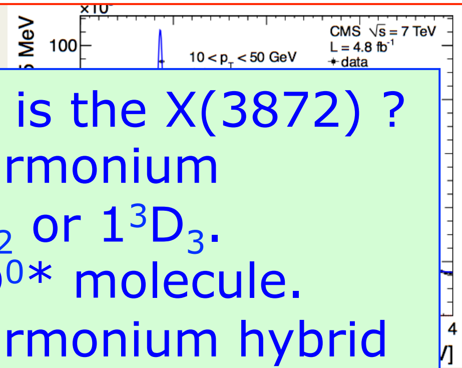
X(3872)

Discovered in 2003 by Belle (+ CDF, D0, BaBar, LHC …) in $B^+ \rightarrow X K^+$ $X \rightarrow J/\psi\pi^+\pi^-$ is the big brother of the new "charmonium like" states. The mass is currently known with < 1.0 MeV/c^2 precision. For the width we have only an upper limit.

$$M(X(3872)) = 3871.95 \pm 0.48(\mathrm{stat}) \pm 0.12(\mathrm{syst})\ \mathrm{MeV}/c^2$$







What is the X(3872) ?

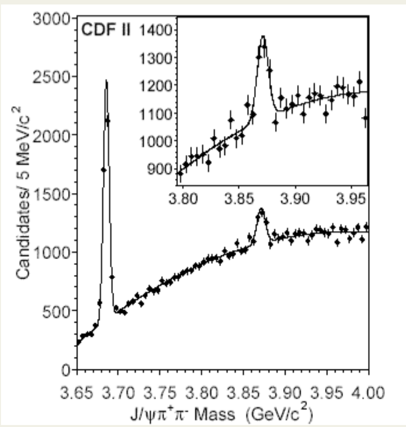
- Charmonium 1^3D_2 or 1^3D_3.
- $D^0\bar{D}^{0*}$ molecule.
- Charmonium hybrid ($c\bar{c}g$).

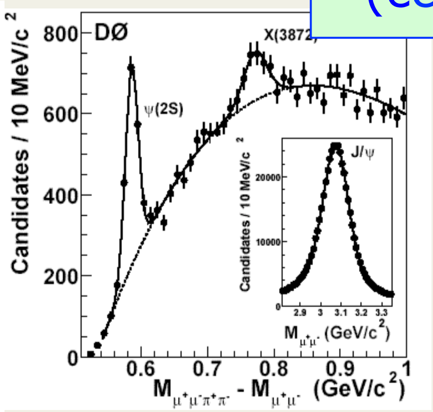
X(3872) has been observed in several decay channels

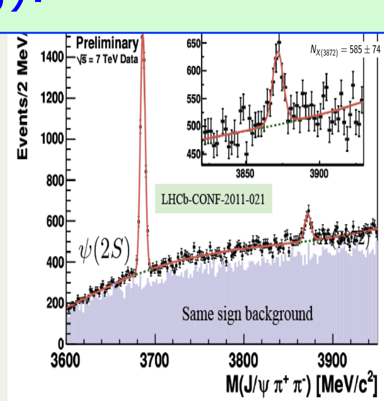
$J/\psi\pi^+\pi^-$, D^*D^0, $\gamma J/\psi$, $\omega J/\psi$

Interpretations oscillate:

- charmonium state;
- D^*D^0 molecule;
- tetra-quark state.

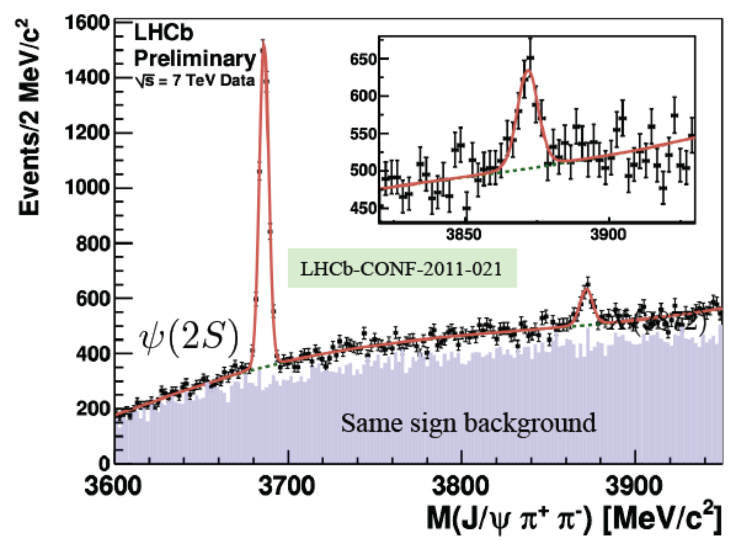






X(3872) lays 0.42 MeV below $D^{*0}\bar{D}^0$. Width is narrow < 1.2 MeV/c^2 @ 90% C.L.

The X(3872) at LHCb

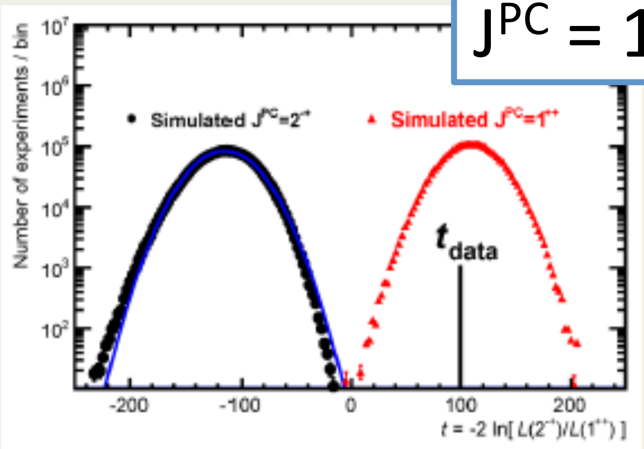


Recently LHCb using a sample of 313 ± 26 candidates performed a full five-dimensional amplitude analysis of the angular correlations between the decay products: $B^+ \to K^+X(3872)$; $X(3872) \to J/\Psi\ \pi^+\pi^-$, $J/\Psi \to \mu^+\mu^-$.

The result of the multidimensional likelihood-ratio test favors $J^{PC} = 1^{++}$ with more than 8σ significance.

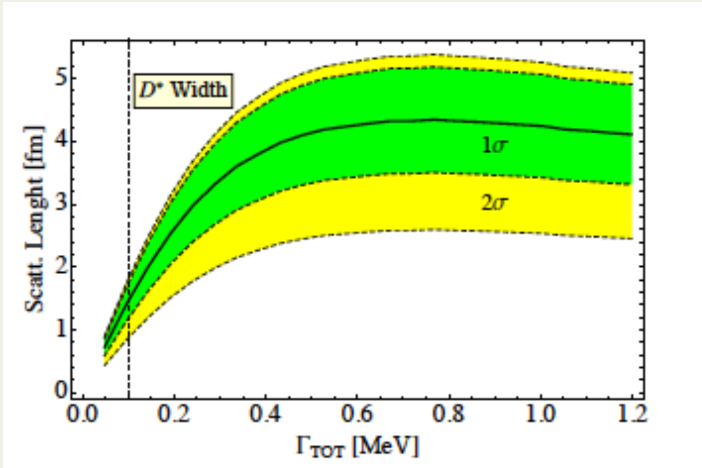
This ruled out some interpretations. Nowadays, the most accredited ascriptions are a four-quark state ($c\bar{c}q\bar{q}$) or a $D^0\bar{D}^{0*}$ molecule.

$J^{PC} = 1^{++}$



Scattering length for the $D^0\bar{D}^{0*} \to X \to D^0\bar{D}^{0*}$ process as a function of the X total width.

[J.M.P. 4 (2013) 1569]



A precise knowledge of the state width will help in constraining these hypotheses.

X(3872) @ $\bar{\text{p}}$anda

Thanks to the precise HESR momentum definition, widths of known states can be precisely measured with an energy scan.

Martin Galuska
(Giessen)

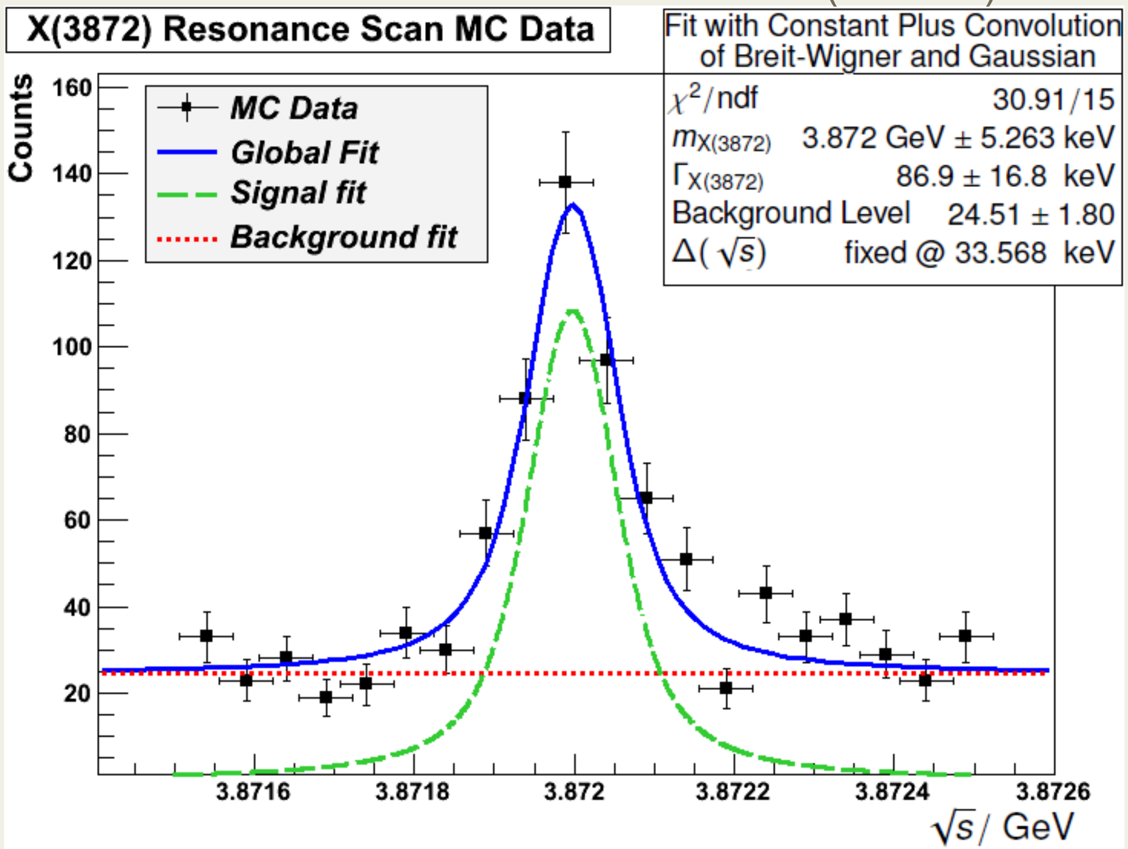
Input parameters:

m = 3.872 GeV/c^2

Γ = 1 MeV/c^2

$\bar{p}p \rightarrow X(3872)$ (σ_{BW}= 50 nb)

$\bar{p}p \rightarrow J/\psi\ \pi^+\pi^-$ (σ= 1.2 nb)



Mass resolution~ 5 keV/c^2

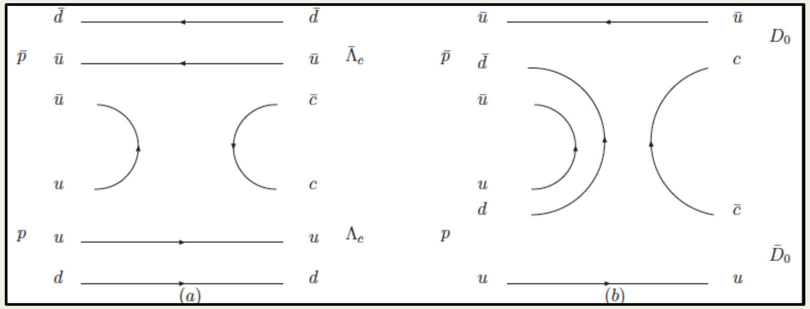
Width precision~ 10-20%

All narrow widths of the states in the charmonium energy range will be precisely determined.

OpenCharm states

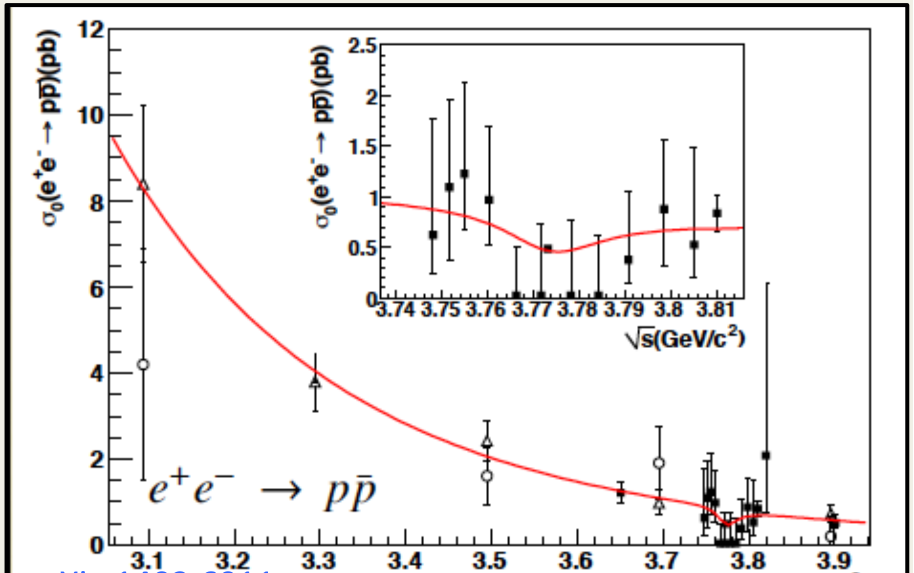
The study of charmed hadrons give access to interesting aspects of strong and weak interactions. Predicted cross sections vary from nano to micro barns

Interesting physics in production mechanisms.



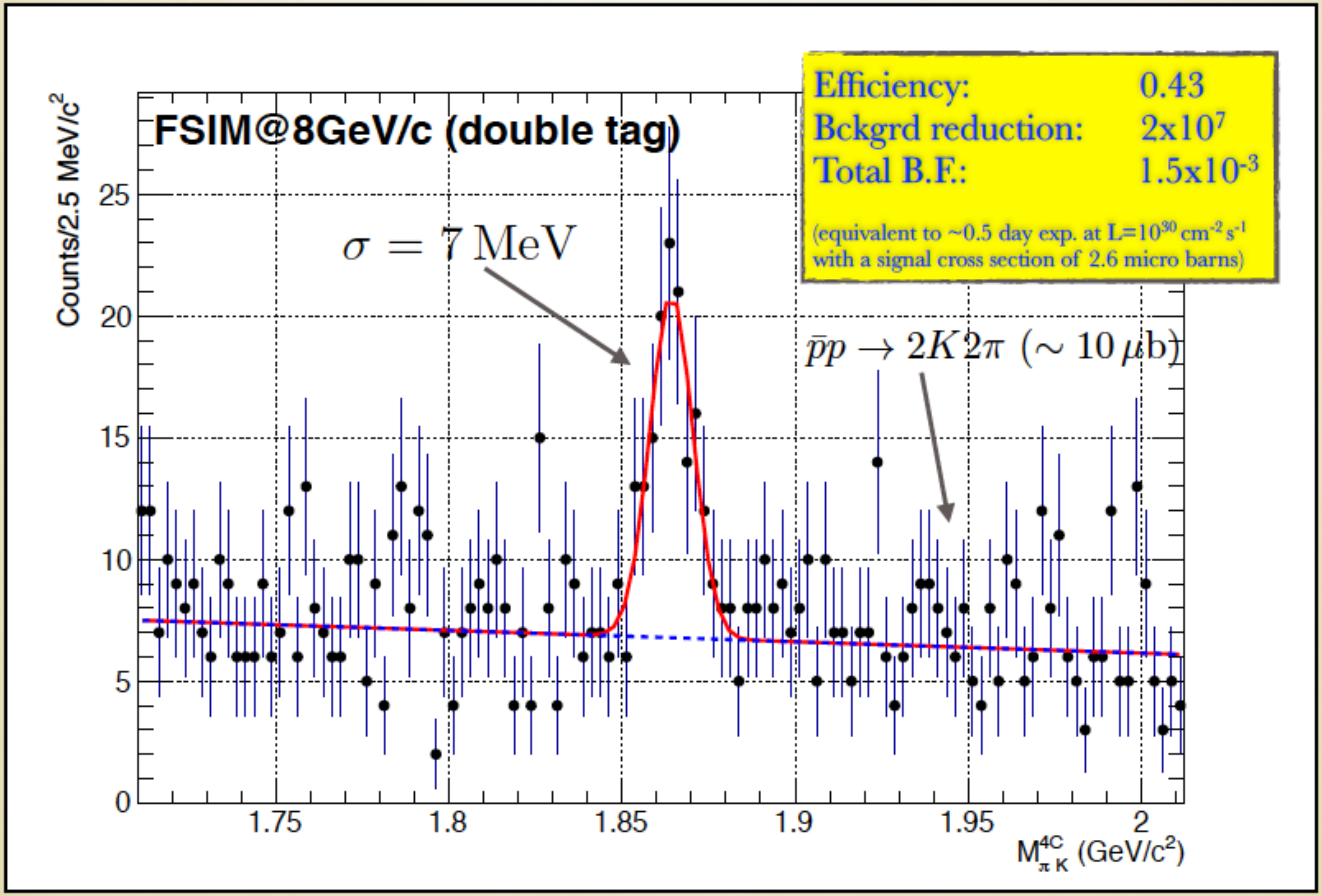
Two solutions for the cross section $\sigma(p\bar{p}) \rightarrow \psi(3770)$ are obtained:

- (9.8+11.8−3.9) nb, is compatible with a simple scaling from J/ψ
- (425.6+42.9−43.7) nb, is two order of magnitudes larger.



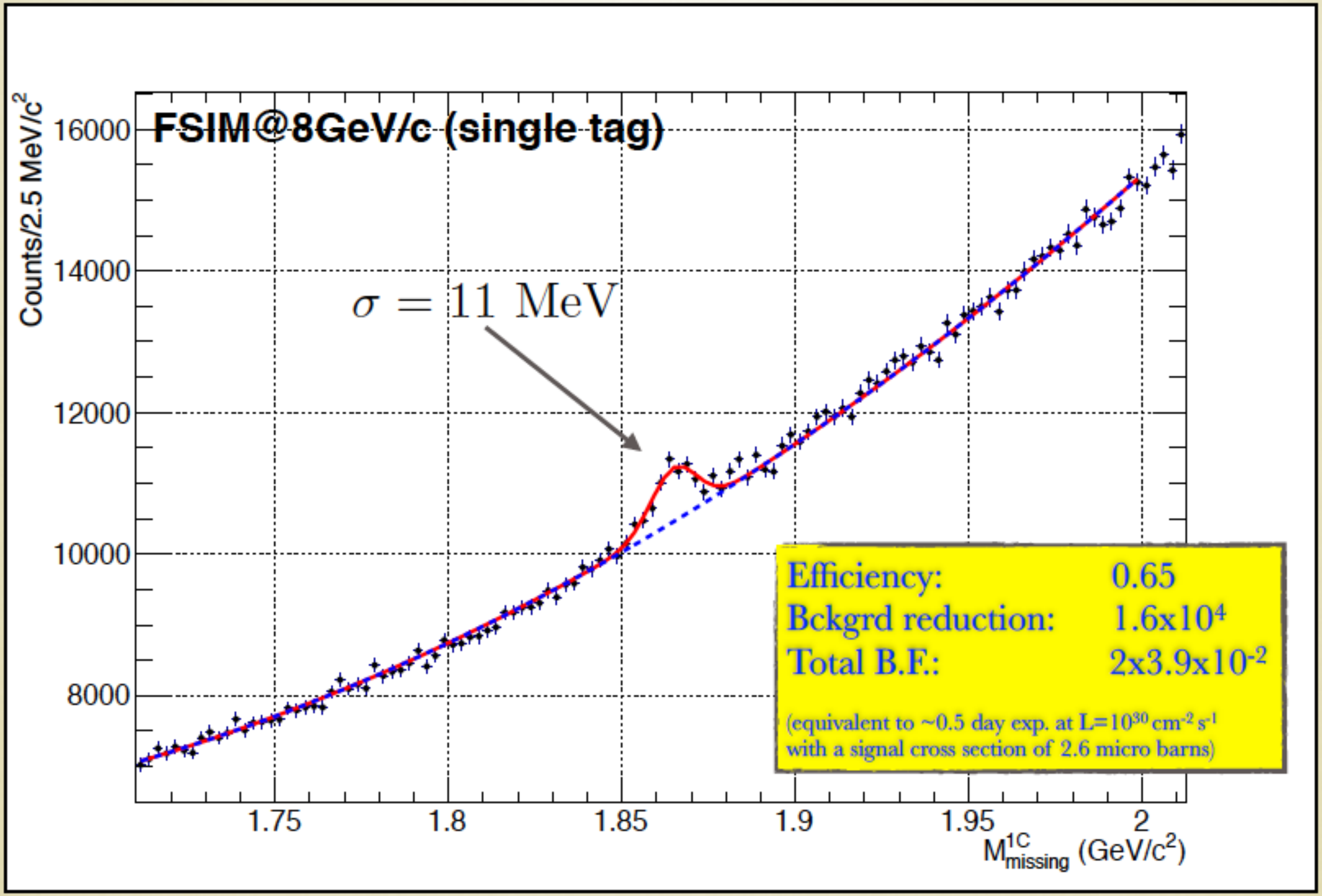
arXiv:1403.6011

Exclusive: $p\bar{p} \to D^0\bar{D}^0 \to (K^-\pi^+)(K^+\pi^-)$ *Alexandros Apostolou, J.M. (KVI-CART)*



Only cuts on kinematics: 4C kin.fit, mass window on opposite Kpi pair

Inclusive: $p\bar{p} \to D^0 \bar{D}^0 \to (K\pi) + X$ *Alexandros Apostolou, J.M. (KVI-CART)*

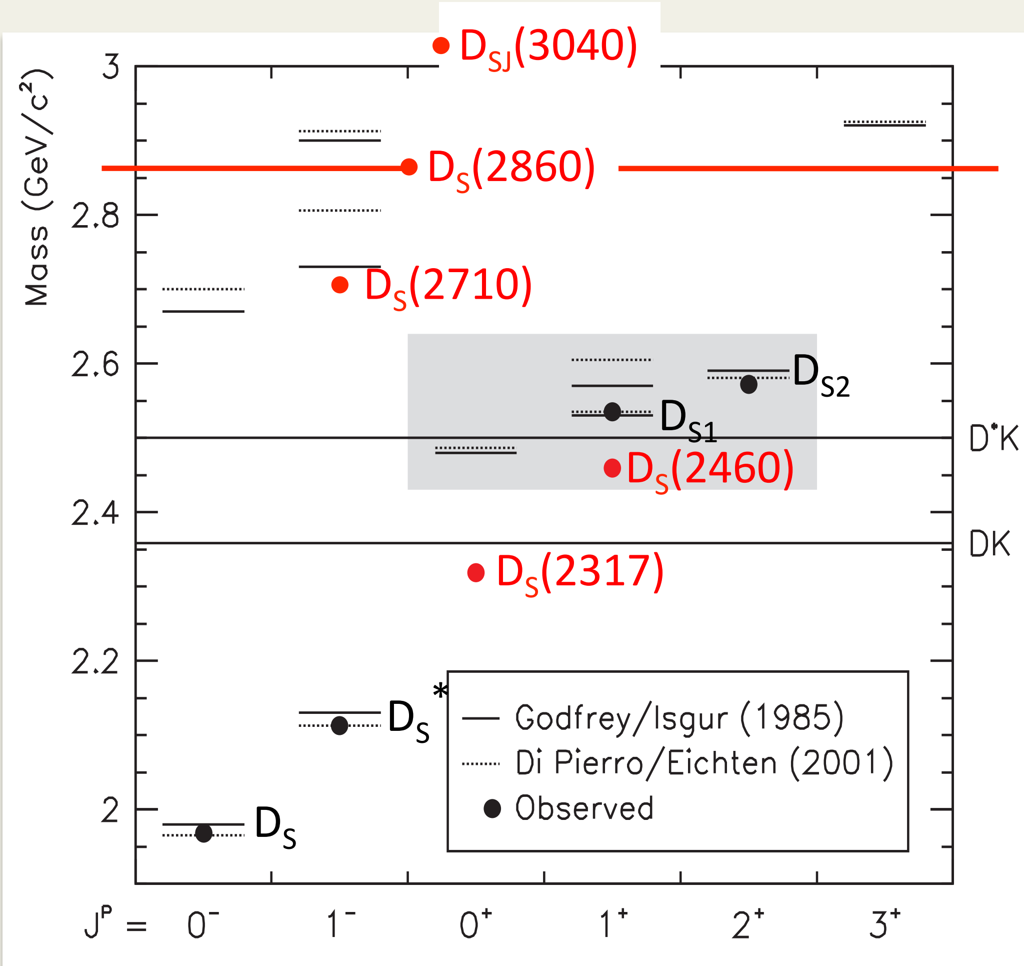


Only cuts on kinematics: 1C kin.fit, mass window on tagged Kpi pair

D_s states

For the states $c(\bar{u}/\bar{d})$ theory and experiment were in agreement, but the discovery of new D_{SJ} states has brought into question theoretical models.

The quantum numbers of $D_{s0}(2317)$ and $D_{s1}(2460)$ are not yet really established, and in order to answer important questions related to their interpretation, we need to measure their widths.

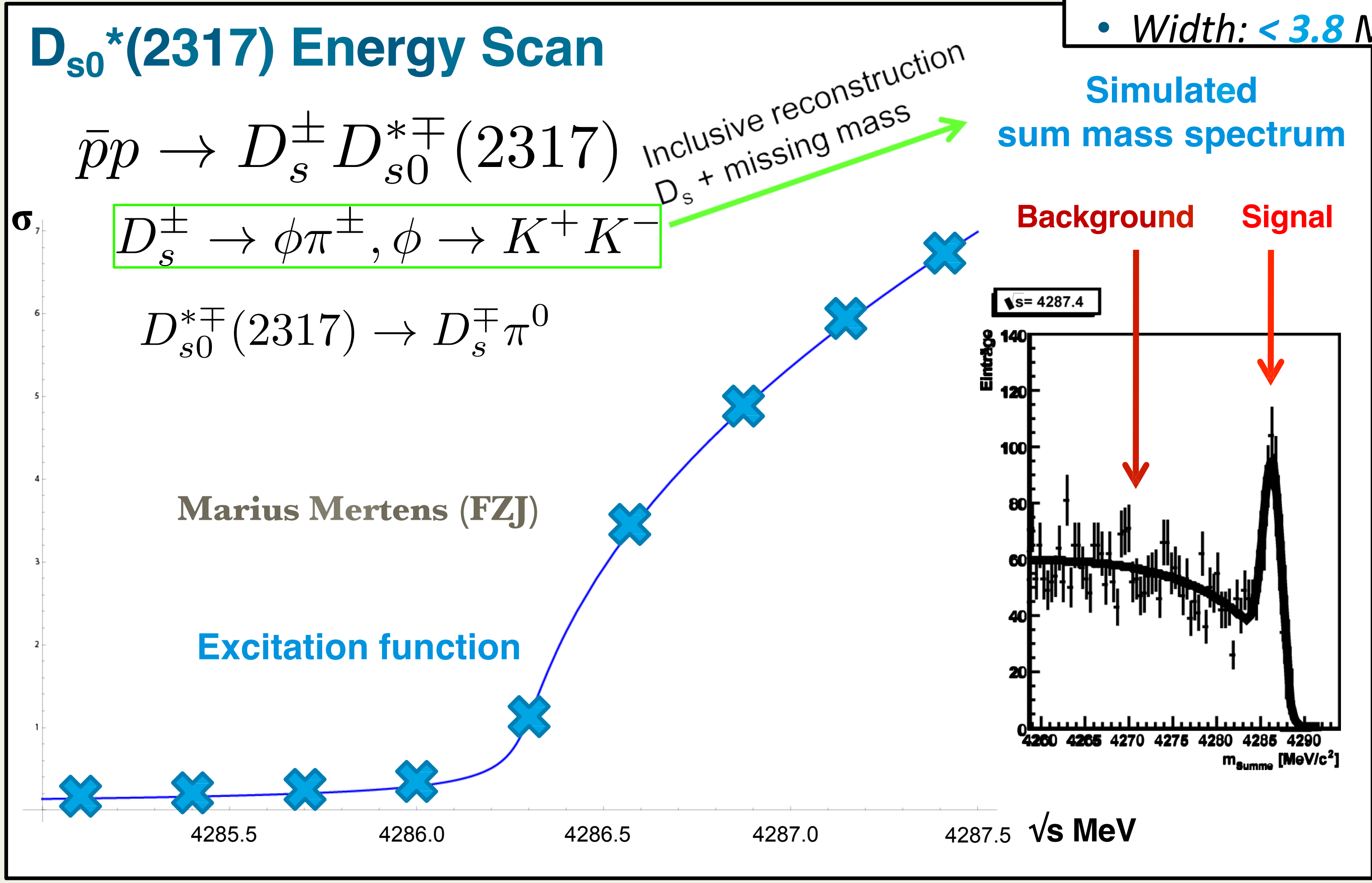


B. Aubert et al., PRD74, 032007 (2006).

panda opportunity D_s meson spectroscopy

D_{s0}*(2317) world average (PDG)

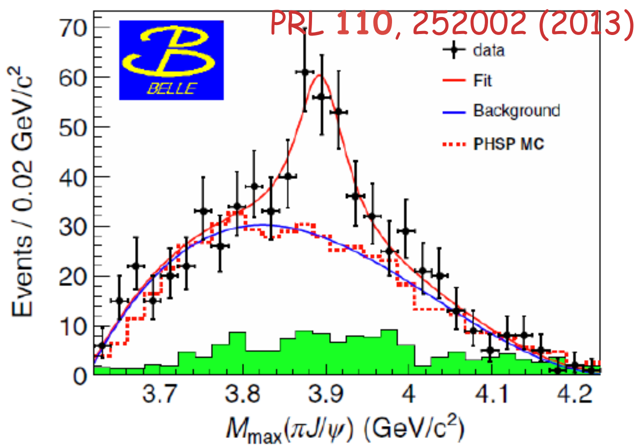
- *Mass: 2317.8 ± 0.6 MeV/c²*
- *Width: < 3.8 MeV/c²*

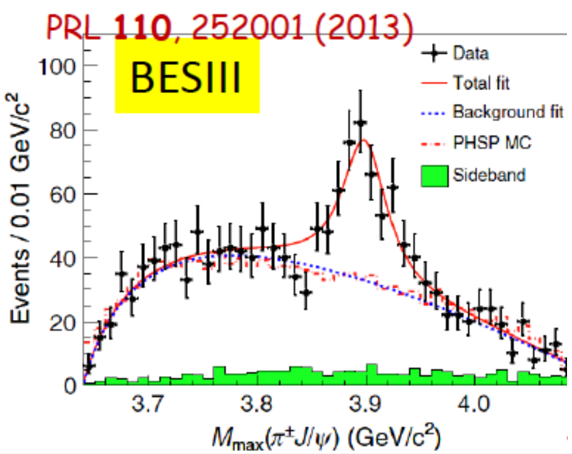


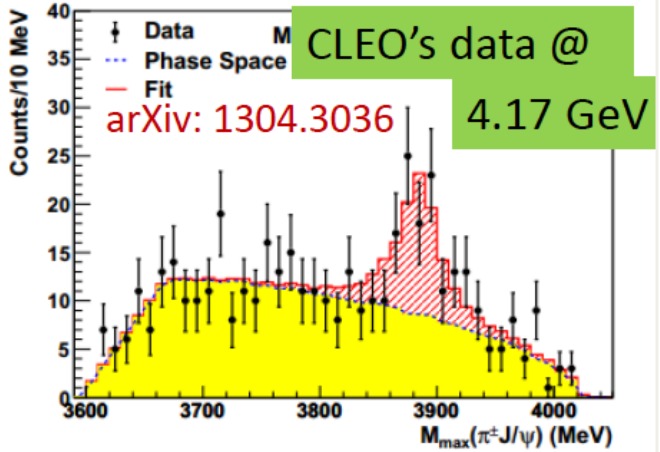
Charged multi-quark states

The first has been the Z(4430) observed in the invariant mass $\Psi'\pi^{\pm}$ by Belle, followed by other states in the bottomomium energy range. Recently, BESIII collaboration discovered an other charged charmonium-like axial meson $Z^{+}_{c} \rightarrow J/\Psi\pi^{\pm}$ (M= 3899±6 MeV, Γ = 46±22 MeV), confirmed by Belle and CLEO. The simplest quantum numbers assignment is $J^{PG} = 1^{++}$, G being the G-parity.

particle	decay	collaboration
$Z^{+}(4430)$	$\psi(2S)\ \pi^{+}$	Belle
$Z^{+}(4050)$ $Z^{+}(4250)$	$\chi_{c1}\ \ \pi^{+}$	Belle, unconfirmed
$Z_c^{+}(3900)$	$J/\psi\ \ \pi^{+}$	BESIII, Belle, CLEOc
$Z_c^{+}(4020)$	$h_c(1P)\ \pi^{+}$	BESIII preliminary
$Z_c^{+}(4025)$	$(D^{*} D^{*})^{+}$	BES III preliminary







Z$^{\pm}$ states @ PANDA

P̄ANDA can study the Z$^{\pm}$ states in both production and formation experiments.

In the production experiment, the Z$^{\pm}$ would be produced, e.g., in the reaction

$$\bar{p}p \rightarrow Z^{\pm}\pi^{\mp}$$

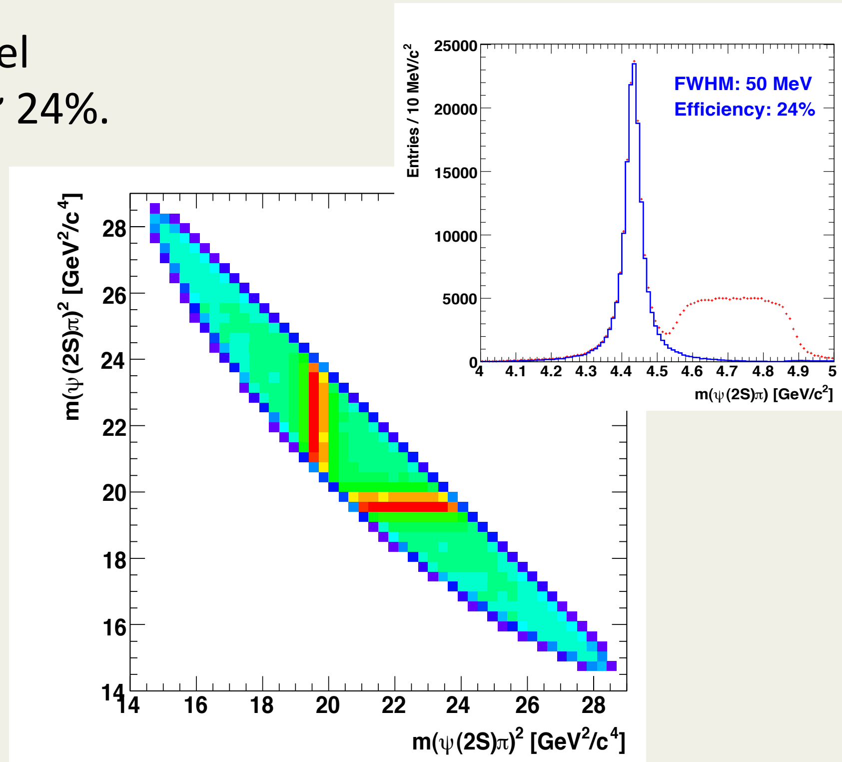
The subsequent decay chain could then be: $Z^{+}(4430) \rightarrow \psi(2S)\pi^{+} \rightarrow J/\psi\pi^{+}\pi^{-}\pi^{+} \rightarrow e^{+}e^{-}\pi^{+}\pi^{-}\pi^{+}$

The reconstruction efficiency for the $Z^{+}(4430)$ channel has been studied in Monte Carlo calculations and is ~ 24%.

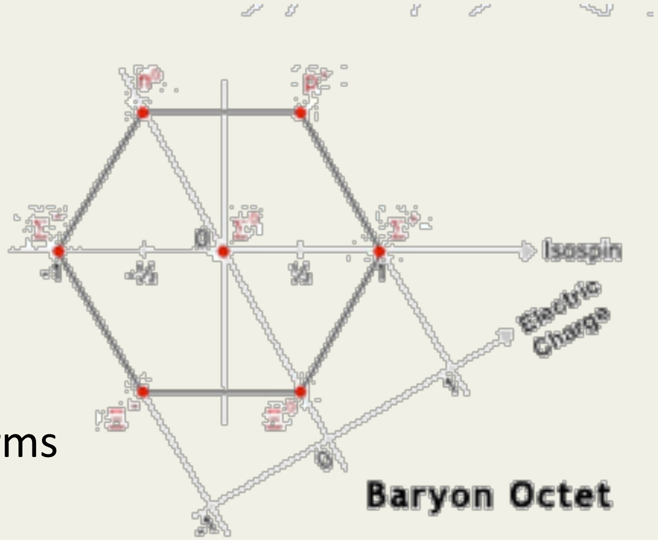
In formation mode Z$^{\pm}$ states can be produced by using a deuterium target:

$$\bar{p}d \rightarrow Z^{-}p_{spectator}$$

The reconstruction efficiency for this channel studied in Monte Carlo reactions is ~ 35%.

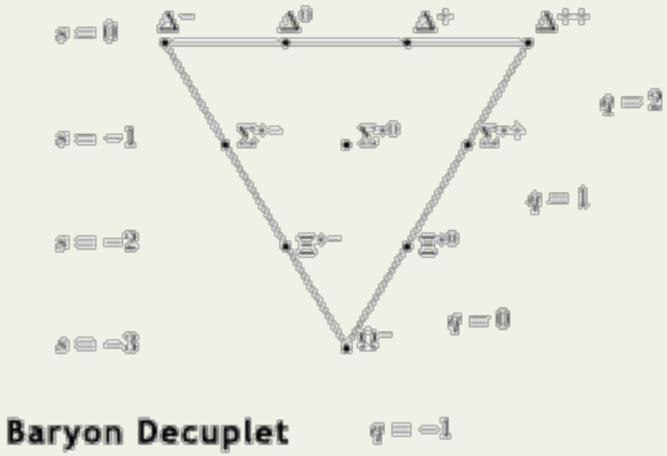


Baryon sector



The investigation of the baryon-baryon interactions is crucial for a deeper understanding of nuclei, structure of neutron matter and astrophysics aspects, etc...

Chiral effective field theories have tried since long time to describe baryon-baryon interaction and recently also lattice QCD calculations allowed to approach nuclear physics in terms of fundamental theory of the strong interaction.



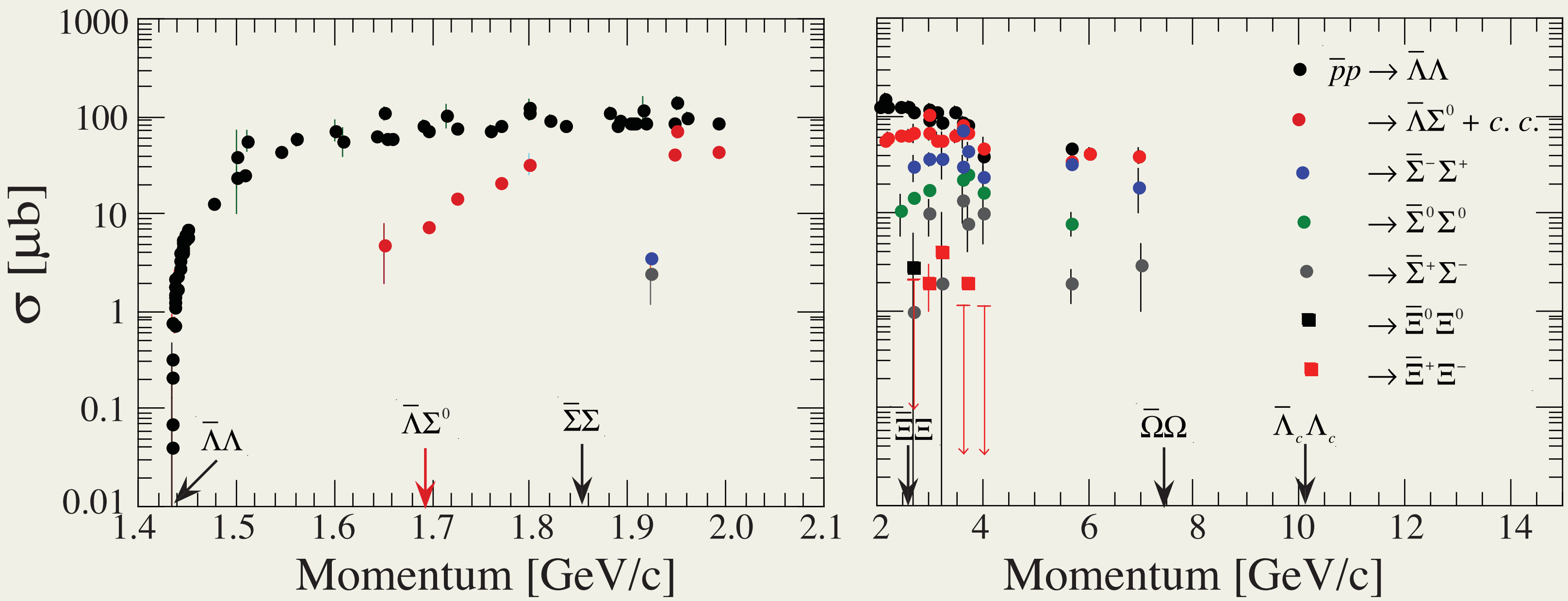
The experimental investigation of the nature of baryon bound states has gone in parallel with meson spectroscopy, nevertheless there are still many open problems and there is lack of high quality data.

Baryon Spectroscopy

In the quark picture hyperon pair production either involves the creation of a quark-antiquark pair or the knock out of such pairs out of the nucleon sea.

Hence, the importance of quark degrees of freedom with respect to the hadronic ones can be studied by measuring the reactions of the type

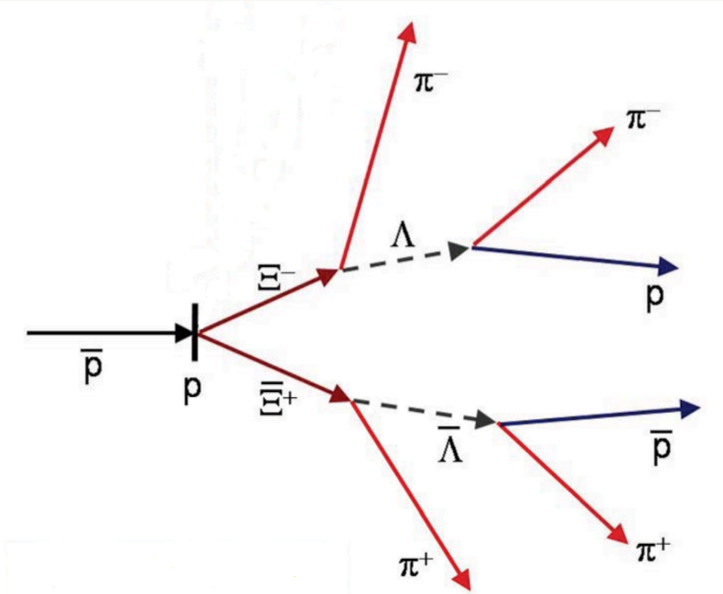
$$\bar{p}p \rightarrow \bar{Y}Y$$



QCD Dynamics

The experimental data set available is far from being complete. All strange hyperons and single charmed hyperons are energetically accessible in $\bar{p}p$ collisions at $\bar{P}$ANDA.

In $\bar{P}$ANDA $\bar{p}p \rightarrow \Lambda\bar{\Lambda}$, $\bar{\Lambda}\Xi$, $\Lambda\bar{\Xi}$, $\Xi\bar{\Xi}$, $\Sigma\bar{\Sigma}$, $\Omega\bar{\Omega}$, $\Lambda_c\bar{\Lambda}_c$, $\Sigma_c\bar{\Sigma}_c$, $\Omega_c\bar{\Omega}_c$
can be produced allowing the study of the dependences on spin observables.



Channel 1.64 GeV/c	Rec. eff.	σ [μb]	Signal
$\bar{p}p \rightarrow \Lambda\bar{\Lambda}$	0.11	64	1
$\bar{p}p \rightarrow \bar{p}p\pi^+\pi^-$	$1.2 \cdot 10^{-5}$	~ 10	$4.2 \cdot 10^{-5}$
Channel 4 GeV/c			
$\bar{p}p \rightarrow \Lambda\bar{\Lambda}$	0.23	~ 50	1
$\bar{p}p \rightarrow \bar{p}p\pi^+\pi^-$	$< 3 \cdot 10^{-6}$	$3.5 \cdot 10^3$	$< 2.2 \cdot 10^{-3}$
$\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0$	$5.1 \cdot 10^{-4}$	~ 50	$2.2 \cdot 10^{-3}$
$\bar{p}p \rightarrow \bar{\Lambda}\Sigma(1385)$	$< 3 \cdot 10^{-6}$	~ 50	$< 1.3 \cdot 10^{-5}$
$\bar{p}p \rightarrow \bar{\Sigma}^0\Sigma^0$	$< 3 \cdot 10^{-6}$	~ 50	$< 1.3 \cdot 10^{-5}$
Channel 15 GeV/c			
$\bar{p}p \rightarrow \Lambda\bar{\Lambda}$	0.14	~ 10	1
$\bar{p}p \rightarrow \bar{p}p\pi^+\pi^-$	$< 1 \cdot 10^{-6}$	$1 \cdot 10^3$	$< 2 \cdot 10^{-3}$
$\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0$	$2.3 \cdot 10^{-3}$	~ 10	$1.6 \cdot 10^{-2}$
$\bar{p}p \rightarrow \bar{\Lambda}\Sigma(1385)$	$3.3 \cdot 10^{-5}$	60	$1.4 \cdot 10^{-3}$
$\bar{p}p \rightarrow \bar{\Sigma}^0\Sigma^0$	$3.0 \cdot 10^{-4}$	~ 10	$2.1 \cdot 10^{-3}$
DPM	$< 1 \cdot 10^{-6}$	$5 \cdot 10^4$	$< .09$
Channel 4 GeV/c	Rec. eff.	σ (μb)	Signal
$\bar{p}p \rightarrow \bar{\Xi}^+\Xi^-$	0.19	~ 2	1
$\bar{p}p \rightarrow \bar{\Sigma}^+(1385)\Sigma^-(1385)$	$< 1 \cdot 10^{-6}$	~ 60	$< 2 \cdot 10^{-4}$

By comparing several reactions involving different quark flavors the OZI rule and its possible violation, can be tested.

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Baryon spectroscopy @ PANDA startup version

Assumptions: 10x lower luminosity
PANDARoot with idealised tracking

	$\bar{\Lambda}\Lambda$			$\bar{\Lambda}_c^+\Lambda_c^-$
1.64 GeV/c	$2x10^5$ h^{-1}			
4 GeV/c	$4x10^4$ h^{-1}	2500 h^{-1}		
15 GeV/c	$2x10^4$ h^{-1}	(≈ 1000 h^{-1})	(30 h^{-1})	((5 day^{-1}))

1. Single strangeness production: $\bar{p}p \to \bar{\Lambda}\Lambda$ **OK**
2. Double strangeness production: $\bar{p}p \to \bar{\Xi}\Xi$ **OK**
3. Triple charm production: $\bar{p}p \to \Omega^+\Omega^-$ **Probably OK**
4. Charm production $\bar{p}p \to \bar{\Lambda}_c^+\Lambda_c^-$ **Questionable**

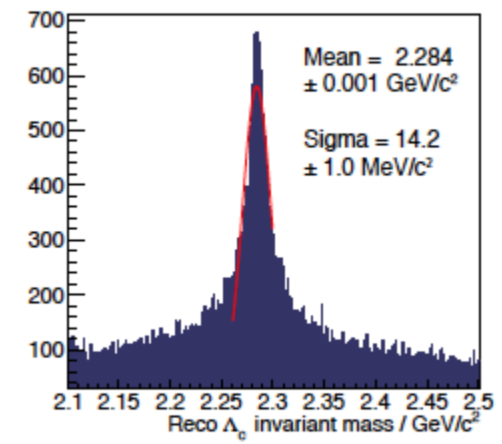
$\bar{p}p \to \Lambda_c \bar{\Lambda}_c$ @ PANDA

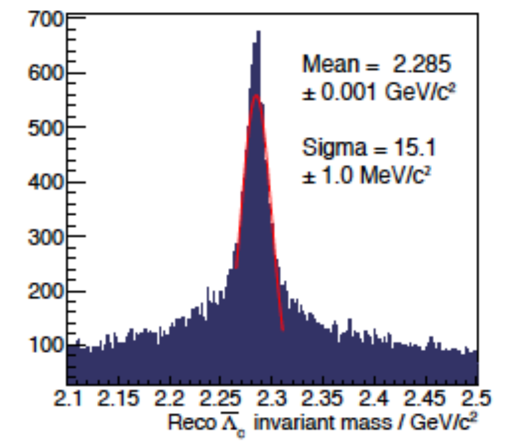
Different theoretical predictions estimated the $p\bar{p} \to \Lambda_c + \bar{\Lambda}_c$ cross section at the $\bar{\text{P}}$ANDA energies: the value ranges between some tens of nb to 200 nb.

We considered the following decay chain: $\bar{p}p \to \Lambda_c^+(2286)\bar{\Lambda}_c^-(2286)$, with $\Lambda_c^+ \to pK^-\pi^+$ and $\bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$

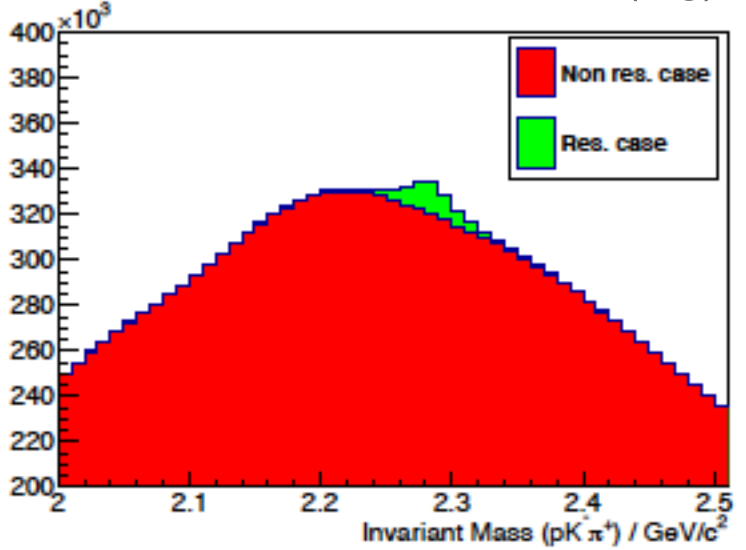
at the maximum beam momentum (15 GeV/*c*; √s = 5.474 GeV)

For the background we assumed $\sigma(\sqrt{s} = 5.474\ \mathrm{GeV})_{\bar{p}p \to pK^-\pi^+\bar{p}K^+\pi^-} = 0.020\ \mathrm{mb}$ extrapolating from measurements at √s = 7.862 GeV

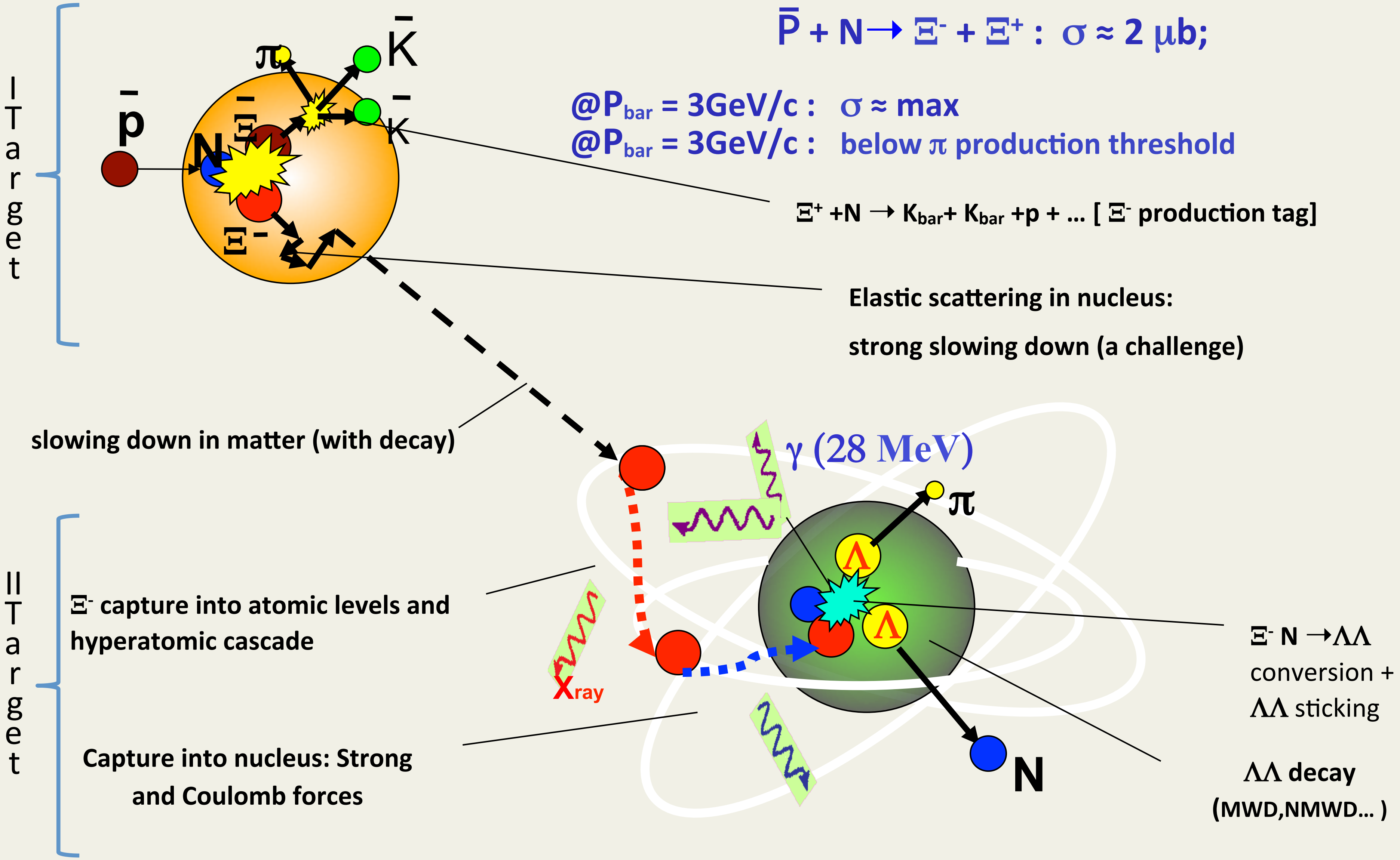




Simone Bianco (FZJ)



Doubly strange systems @ panda

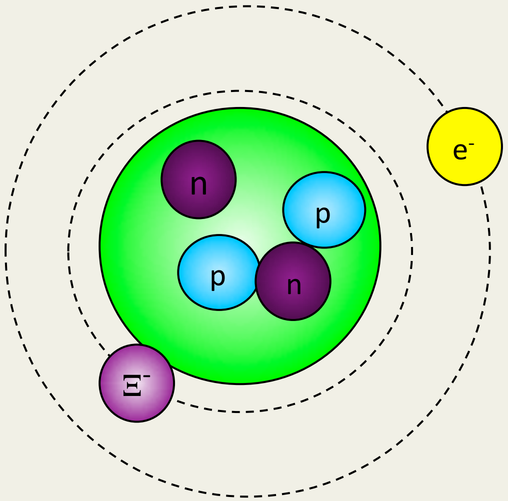


Doubly strange systems

(S=±2) hyperon –antihyperon systems are fully accessible at P̅ANDA

Exotic hyperatom:

Ξ⁻ occupies an atomic level

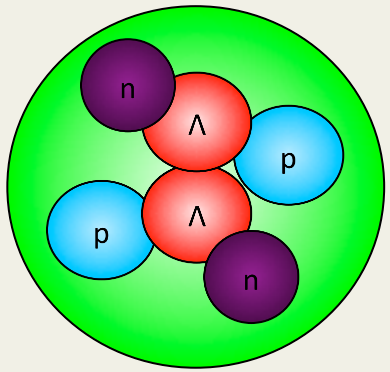


Ξ⁻ -nucleus interaction

- Atomic orbits overlap nucleus
- Strong interaction and Coulomb force interplay
- Lowest atomic levels are shifted and broadened
- Potential: Coulomb + optical

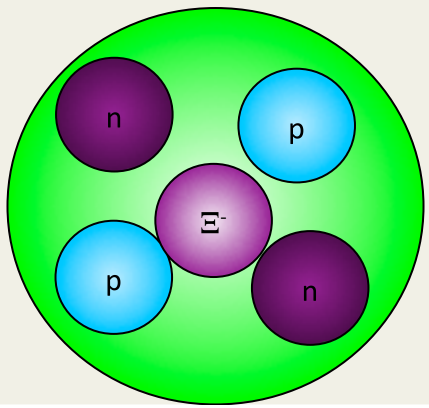
Double Λ Hypernucleus:

2 Λ 's replace 2 nucleons in a nucle



Doubly Strange Hypernucleus:

Ξ⁻ occupies a nuclear level



ΛΛ strong interaction

- only possible in double hypernuclei
- YY potential: attractive/repulsive?
- hyperfragments probability dependence on YY potential

One Boson Exchange features

ΛΛ → ΛΛ: only *non strange, I =0 meson* exchange (ω,η...)

ΛΛ weak interaction: hyperon induced decay:

- ΛΛ → Λ n: $\Gamma_{\Lambda n} << \Gamma_{free}$ (expected)
- ΛΛ → Σ⁻p: $\Gamma_{\Sigma p} << \Gamma_{free}$ (expected)

Ξ -N interaction:

- short range interaction
- long range interaction
- .....

ΛΛ Hypernuclei

Status of the art:

Nucleus	$B_{\Lambda\Lambda}({}_{\Lambda\Lambda}{}^{A}Z)$ [MeV]	$\Delta B_{\Lambda\Lambda}({}_{\Lambda\Lambda}{}^{A}Z)$ [MeV]	Reference	Reaction
${}_{\Lambda\Lambda}{}^{10}Be$	17.7± 0.4	4.3±0.4	M.Danysz et al., PRL.11(1963) 29	$K^- + A \to K^+ + \Xi^-$
${}_{\Lambda\Lambda}{}^{6}He$	10.9±0.5	4.6±0.5	D.J.Prowse, PRL.17(1966) 782	$K^- + A \to K^+ + \Xi^-$
${}_{\Lambda\Lambda}{}^{10}Be$	8.5±0.7	-4.9±0.7	KEK-E176	$K^- + p \to K^+ + \Xi^-$ (q.f)
${}_{\Lambda\Lambda}{}^{13}B$	$27.6\pm0.7^{+0.18}_{-0.11}$	$4.9\pm0.7^{+0.18}_{-0.11}$	S.Aoki et al., PTP.85(1991) 1287	$K^- + p \to K^+ + \Xi^-$ (q.f)
${}_{\Lambda\Lambda}{}^{12}B$		4.5±0.5	P.Khaustov et al., PRC.61(2000)027601	$({}^{12}C)_{atom}\Xi^- \to {}^{12}B_{\Lambda\Lambda} + n$
${}_{\Lambda\Lambda}{}^{6}He$	$7.25\pm0.19^{+0.18}_{-0.11}$	1.01±0.2	KEK-E373,NAGARA H.Takahashi et al., PRL.87(2001)212502-1	$K^- + p \to K^+ + \Xi^-$ (q.f)
${}_{\Lambda\Lambda}{}^{12}B$		$\sigma\ (\theta<8^0) \approx$ 6-10nb	K.Yamamoto et al., PLB.478(2000) 401	$K^- + {}^{12}C \to K^+ + {}^{12}B_{\Lambda\Lambda}$

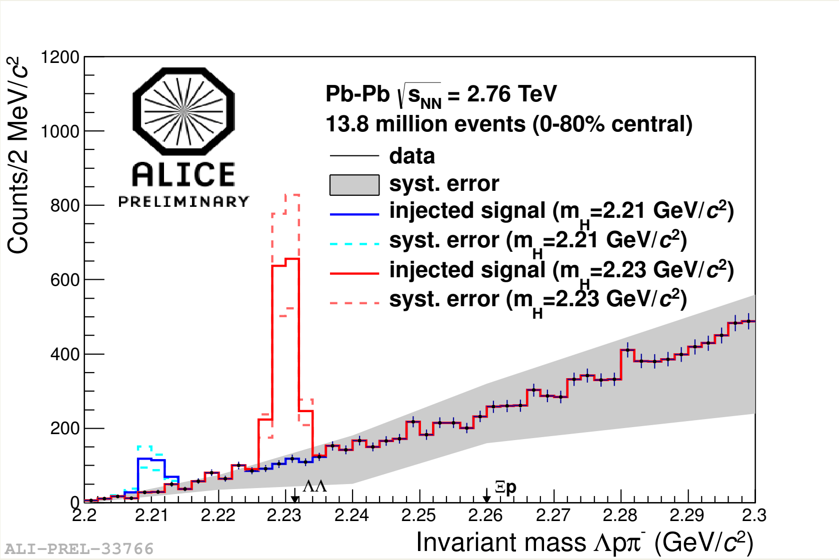
Features:

$$-V_{\Lambda\Lambda} = \Delta B_{\Lambda\Lambda}({}_{\Lambda\Lambda}^{A}Z) \equiv B_{\Lambda\Lambda}({}_{\Lambda\Lambda}^{A}Z) - 2B_{\Lambda}({}_{\Lambda}^{A-1}Z)$$

- **Binding energy →** parameters in potential models
- **Core of the ΛΛ interaction ($V_{\Lambda\Lambda}$)** : needs of several A-hypernuclei
- ΛΛ interaction: only I=0 ***non**-strange mesons* contributes (only ω,η)
- **Weak Decay presents some peculiarities**

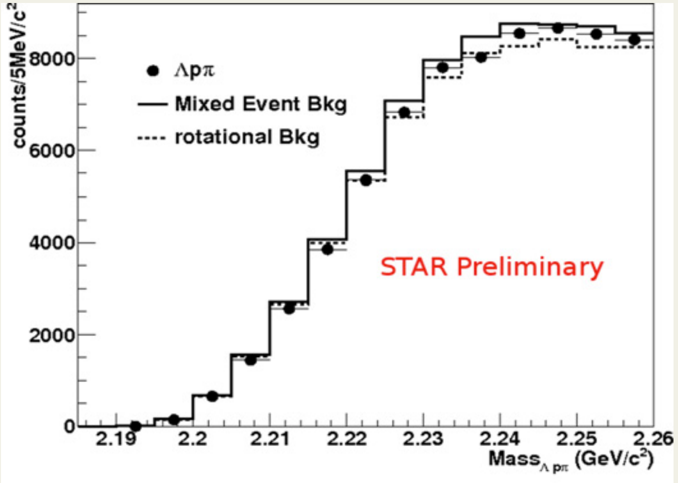
H-Dibarion

The measurement of the $_{\Lambda\Lambda}{}^{6}He$ binding energy has triggered new speculations on the H-dibarion existence [PRL106 (2011)162001]. The original prediction of a 6-quark state with a binding ≃ 81 MeV has been ruled out.



Nowadays, the only possibility is for a baryon-baryon molecule.

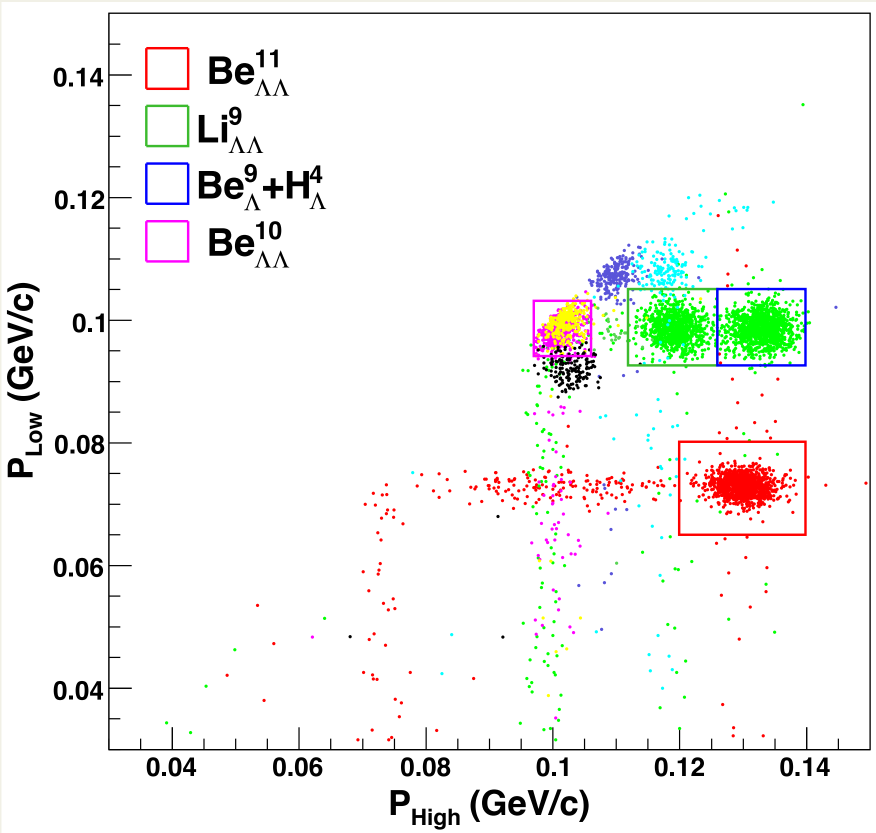
HI collision experiments searched in the Λp invariant mass system for a possible signal.

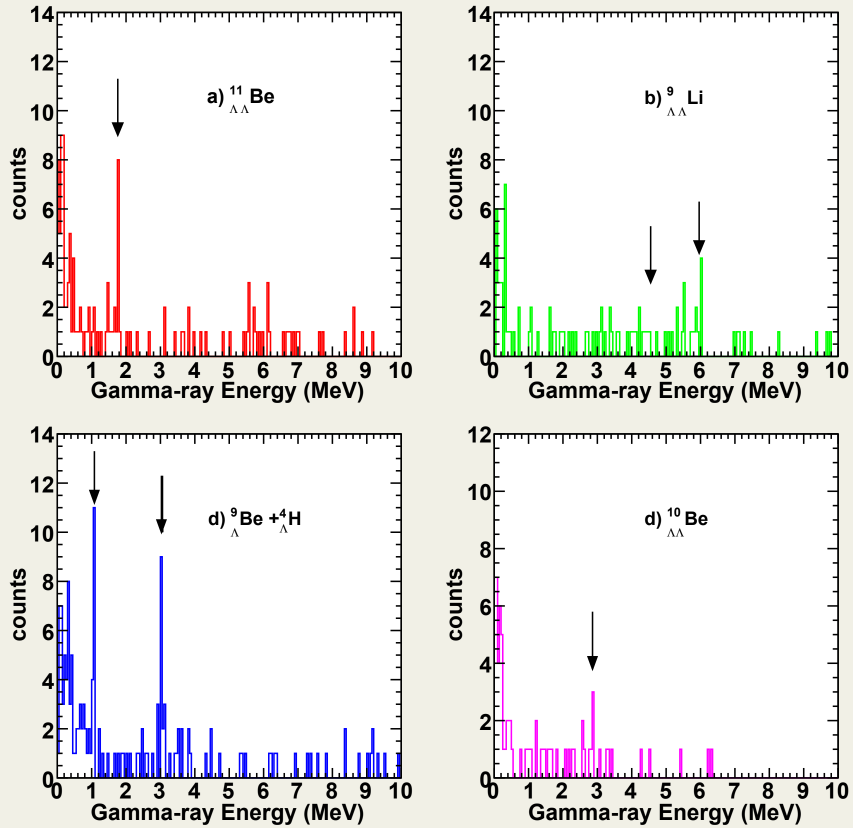


A deeper knowledge of S=−2 sector would help to extend models that have been successful in describing the S=0 and −1 sectors to account for SU(3) symmetry.

ΛΛ hypernuclei

We assumed a Ξ⁻+p → ΛΛ conversion probability of 5%.
The identication of the double hypernuclei relys on the unique assignment of the detected γ-transitions.





To determine the binding energies we will perform γ-rays spectroscopy detecting in coincidence the pions coming out from the Λ decays.

Conclusions

- Hadron spectroscopy is experiencing a new renascence;
- New high quality measurements are coming form e^+-e^- colliders and LHC experiments reveling unexpected properties of hadrons;
- All over the world there is lack of antiproton beams that in the past were showing great capabilities in the field;
- It is urgent to have an high-quality antiproton beam to contribute to the field;
- The $\bar{P}$ANDA detector coped to the HESR will be the perfect combination of tools to make a break-through!