QNP2015,
Valparaiso, March 2-6, 2015

Hadron physics at J-PARC

Tomofumi NAGAE (Kyoto University)

Contents-

- Introduction of J-PARC
- E19 : Search for penta-quark Θ^+
- E27 : Search for "$K^- pp$"
- Future program
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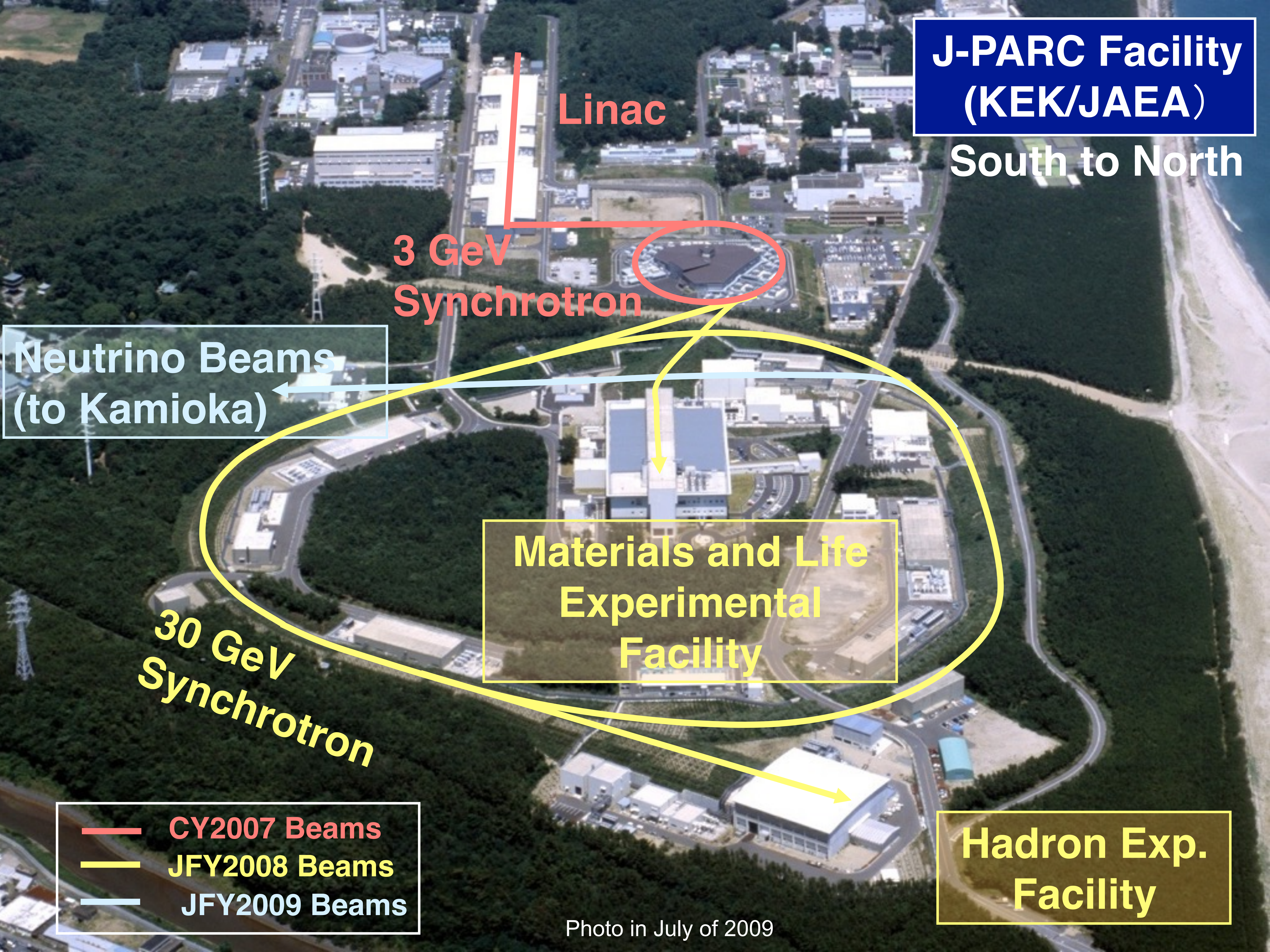
  - E50 : Charmed baryon spectroscopy
- Summary

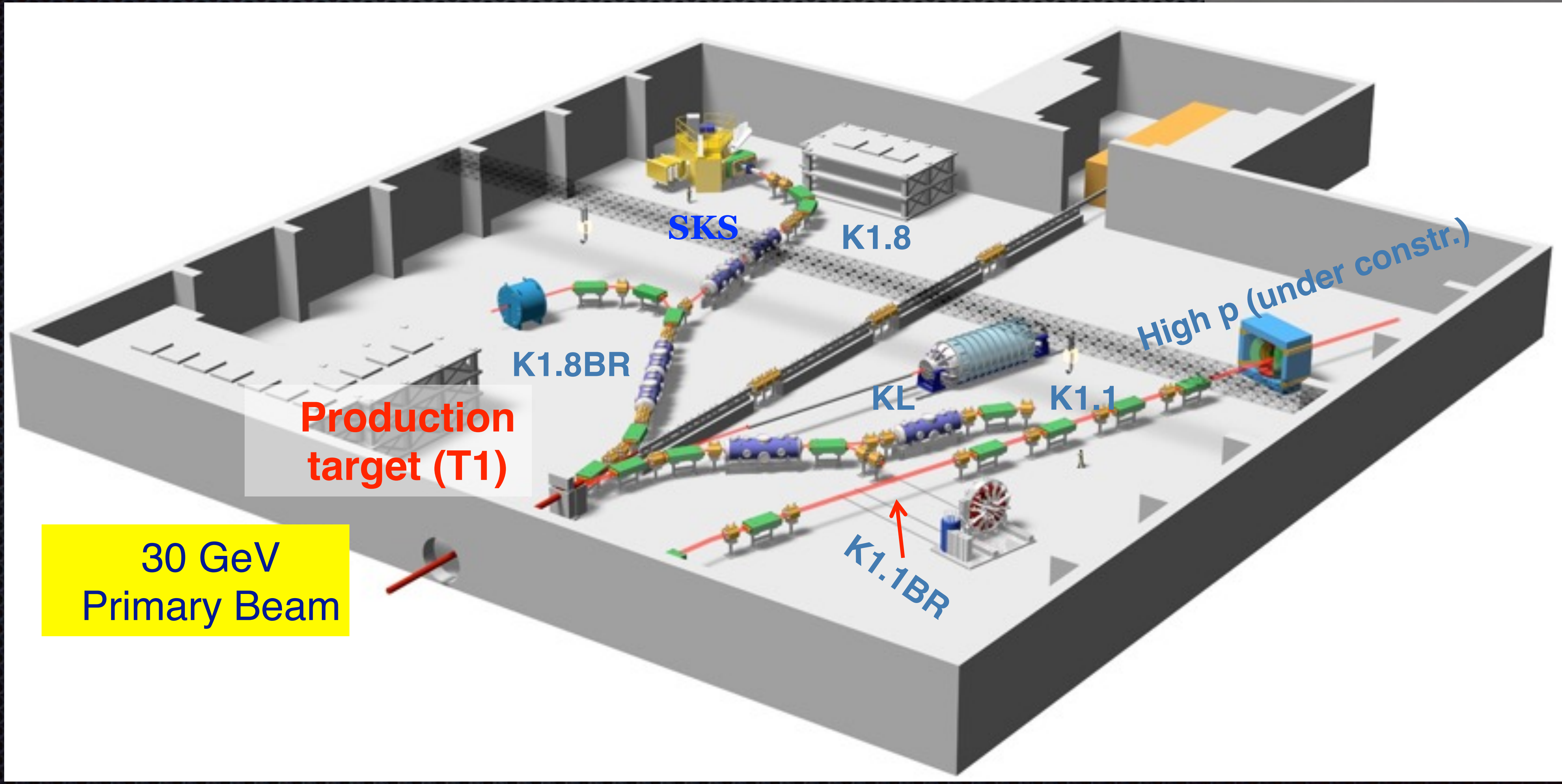

J-PARC Facility
(KEK/JAEA)
South to North
Linac
3 GeV
Synchrotron
Neutrino Beams
(to Kamioka)
Materials and Life
Experimental
Facility
30 GeV
Synchrotron
Hadron Exp.
Facility
CY2007 Beams
JFY2008 Beams
JFY2009 Beams
Photo in July of 2009

Hadron Experimental Hall

World highest intensity Kaon beams !

First beam in Feb. 2009

60m x 56m



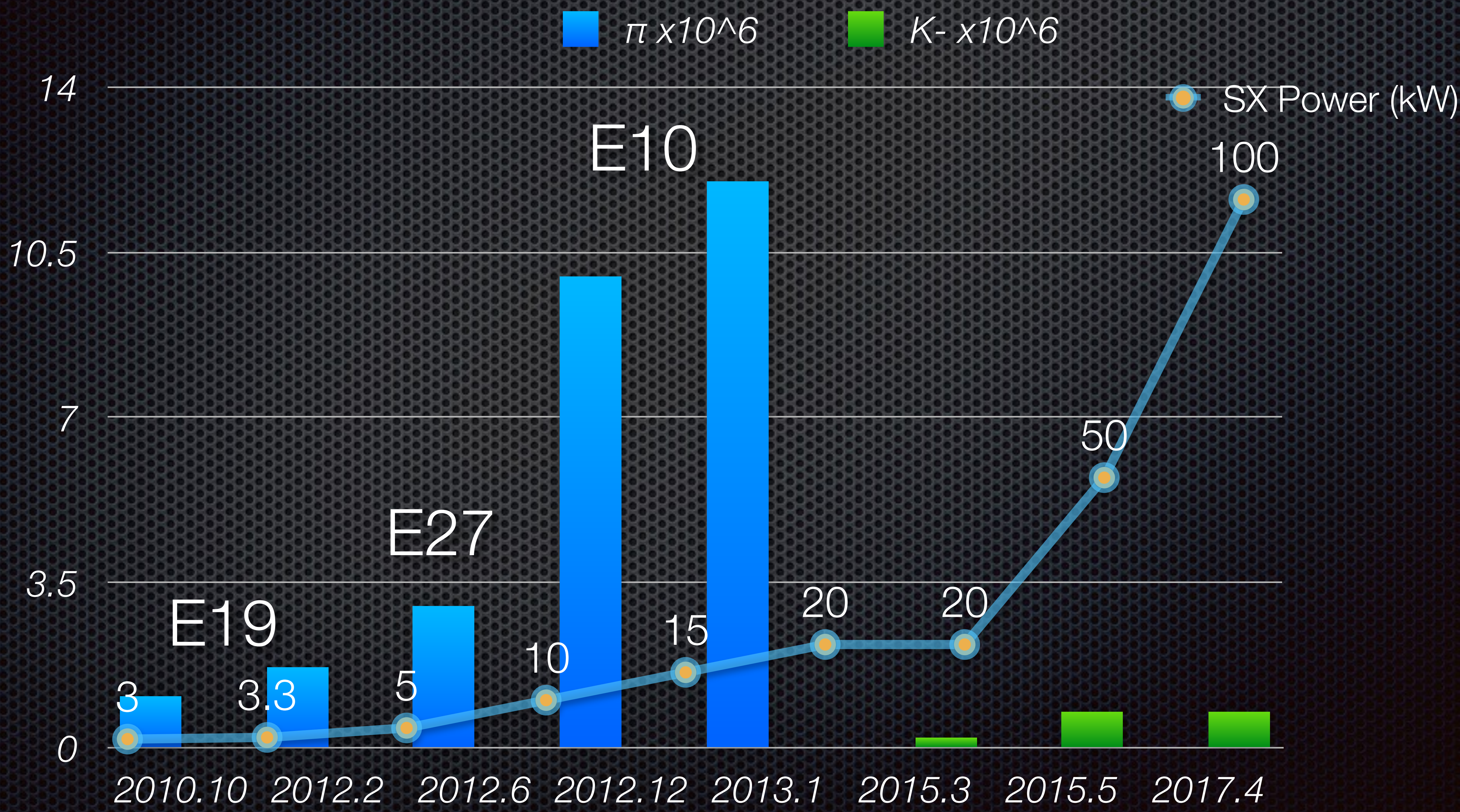
Hadron Program History

- 2010: Oct.-Nov.
  - E19: Penta-quark search in $\pi^- p \to K^- X$ at 1.92 GeV/c
    - *First physics data taking in Hadron Hall*
- 2012: Feb. , *after the Earthquake*
  - E19: $\pi^- p \to K^- X$ at 2 GeV/c
- 2012: June
  - E27: $d(\pi^+,K^+)$ for $K^- pp$, *a pilot run* 5 kW / 270 kW

Hadron Program History

- 2012: Dec. 10 kW
  - E10: $(\pi^-,K^+)^6{}_\Lambda H$
- 2013: March - May 20 kW
  - E15: $^3He(K^-,n)$ for K^-pp
  - *Radiation Accident*
  - E13: Hypernuclear γ-ray spectroscopy; $^4{}_\Lambda He$, $^{19}{}_\Lambda F$

Beams at K1.8: $\pi^{\pm} \rightarrow K^{-}$



E19 : Search for penta-quark Θ^+

Spokesperson : M. Naruki (Kyoto)

K. Shirotori et al., Phys. Rev. Lett. 109 (2012) 132002.

M. Moritsu et al., Phys. Rev. C 90 (2014) 035205.

M. Moritsu[a], S. Adachi[a], M. Agnello[b,c], S. Ajimura[d], K. Aoki[e], H.C. Bhang[f], B. Bassalleck[g], E. Botta[h,c], S. Bufalino[c], N. Chiga[i], H. Ekawa[a], P. Evtoukhovitch[j], A. Feliciello[c], H. Fujioka[a], S. Hayakawa[k], F. Hiruma[i], R. Honda[i], K. Hosomi[i], Y. Ichikawa[a], M. Ieiri[e], Y. Igarashi[e], K. Imai[l], N. Ishibashi[k], S. Ishimoto[e], K. Itahashi[m], R. Iwasaki[e], C.W. Joo[f], S. Kanatsuki[a], M.J. Kim[f], S.J. Kim[f], R. Kiuchi[f], T. Koike[i], Y. Komatsu[n], V.V. Kulikov[o], S. Marcello[h,c], S. Masumoto[n], Y. Matsumoto[i], K. Matsuoka[k], K. Miwa[i], T. Nagae[a], M. Naruki[e], M. Niiyama[a], H. Noumi[d], Y. Nozawa[a], R. Ota[k], K. Ozawa[e], N. Saito[e], A. Sakaguchi[k], H. Sako[l], V. Samoilov[j], M. Sato[i], S. Sato[l], Y. Sato[e], S. Sawada[e], M. Sekimoto[e], K. Shirotori[d], H. Sugimura[a], S. Suzuki[e], H. Takahashi[e], T. Takahashi[e], T.N. Takahashi[m], H. Tamura[i], T. Tanaka[k], K. Tanida[f,l], A.O. Tokiyasu[a], N. Tomida[a], Z. Tsamalaidze[j], M. Ukai[i], K. Yagi[i], T.O. Yamamoto[i], S.B. Yang[f], Y. Yonemoto[i], C.J. Yoon[d], K. Yoshida[k]

[a] *Department of Physics, Kyoto University, Kyoto 606-8502, Japan*
[b] *Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino, I-10129, Italy*
[c] *INFN, Istituto Nazionale di Fisica Nucleare, Sez. di Torino, I-10125 Torino, Italy*
[d] *Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*
[e] *High Energy Accelerator Research Organization (KEK), Tsukuba 305-0801, Japan*
[f] *Department of Physics and Astronomy, Seoul National University, Seoul 151-747, Republic of Korea*
[g] *Department of Physics and Astronomy, University of New Mexico, NM 87131-0001, USA*
[h] *Dipartimento di Fisica, Università di Torino, I-10125 Torino, Italy*
[i] *Department of Physics, Tohoku University, Sendai 980-8578, Japan*
[j] *Joint Institute for Nuclear Research, Dubna, Moscow Region 141980, Russia*
[k] *Department of Physics, Osaka University, Toyonaka 560-0043, Japan*
[l] *Japan Atomic Energy Agency (JAEA), Tokai, Ibaraki 319-1195, Japan*
[m] *RIKEN, Wako, Saitama 351-0198, Japan*
[n] *Department of Physics, University of Tokyo, Tokyo 113-0033, Japan*
[o] *ITEP, Institute of Theoretical and Experimental Physics, Moscow 117218, Russia*

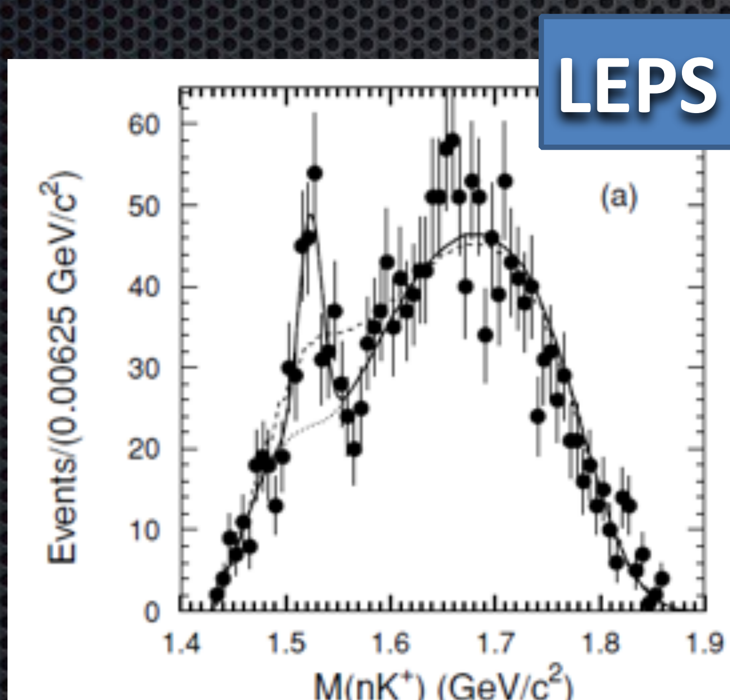




Experimental search

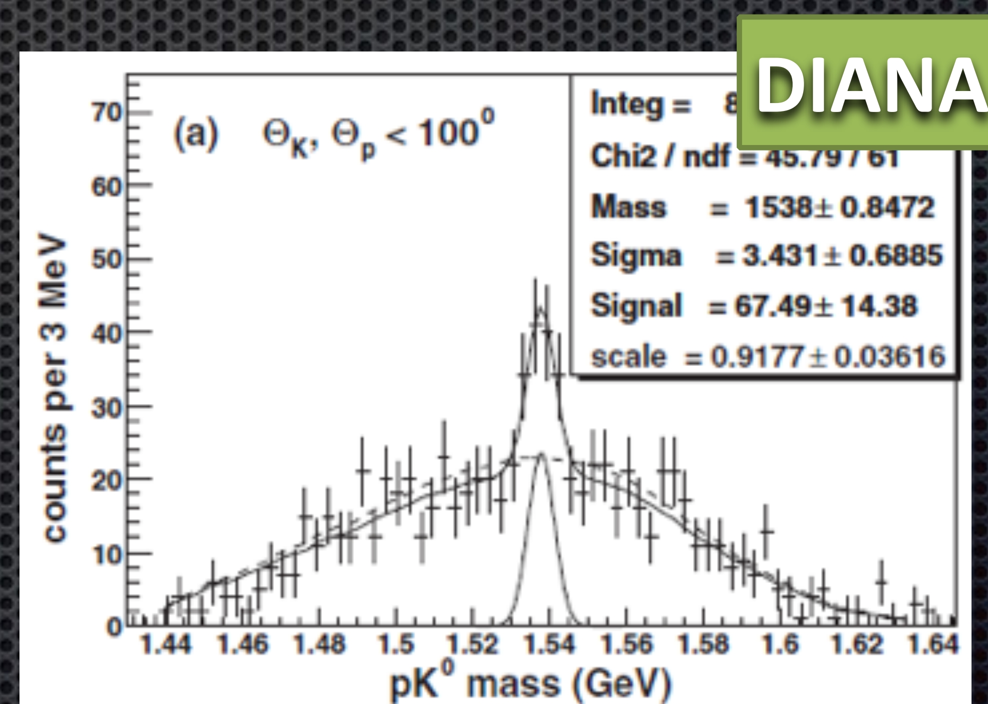
- SPring8/LEPS group reported the first evidence for Θ^+ in 2003.
- Dozen experimental groups published supporting evidence for the Θ^+.
- Some reconfirmed their evidence, but many others disappeared or faded out.

LEPS Collaboration,
PRL 91, 012002 (2003);
PRC 79, 025210 (2009), ... next ?



- $\gamma d \to K^- K^+ pn$
- 5.1 σ
- M = 1524 ± 2 + 3 GeV

DIANA Collaboration,
Phys. Atom. Nucl. 66, 1715 (2003); 70, 35 (2007);
73, 1168 (2010); PRC 89, 045204 (2014).



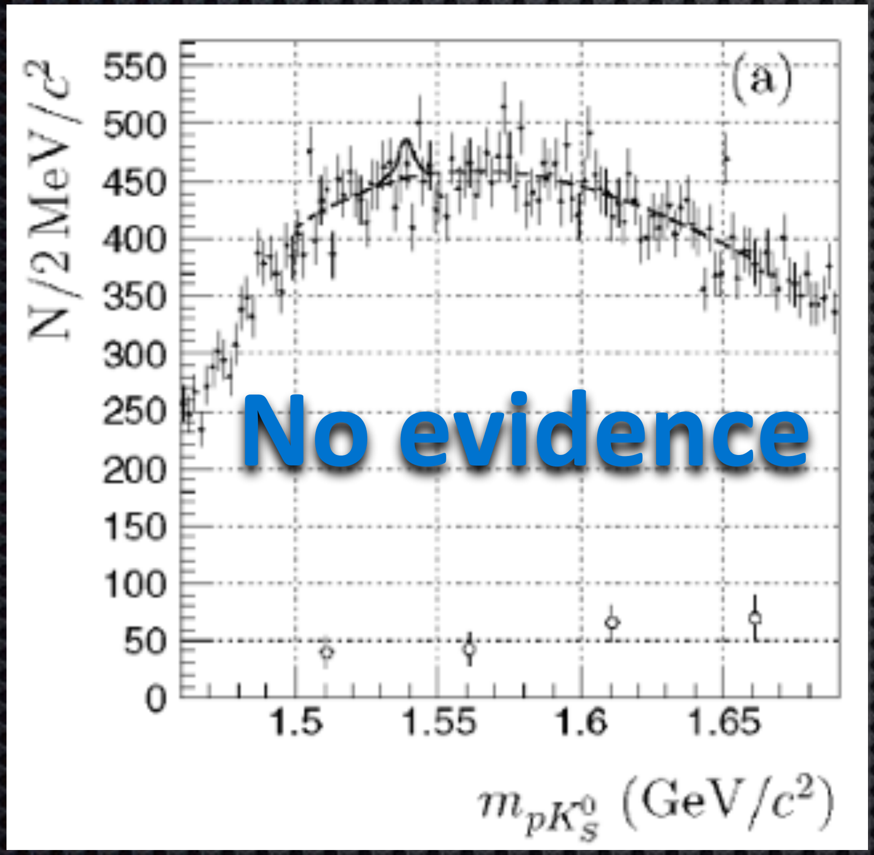
- $K^+ Xe \to K^0 p Xe'$
- 5.5 σ
- M = 1538 ± 2 MeV
- $\Gamma = 0.34 \pm 0.10$ MeV

$$\Gamma_{\Theta^+} = \frac{N_{\Theta^+}}{N^{\rm ch}} \frac{\sigma^{\rm ch}}{107\ {\rm mb}\ B_i B_f} \Delta m,$$

Experimental search

R. Mizuk et al. (Belle Collaboration), Phys. Lett. B 632, 173 (2006).

- Kaon secondary interactions in detector material. $K^+ n \to \Theta(1540)^+ \to p K_S^0$



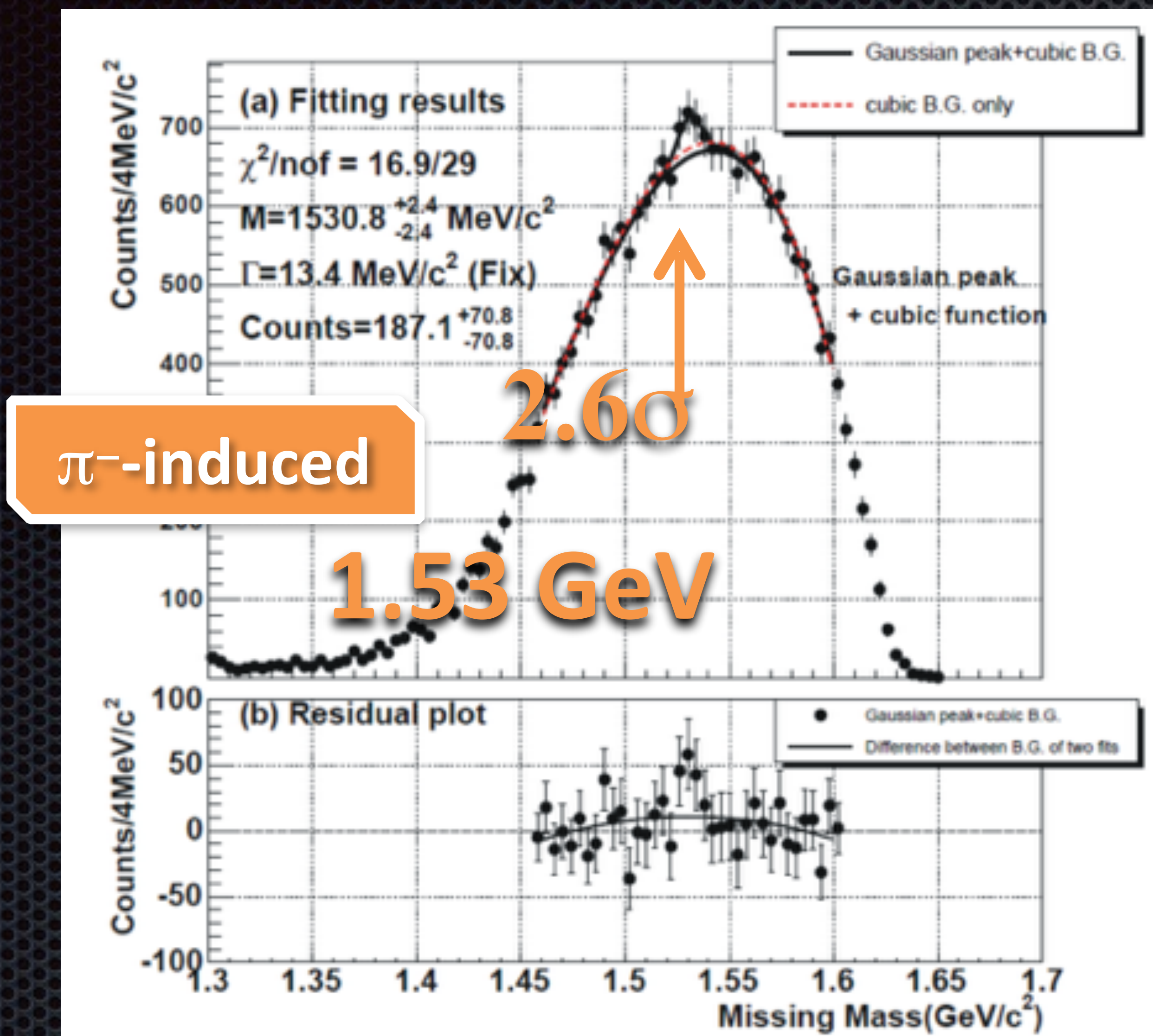
$$\frac{\sigma(KN \to \Theta(1540)^+ X)}{\sigma(\bar{K}N \to \Lambda(1520) X)} < 2.5\% \text{ at the } 90\% \text{ C.L.}$$

$$\Gamma\left(K^+ n \to \Theta(1540)^+ \to p K_S^0\right) < 0.64 \text{ MeV at the } 90\% \text{ C.L.}$$

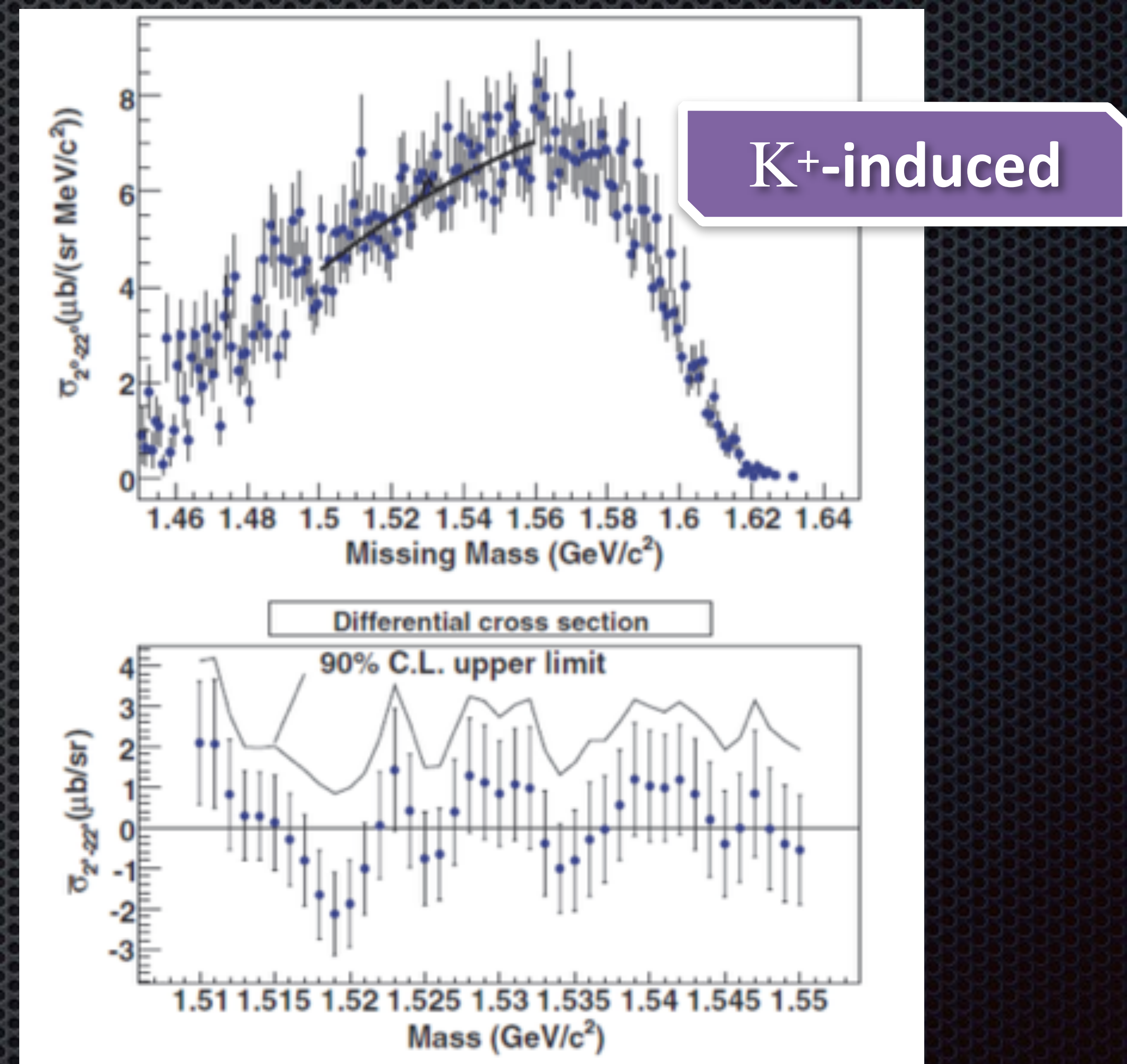
Previous experiments at KEK-PS

E522 : $\pi^- p \rightarrow K^- \Theta^+$ @ 1.92 GeV/c

E559 : $K^+ p \rightarrow \pi^+ \Theta^+$ @ 1.20 GeV/c



K. Miwa *et al.*, PLB 635, 72 (2006).



K. Miwa *et al.*, PRC 77, 045203 (2008).

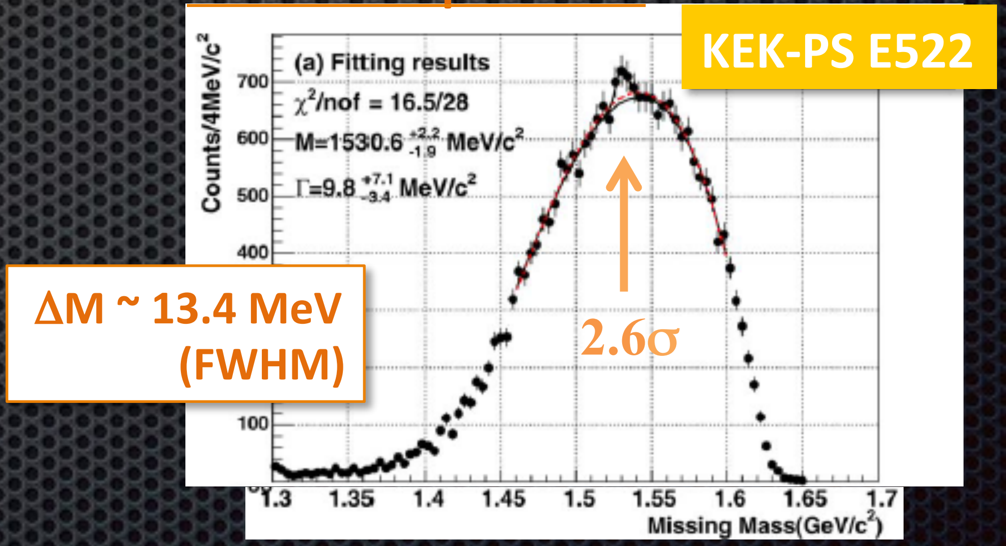
- **Bump structure (2.6σ)**
  - ➔ **Not enough to claim the existence**
- **Upper limit: σ < 3.9 μb (90% C.L.)**

- **No peak structure**
- **Upper limit: σ < 3.5 μb/sr (90% C.L.)**

Our Approach (J-PARC E19)

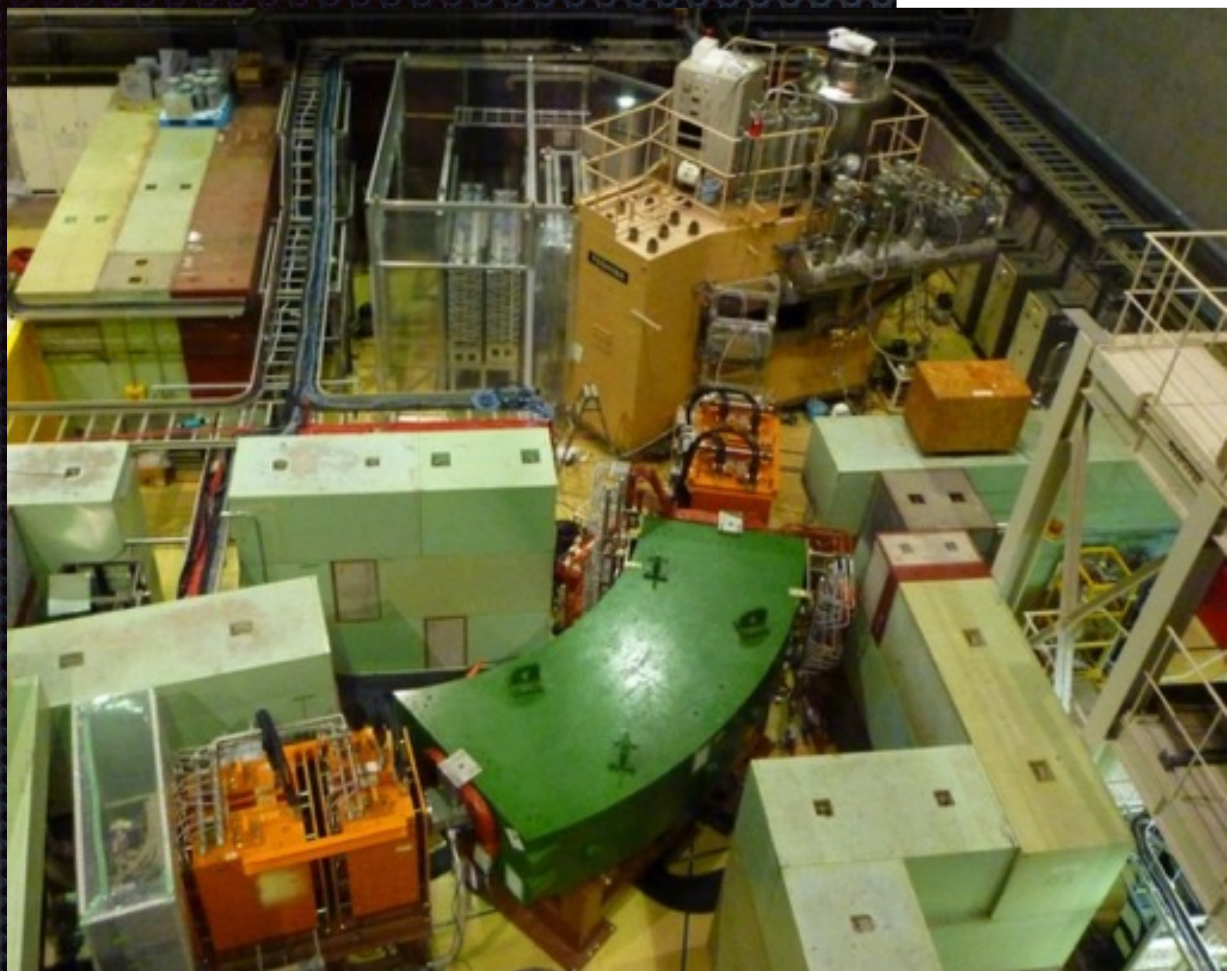
1. **Pion induced reaction** $\pi^- + p \rightarrow K^- + \Theta^+$
   - Complementary to photo-production (LEPS/CLAS).
   - Expect sizable production cross section. => **High statistics**
2. **High resolution missing mass spectroscopy**
   - K1.8 beam line & SKS : ΔM = 2 MeV (FWHM)

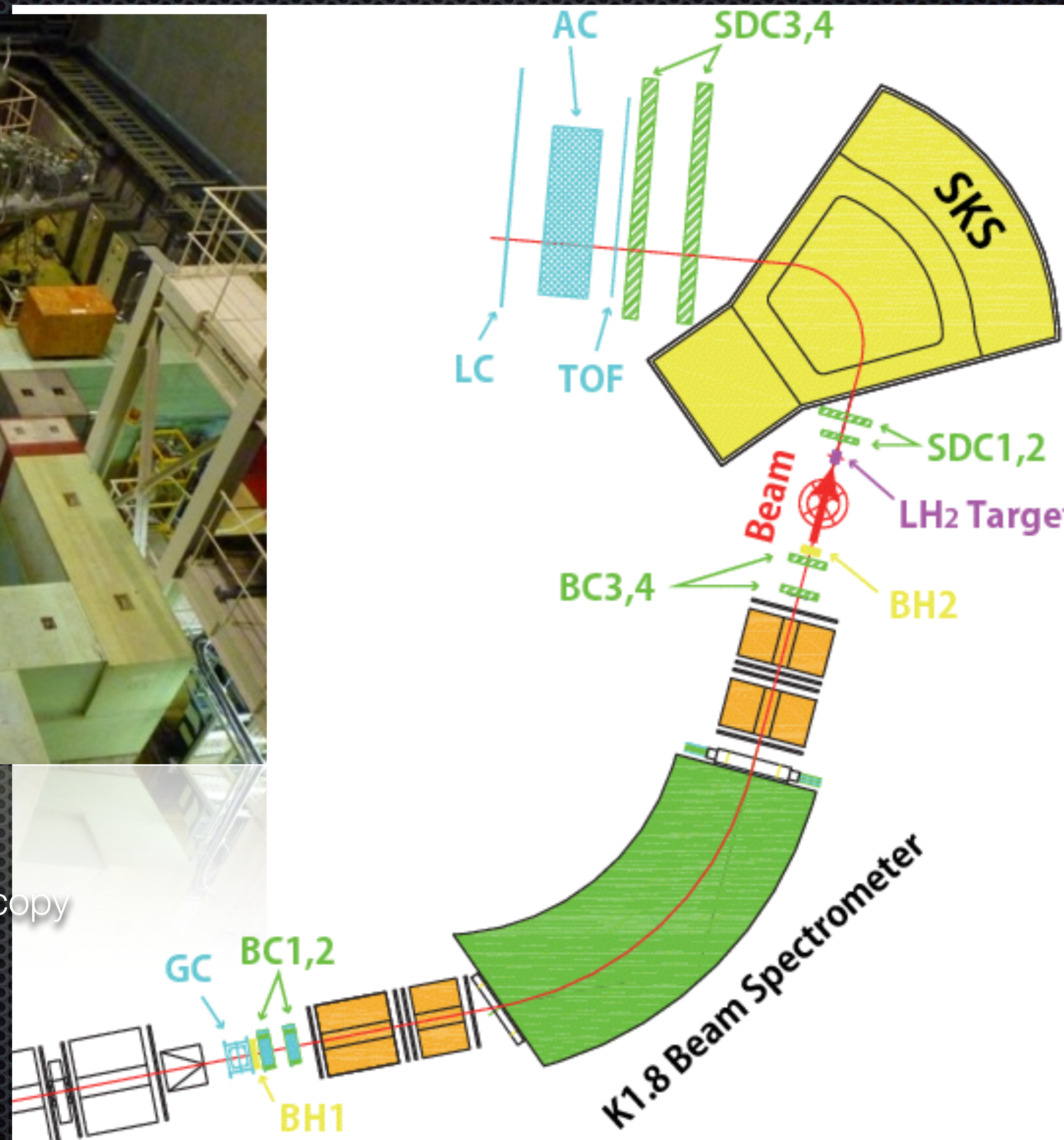
Previous experiment



Conclusive result in higher sensitivity !!

E19 Experimental setup





J-PARC K1.8

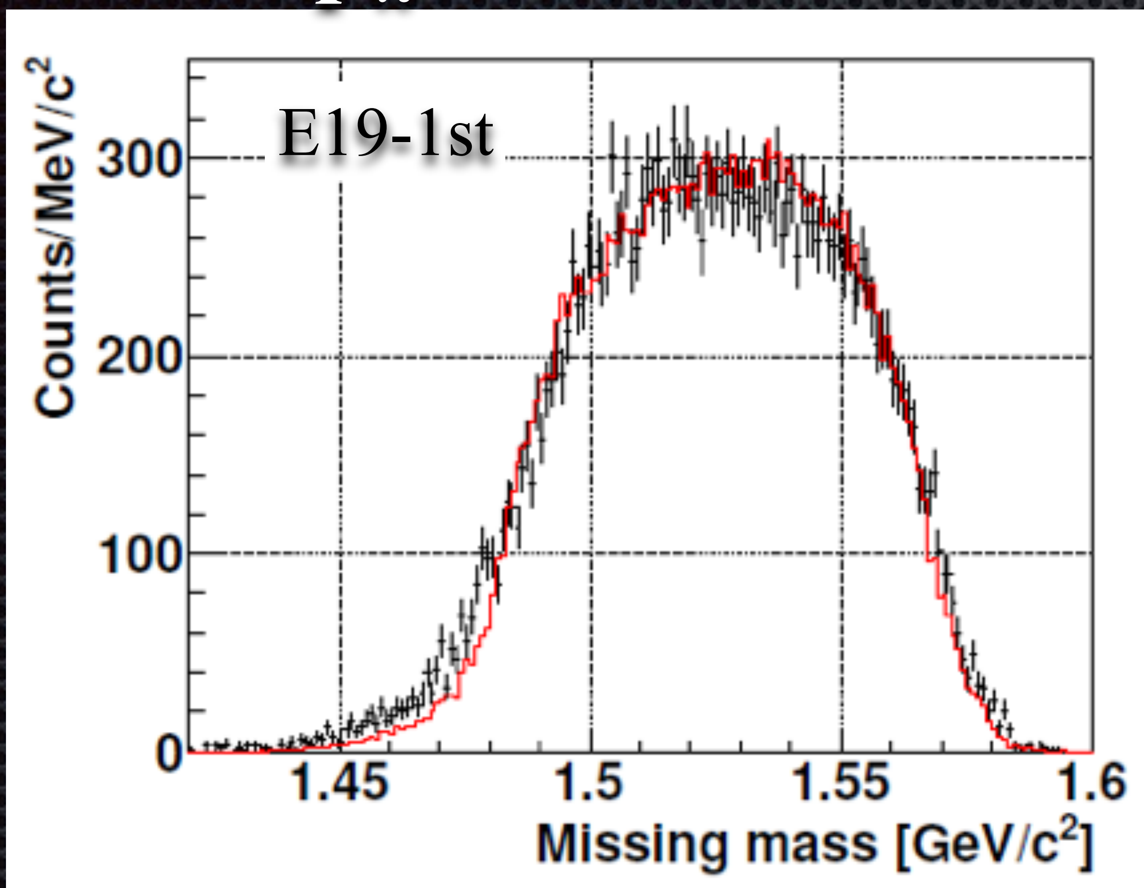
Dedicated to the (π,K) reaction spectroscopy

π^- beam
1.92/2.00 GeV/c

Results

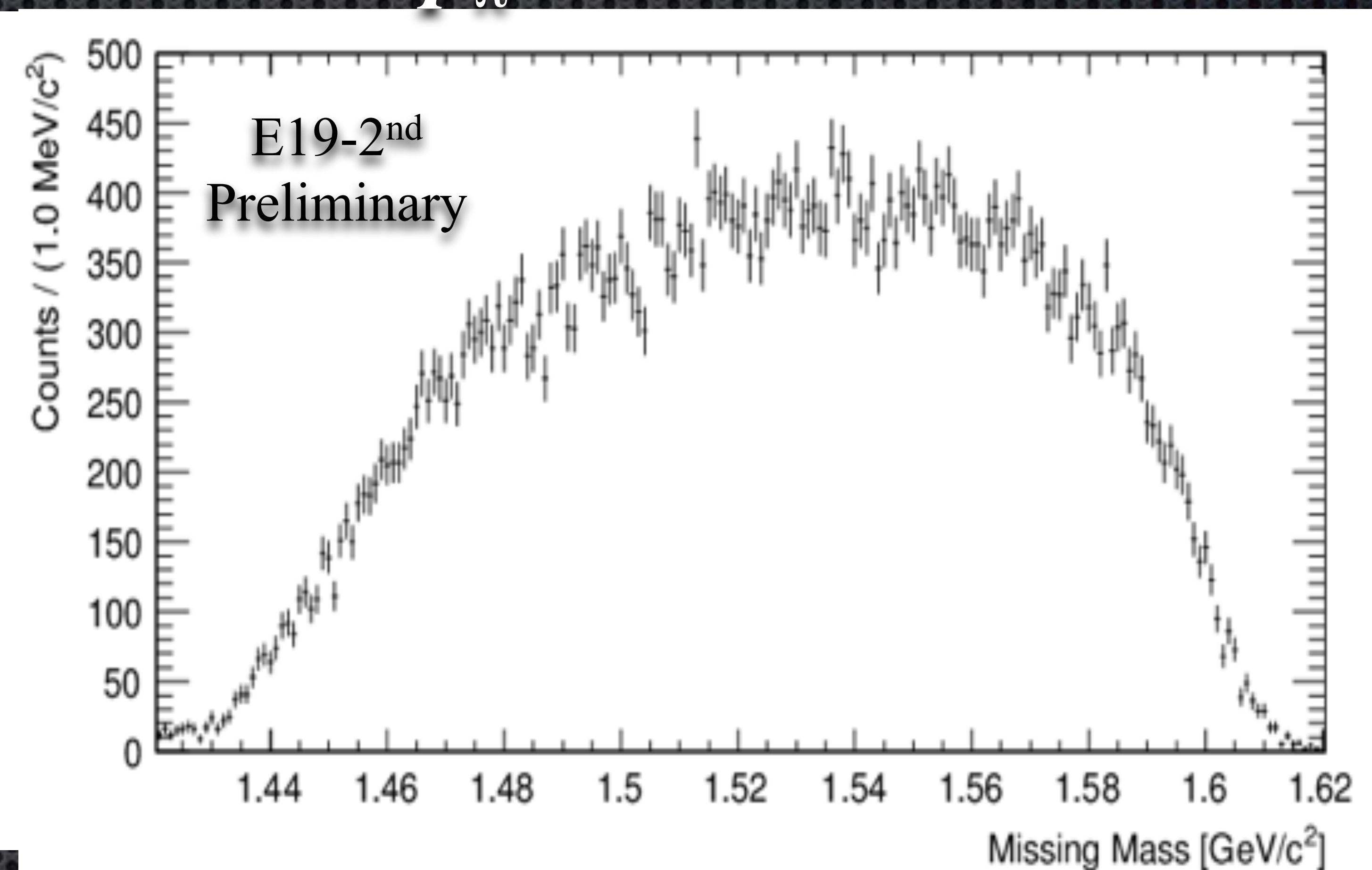
$$\pi^- + p \rightarrow K^- + X$$

$p_\pi = 1.92$ GeV/c



Shirotori et al., PRL 109, 132002 (2012).

$p_\pi = 2.01$ GeV/c



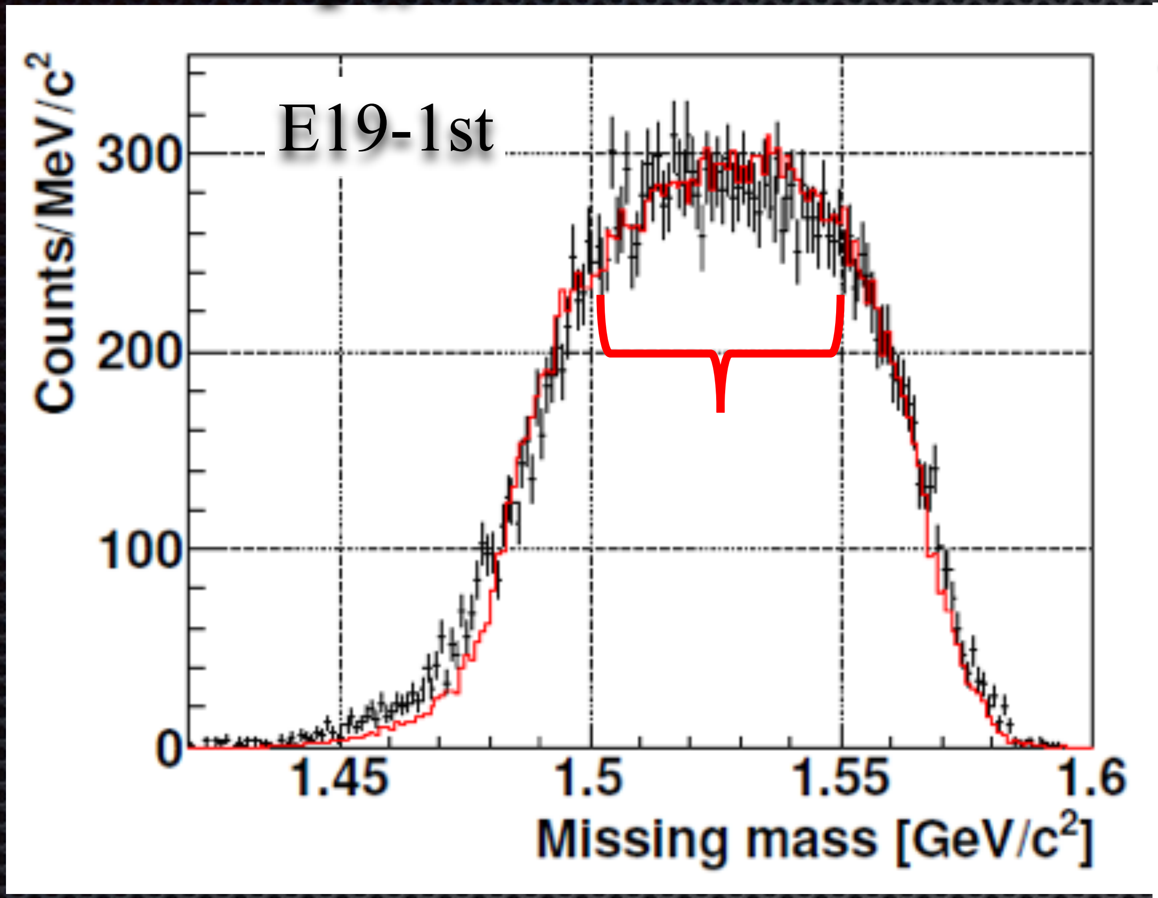
Moritsu et al., PRC 90, 035205 (2014).

- Missing mass of (π,K) @ scattering angle: 2—15 deg (Lab)
- No peak structure was observed.
- 2nd run has wider acceptance than 1st run.

Results

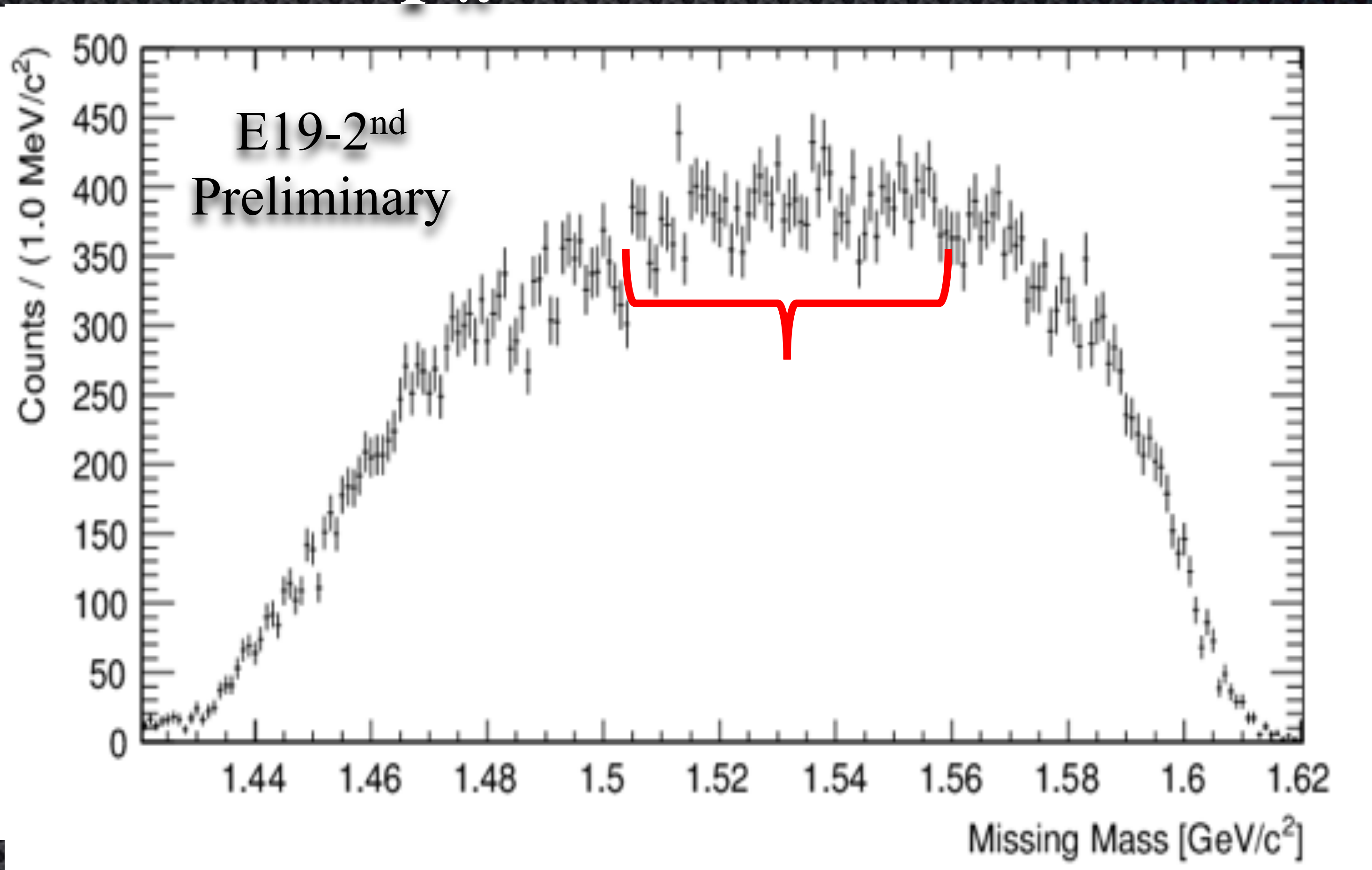
$$\pi^- + p \rightarrow K^- + X$$

$p_\pi = 1.92$ GeV/c



Shirotori et al., PRL 109, 132002 (2012).

$p_\pi = 2.01$ GeV/c



Moritsu et al., PRC 90, 035205 (2014).

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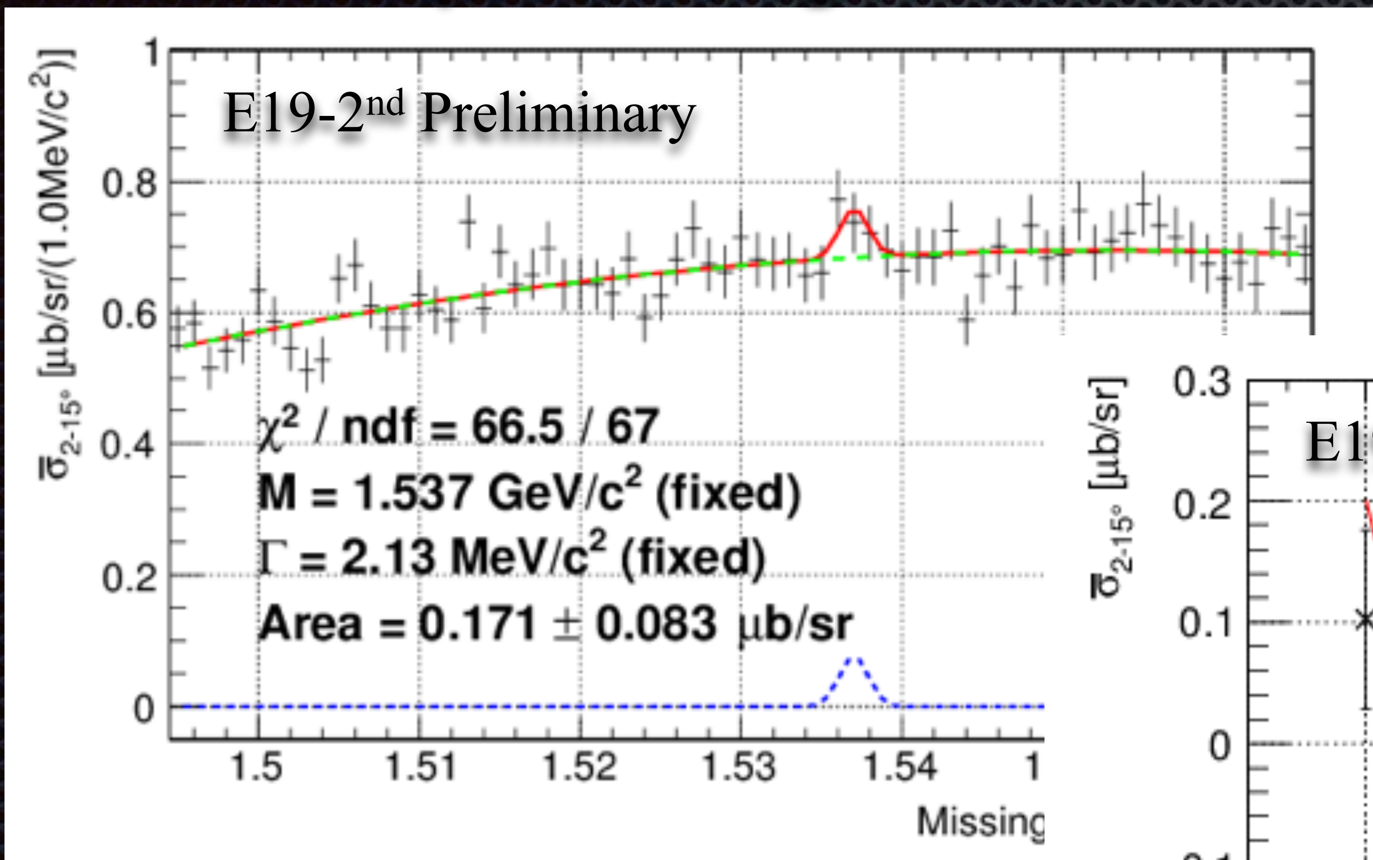
Upper limit for Θ^+ production cross section

An example of fitting result

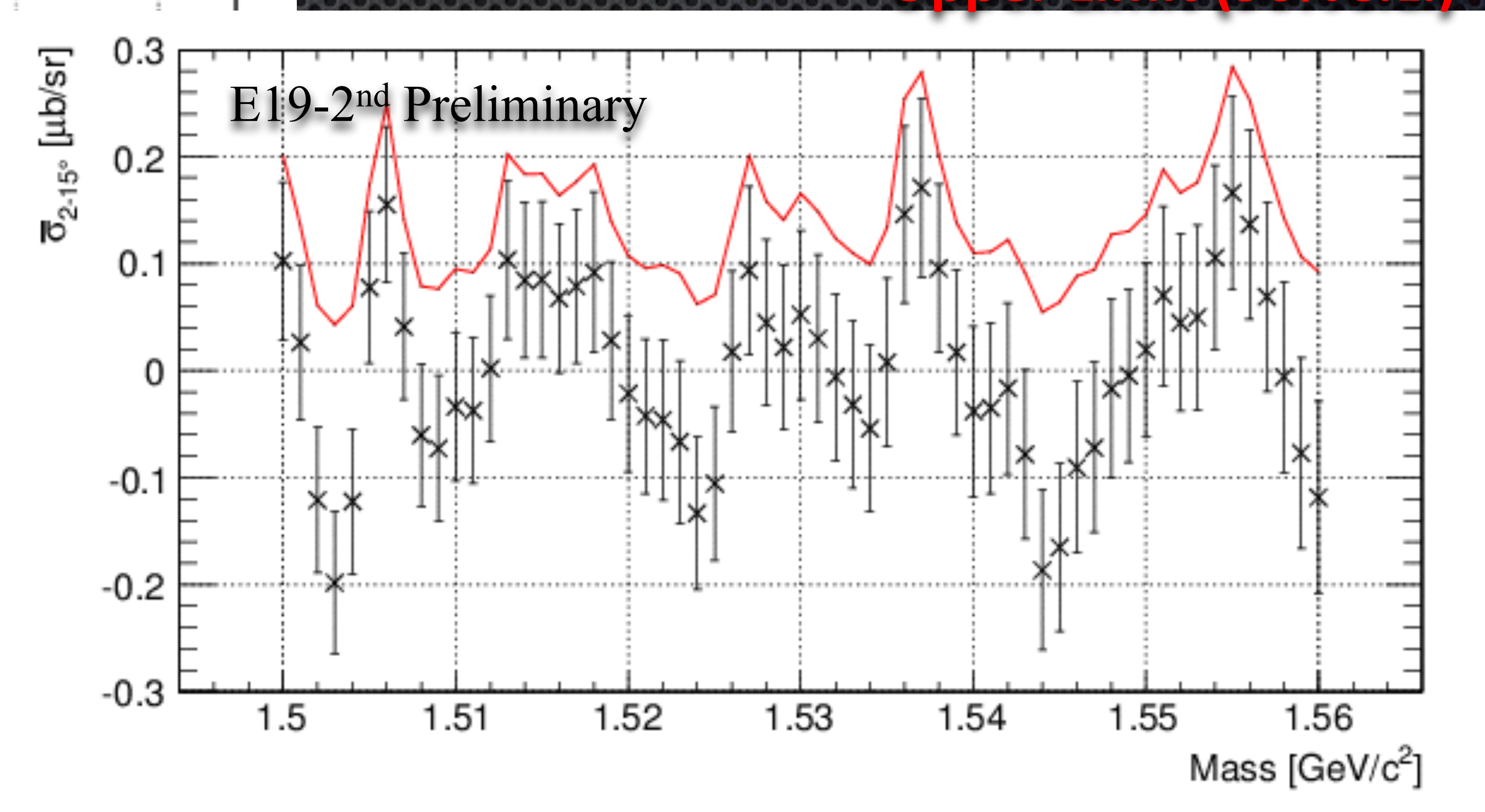


Signal: Gaussian with fixed experimental width.

B.G.: 2nd order polynomial

Fitting results of each mass

Upper Limit (90%C.L.)



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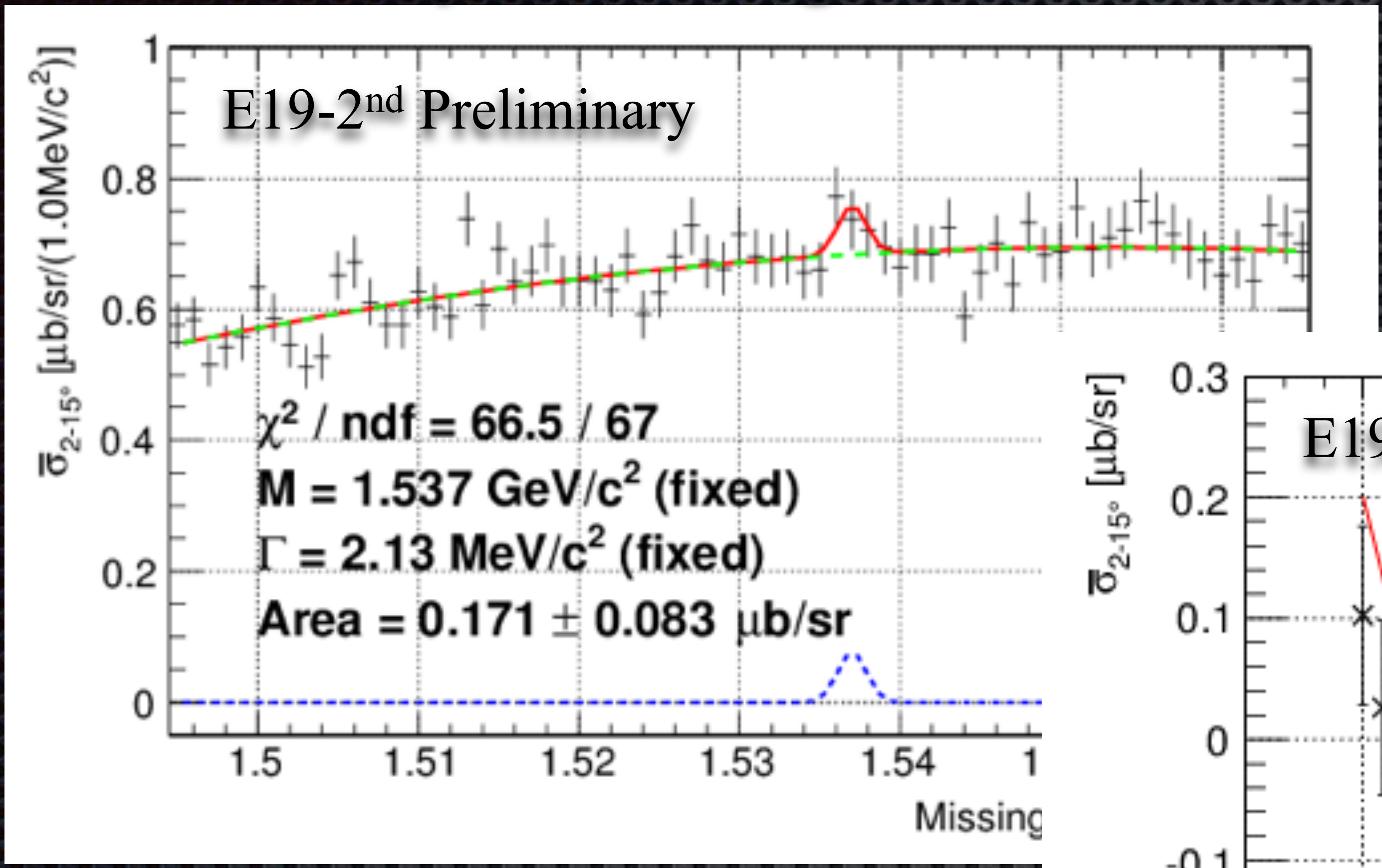

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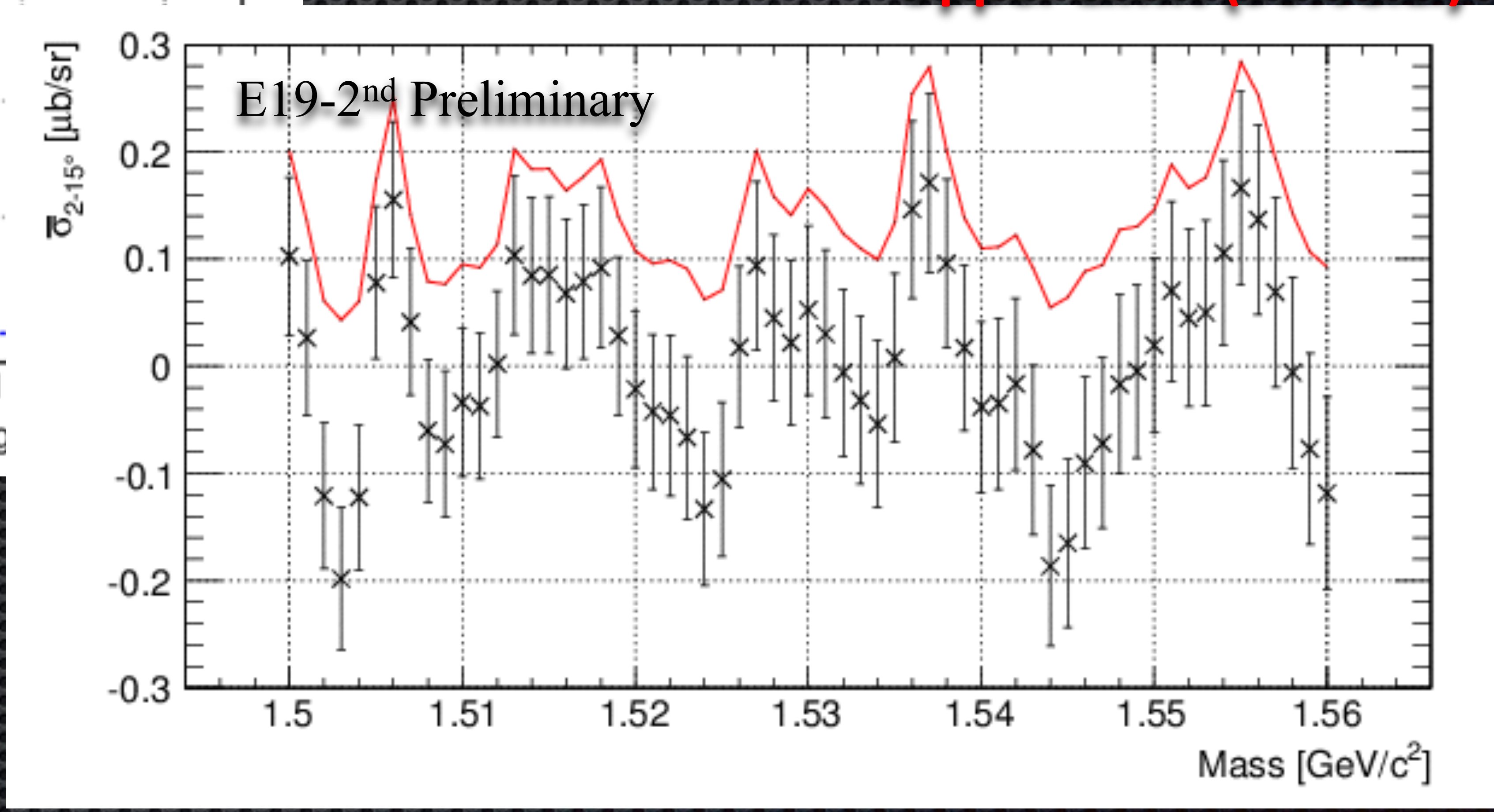


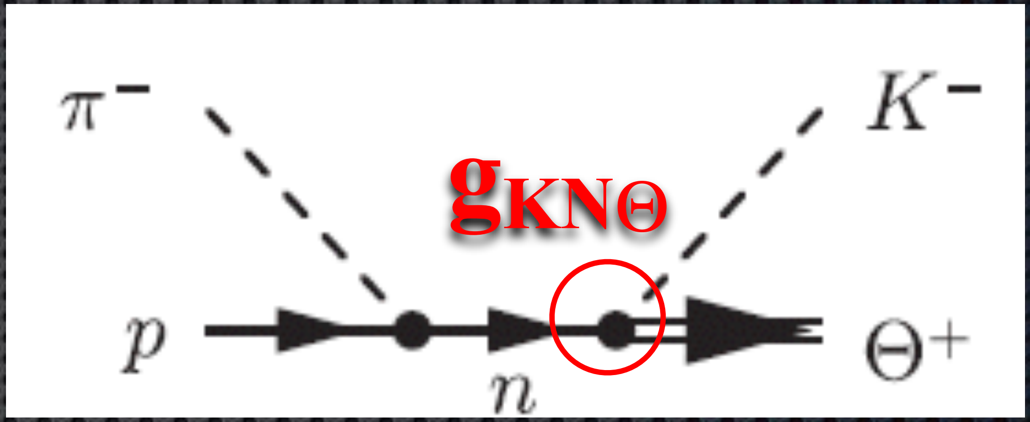
- ☐ Upper limit for differential cross section averaged from 2 to 15 deg:

  < 0.28 μb/sr @ 1.50 – 1.56 GeV/c^2

- ✓ **This limit is an order of magnitude smaller than that of KEK-E522.**

Theoretical calculation of meson-induced Θ^+ production

T. Hyodo et al., PTP 128, 523 (2012).



- **Effective Lagrangian approach**
- **Less ambiguous than photoproduction**

✓ **Theoretical uncertainty**

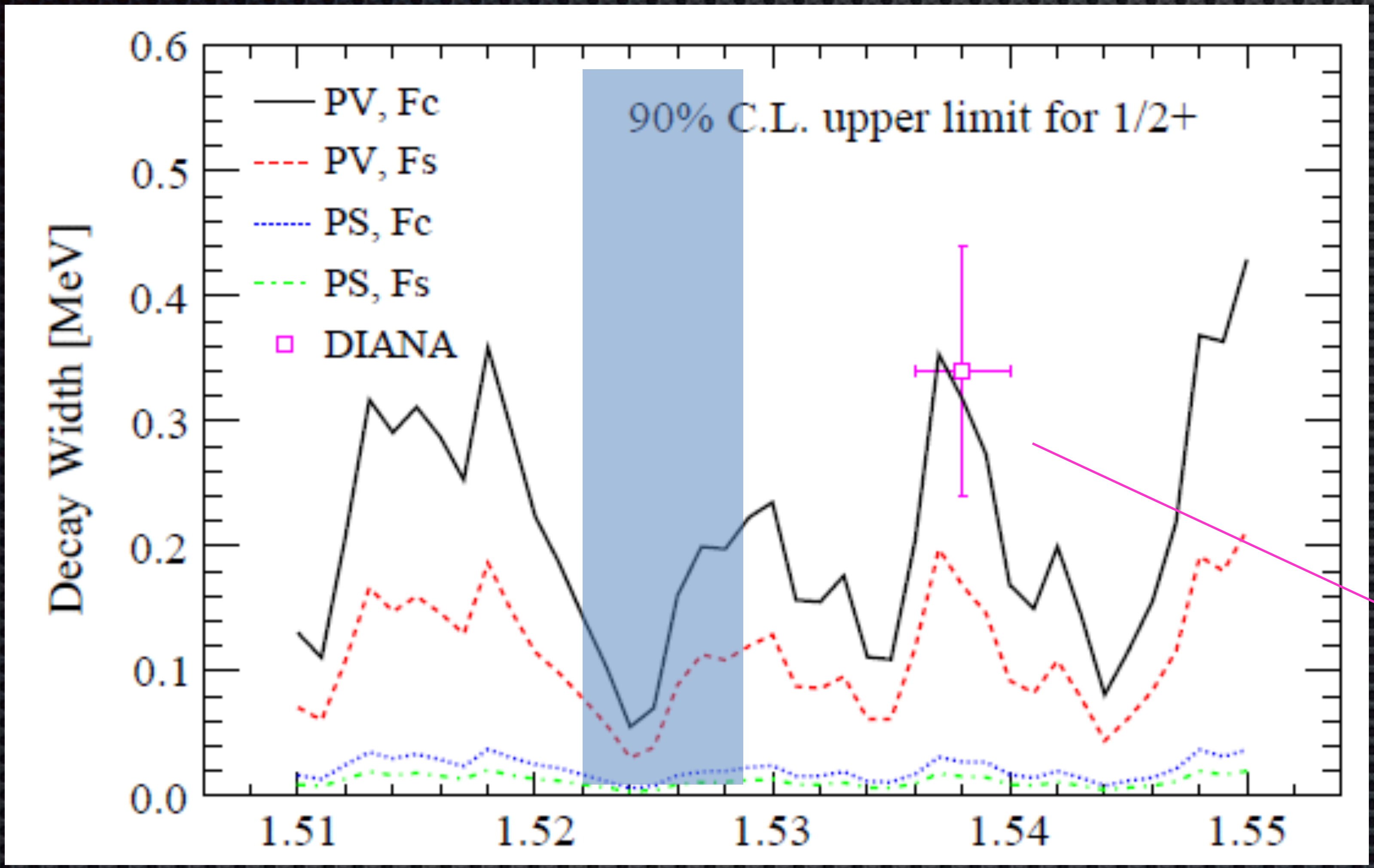
- Coupling scheme: PS/PV
- Form factor: static/covariant
- Form factor cutoff value was determined by hyperon prod.
- Θ^+ mass dependence was considered; 1.510—1.550 GeV

$\Gamma_\Theta \propto g^2_{KN\Theta} \propto \sigma$

There are some ambiguity,
But we took all variations into account
and adopted the "most conservative" case.
This is confident for "upper limit estimation".

Discussion (for ½+) comparison with other experiment

✓ **Our U.L. overcame the U.L. from Belle (Γ_Θ < 0.64 MeV).** R.Mizuk et al., PLB 632, 173 (2006)



U.L. in mass region of 1.51--1.55 GeV
→ **Γ_Θ < 0.36 MeV**

LEPS:
M = 1524±2 + 3 MeV
PRC 79, 025210 (2009).

DIANA:
M = 1538±2 MeV
Γ = 0.34±0.10 MeV
PRC 89, 045204 (2014)

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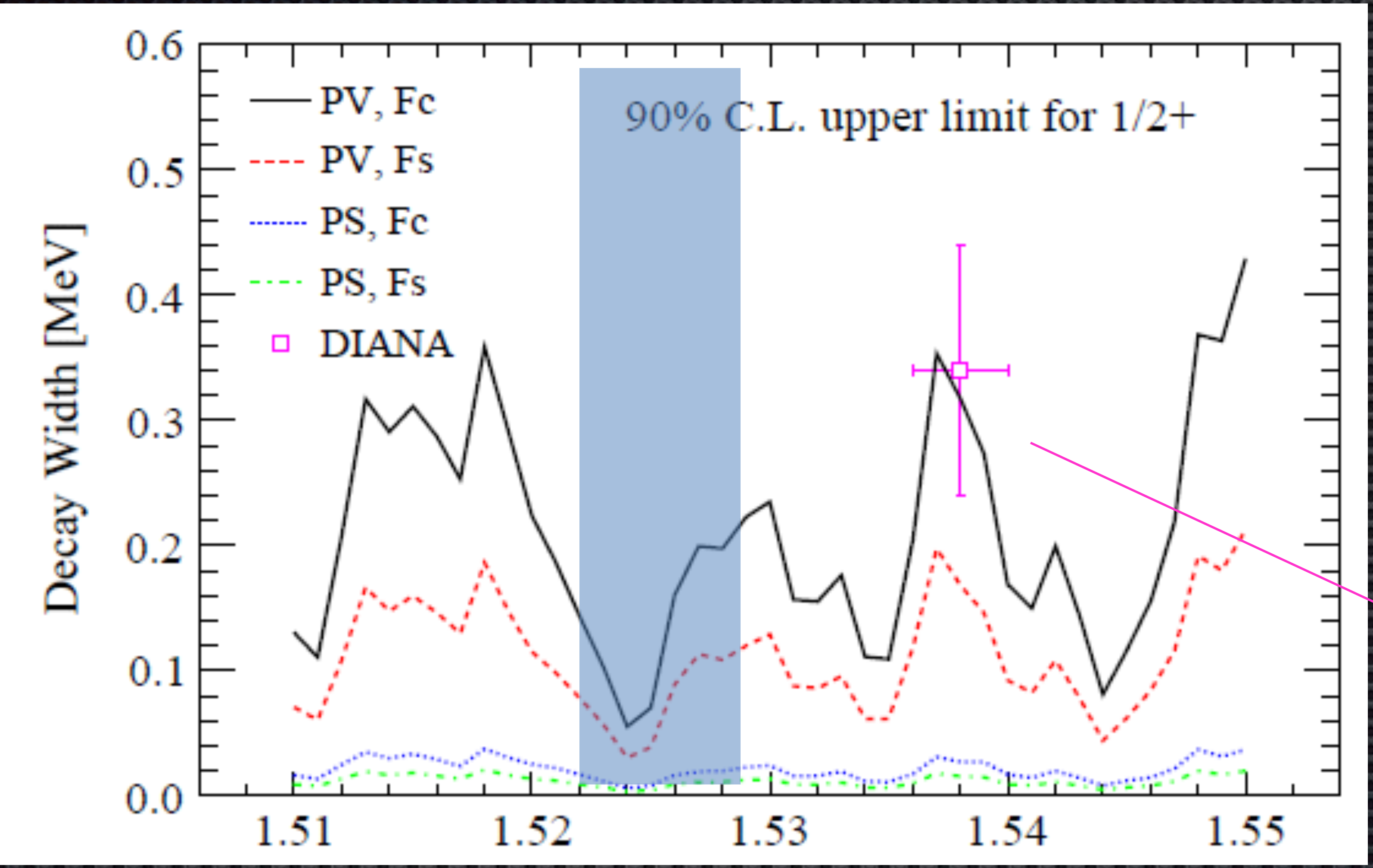

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M = 1538±2 MeV
Γ = 0.34±0.10 MeV
PRC 89, 045204 (2014)

LEPS:
M = 1524±2 + 3 MeV
PRC 79, 025210 (2009).

For DIANA region,
Our U.L. is comparable to their width.

For LEPS region, Γ < 0.22 MeV.

E27 : Search for "$K^{-}pp$" in $d(\pi^{+},K^{+})$

Spokesperson : T. Nagae (Kyoto)

Y. Ichikawa et al., PTEP (2014) 101D03.

Y. Ichikawa et al., PTEP (2015) 021D01.

J-PARC E27 Collaboration

Yudai Ichikawa[1,2], Tomofumi Nagae[1], Hyoungchan Bhang[3], Stefania Bufalino[4], Hiroyuki Ekawa[1,2], Petr Evtoukhovitch[5], Alessandro Feliciello[4], Hiroyuki Fujioka[1], Shoichi Hasegawa[2], Shuhei Hayakawa[6], Ryotaro Honda[7], Kenji Hosomi[2], Kenichi Imai[2], Shigeru Ishimoto[8], Changwoo Joo[3], Shunsuke Kanatsuki[1], Ryuta Kiuchi[2], Takeshi Koike[7], Harphool Kumawat[9], Yuki Matsumoto[7], Koji Miwa[7], Manabu Moritsu[10], Megumi Naruki[1], Masayuki Niiyama[1], Yuki Nozawa[1], Ryota Ota[6], Atsushi Sakaguchi[6], Hiroyuki Sako[2], Valentin Samoilov[5], Susumu Sato[2], Kotaro Shirotori[10], Hitoshi Sugimura[2], Shoji Suzuki[8], Toshiyuki Takahashi[8], Tomonori Takahashi[11], Hirokazu Tamura[7], Toshiyuki Tanaka[6], Kiyoshi Tanida[3], Atsushi Tokiyasu[10], Zviadi Tsamalaidze[5], Bidyut Roy[9], Mifuyu Ukai[7], Takeshi Yamamoto[7] and Seongbae Yang[3]

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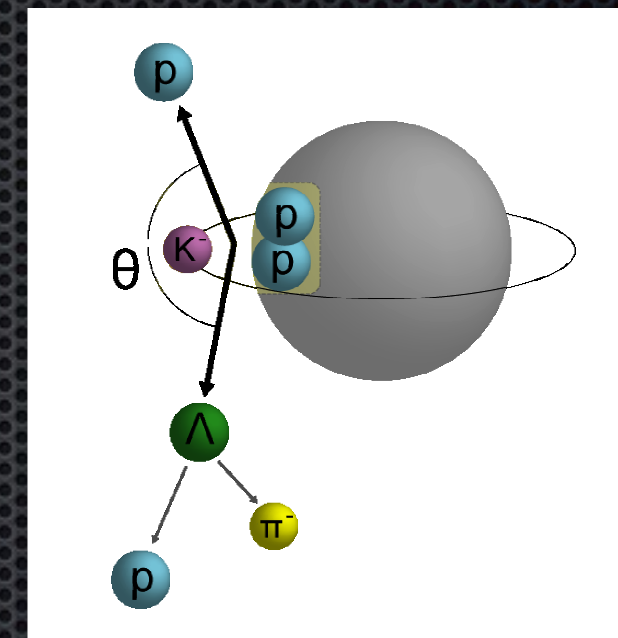
[9] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, India*
[10] *Research Center for Nuclear Physics, Osaka 567-0047, Japan*
[11] *RIKEN, Saitama 351-0198, Japan*

$K^{-}pp$

- $\overline{KN}$: attraction in Isospin=0
  - Kaonic hydrogen X-ray ; SIDDHARTA,
    M.Bazzi et al., NPA 881 (2012) 88-97.
  - Low-energy scattering measurements
  - Λ(1405) below the $K^{-}p$ threshold
- $K^{-}pp$: Y=1, I=1/2, $J^{\pi}=0^{-}$

Experiments on $K^{-}pp$

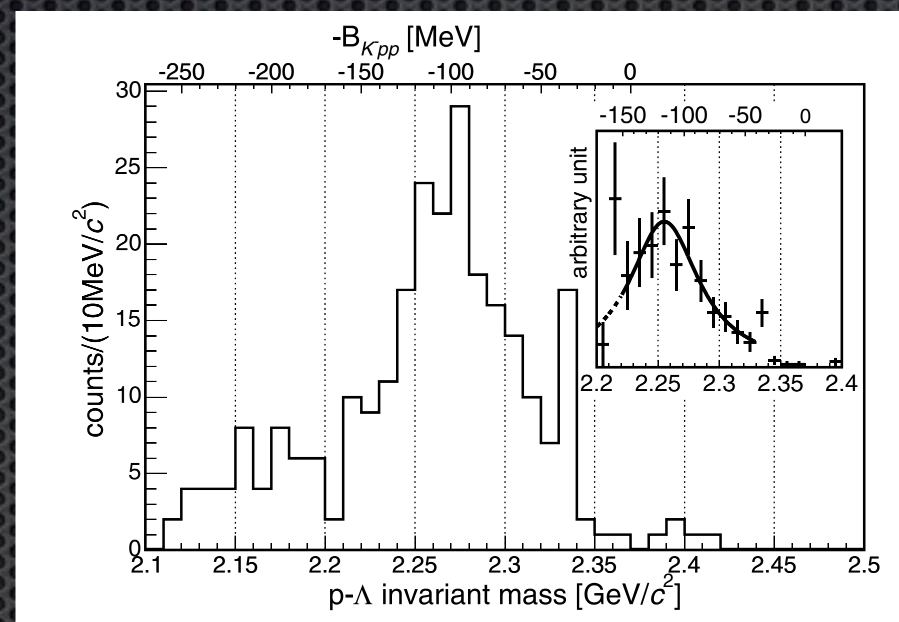
M. Agnello et al., PRL94, (2005) 212303



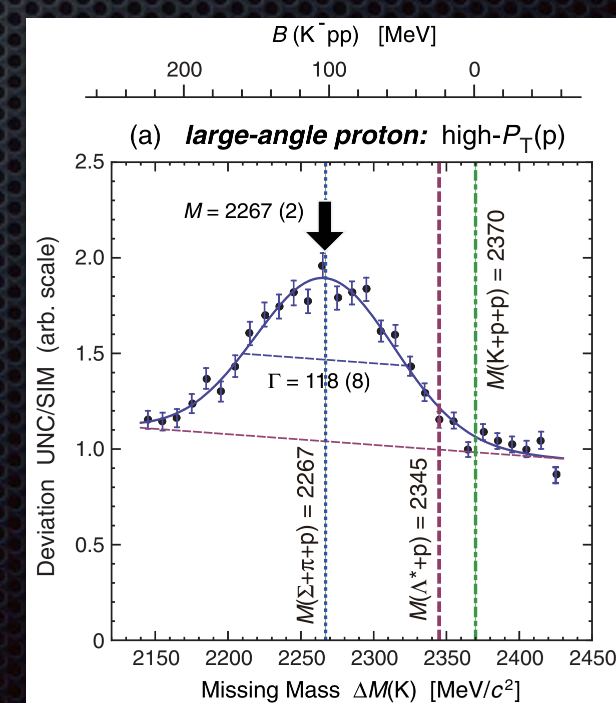
- First evidence of $K^{-}pp$ with ^{6}Li+^{7}Li+^{12}C by FINUDA

B=115+6/-5+3/-4 MeV

Γ= 67+14/-11+2/-3 MeV



- DISTO data: p+p→$K^{-}pp$ + K^{+} at 2.85 GeV
  - M=2267±3±5 MeV/c^{2}
  - Γ= 118±8±10 MeV



T. Yamazaki et al., PRL 104 (2010) 132502.
P. Kienle et al., Eur. Phys. J. A 48 (2012) 183.

Theoretical work on $K^{-}pp$

- $K^{-}pp$ does exist !!

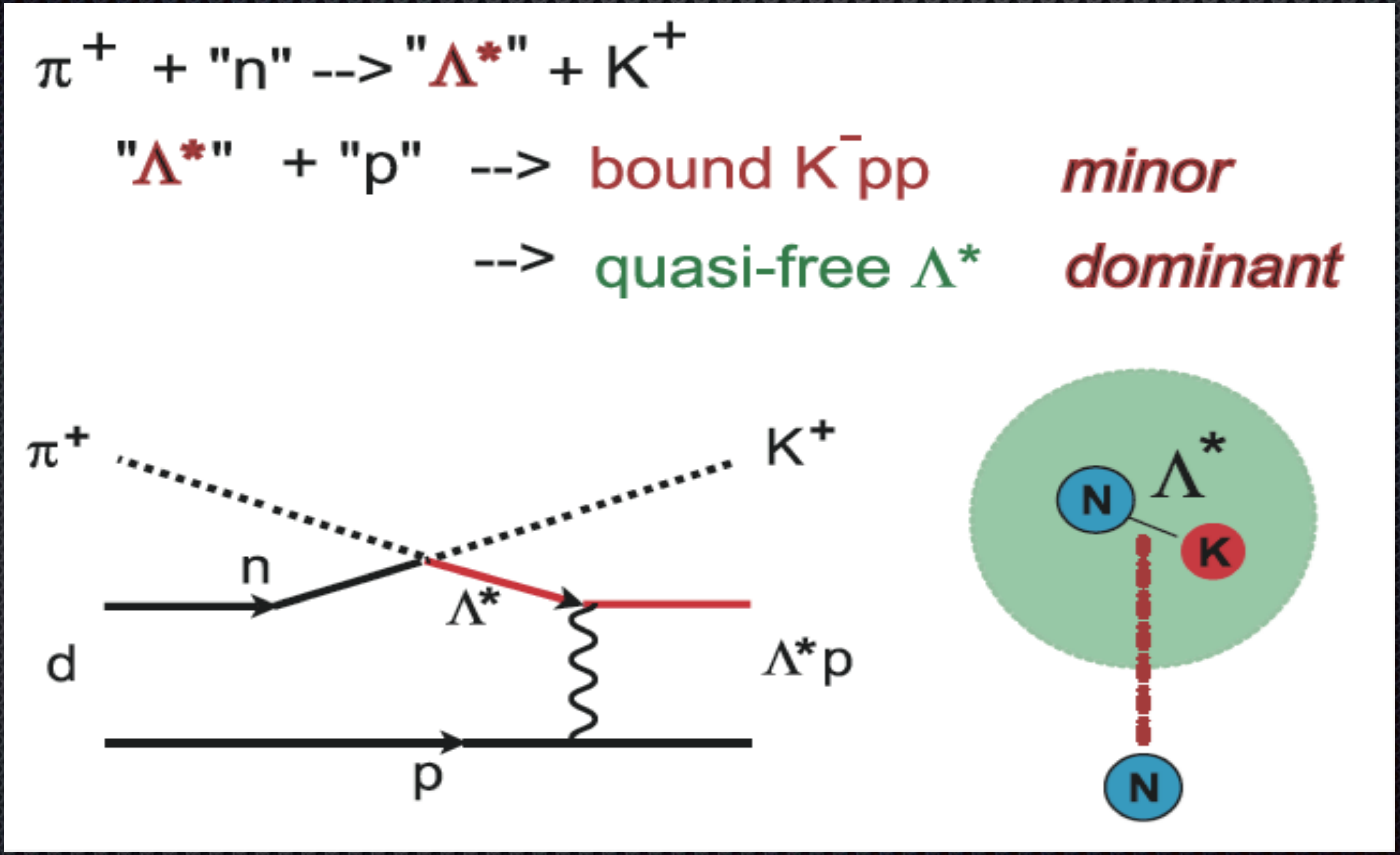
...but maybe broad (consistent with EXPs)

(MeV)	ATMS Yamazaki & Akaishi, PLB535 (2002) 70.	Faddeev Shevchenko, Gal, Mares, PRL98 (2007) 082301.	Faddeev Ikeda & Sato, PRC79 (2009) 035201.	Variational Wycech & Green, PRC79 (2009) 014001.	Faddeev, Maeda, Akaishi, Yamazaki, Proc. Jpn. Acad., B, 89 (2013) 418.	Variational Dote, Hyodo, Weise, PRC79 (2009) 014003.	Faddeev Ikeda, Kamano, Sato, PTP124 (2010) 533.	Faddeev Barnea, Gal, Liverts, PLB 712 (2012) 132.
B	48	50-70	60-95	40-80	51.5	17-23	9-16	16
Γ	61	90-110	45-80	40-85	61	40-70	34-46	41

- FSI effects ? ; V.K. Magas et al., PRC 74 (2006) 025206.
- $\Lambda^{*}N$ bound state ? ; T. Uchino et al., NPA 868-869 (2011) 53.

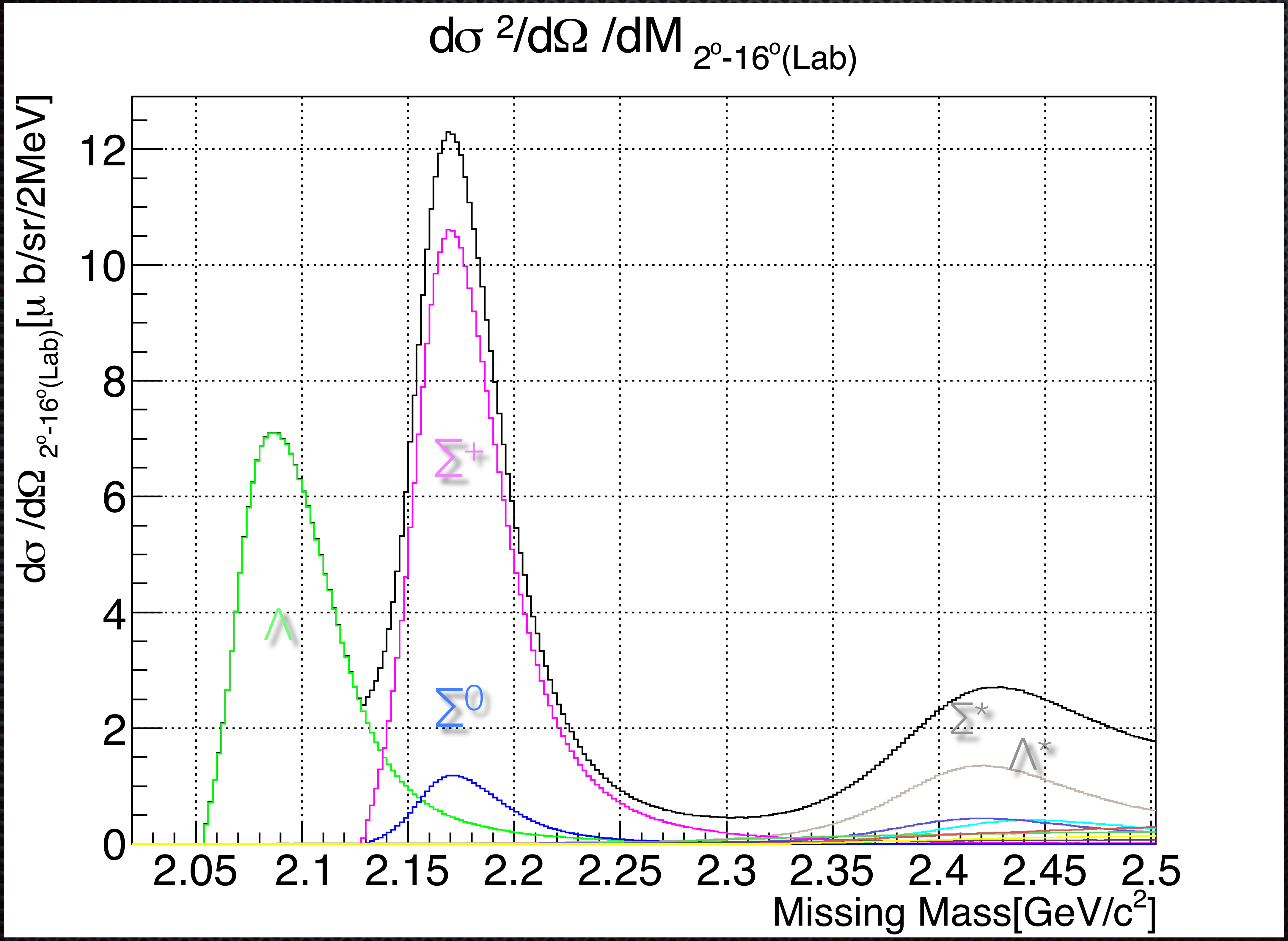
E27: *d*(π^+,K^+) reaction

1.69 GeV/c

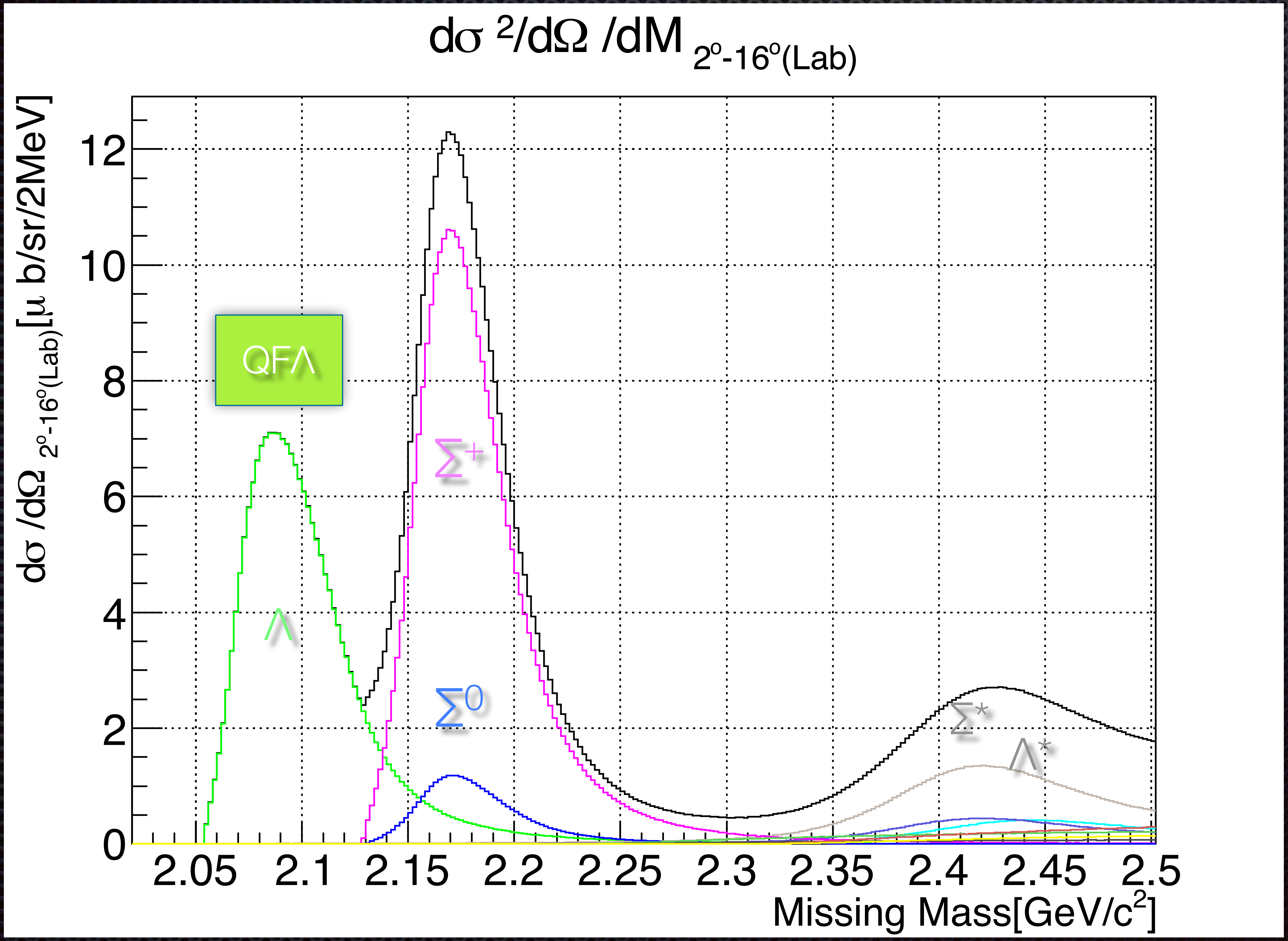


Yamazaki & Akaishi, Phys. Rev. C76 (2007) 045201.

d(π^+,K^+) inclusive spectrum; in simulation



d(π⁺,K⁺) inclusive spectrum; in simulation



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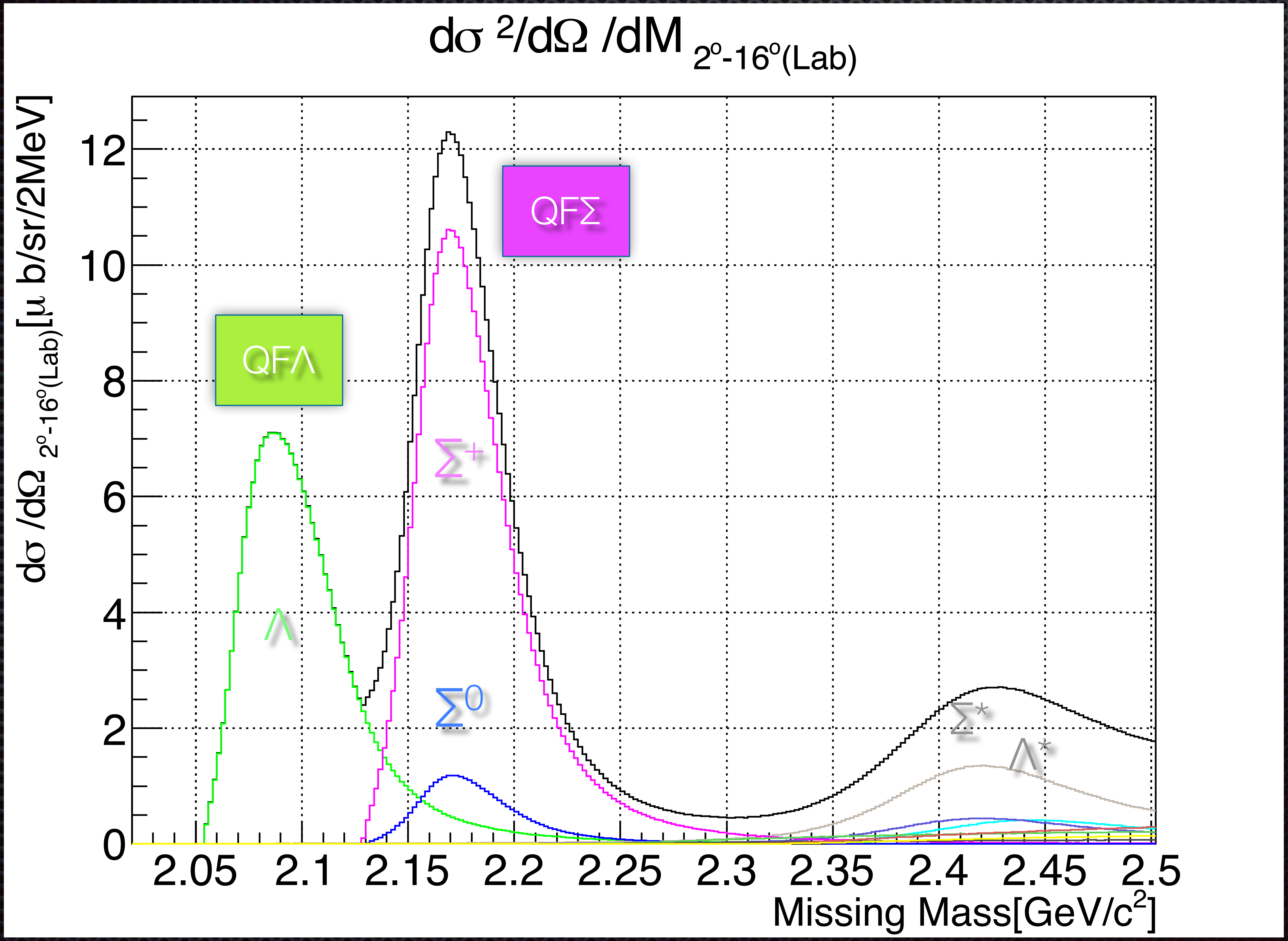

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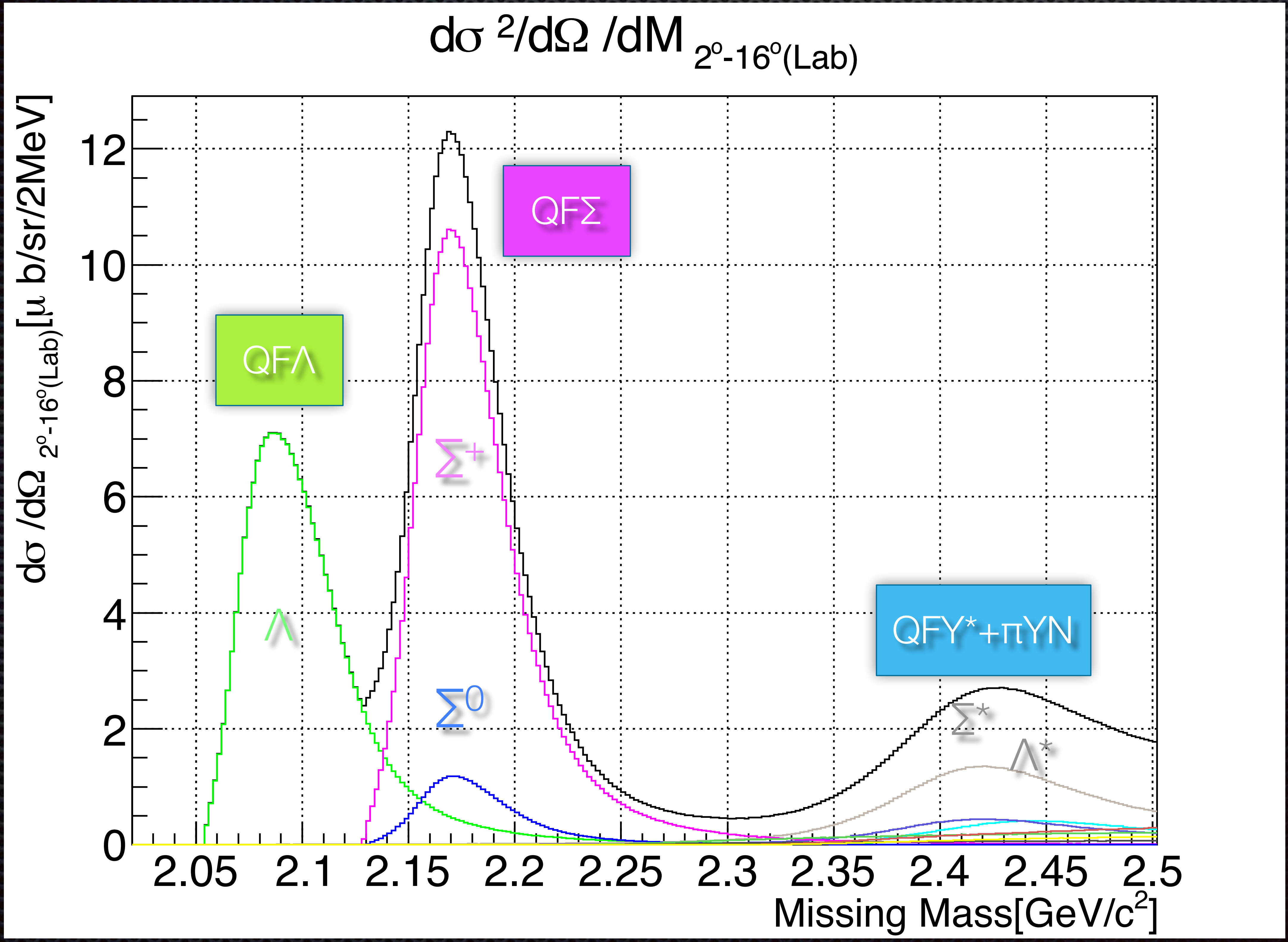
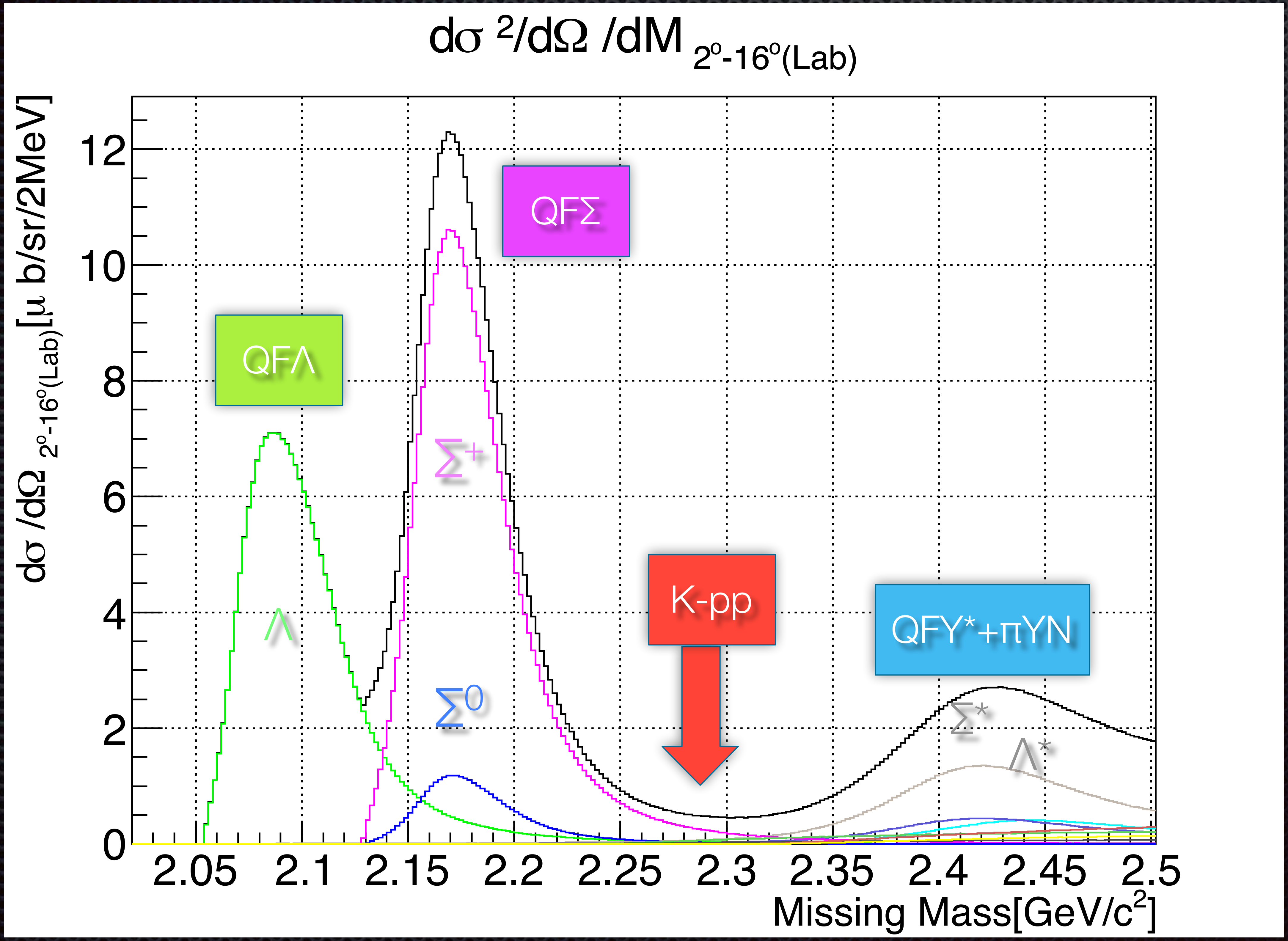
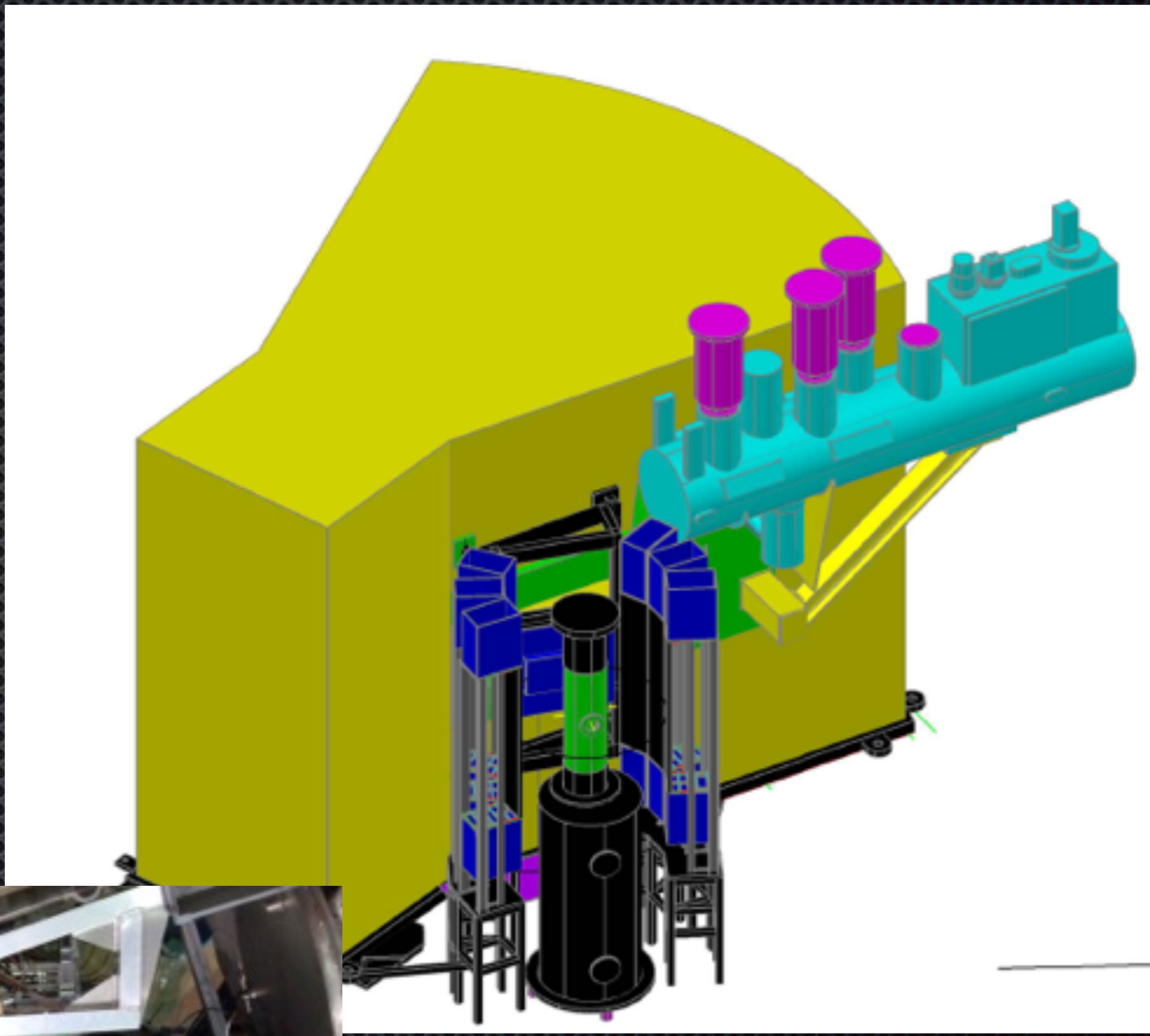


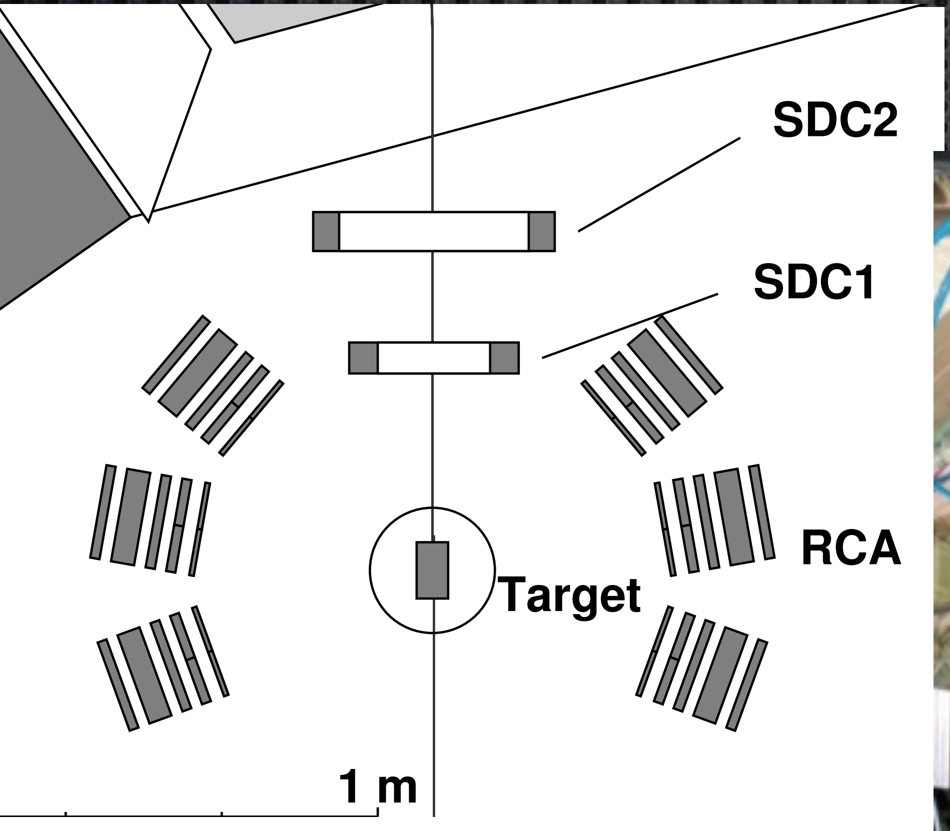
$d(\pi^+,K^+)$ inclusive spectrum; in simulation

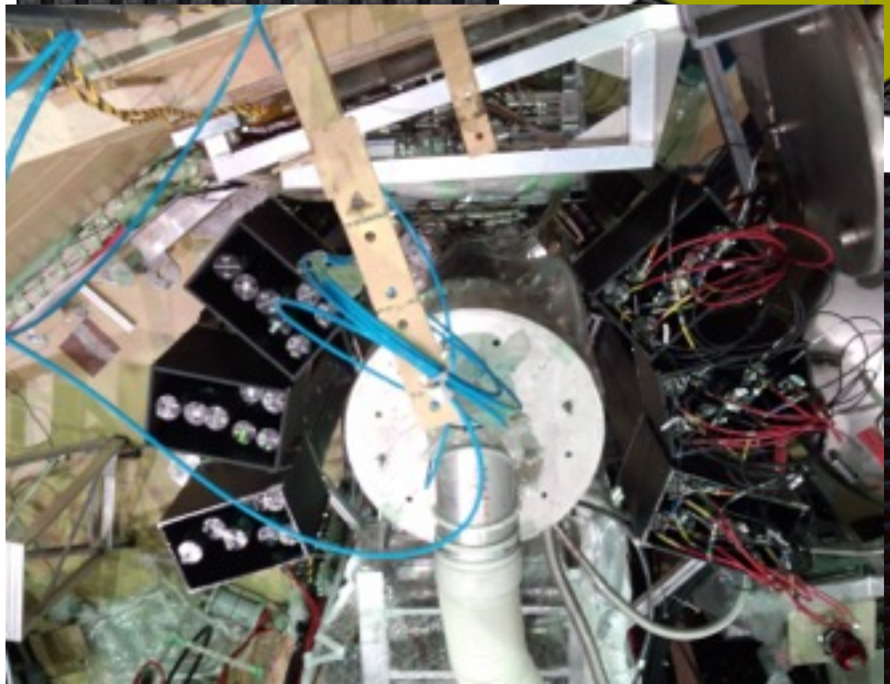


Range Counter System for E27

- 5 layers (1+2+2+5+2cm) of plastic scinti.
- 39 - 122 deg. (L+R)
- 50 cm TOF



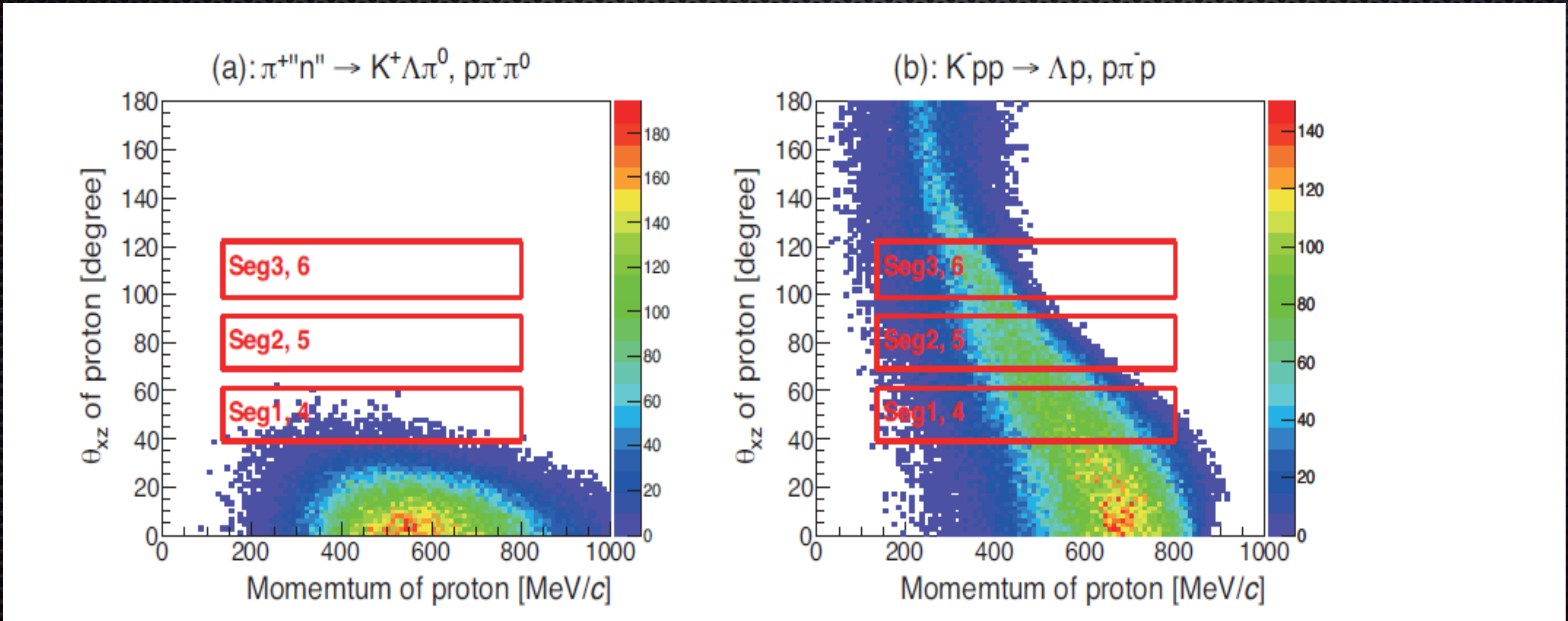




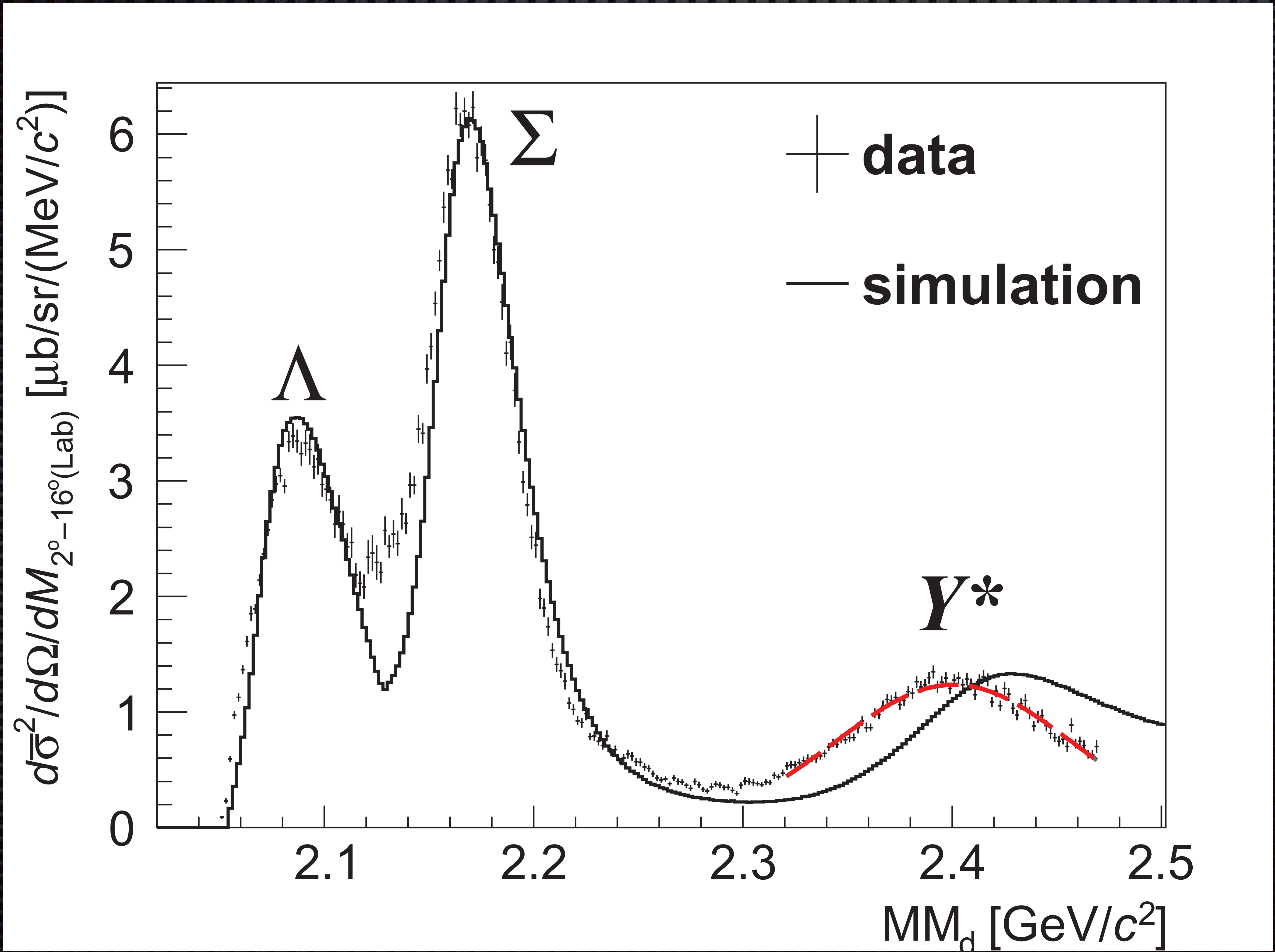
One-proton tagging

Quasifree Y productions

Decays from K-pp

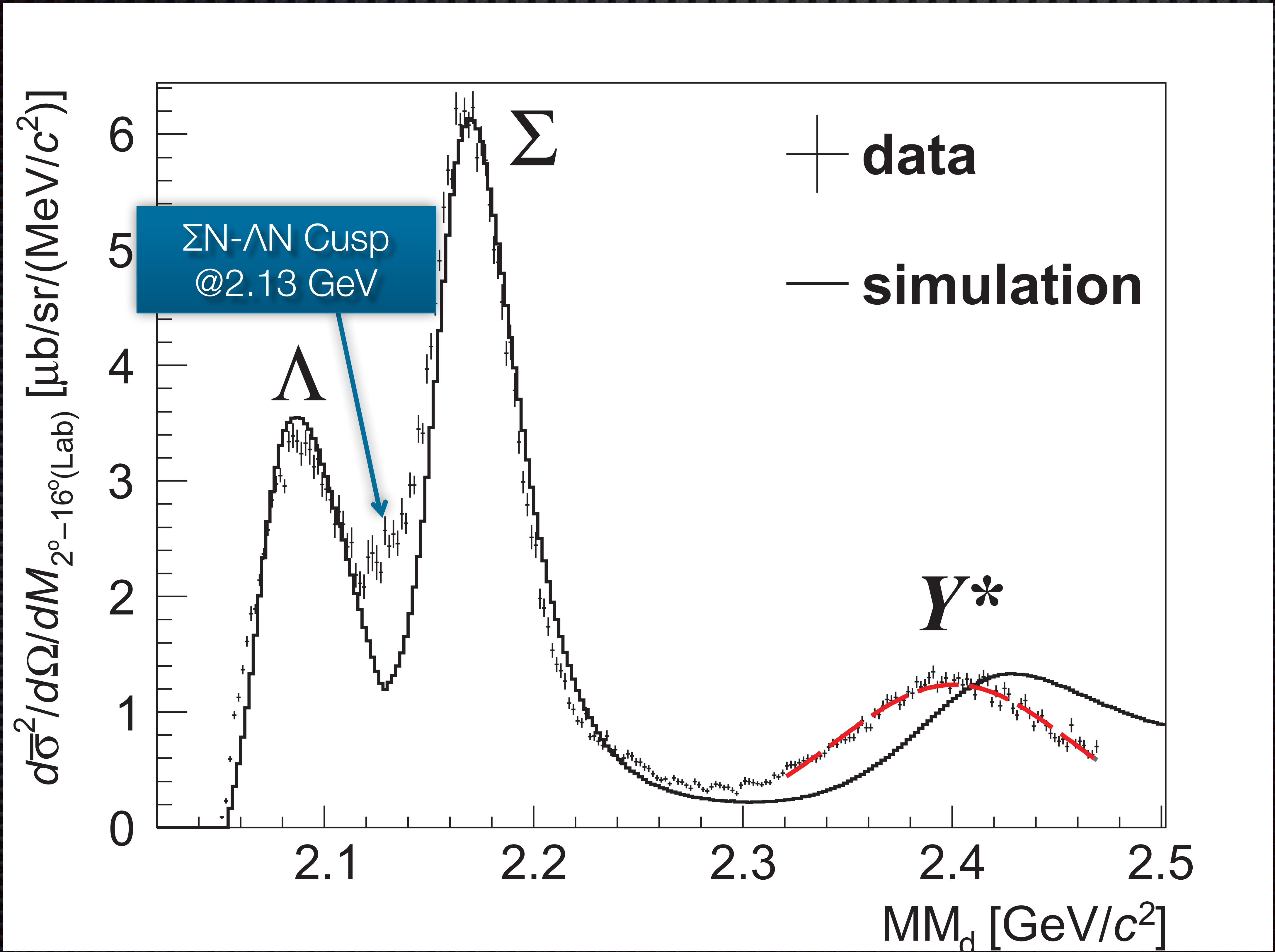


d(π⁺, K⁺) @1.69 GeV/c

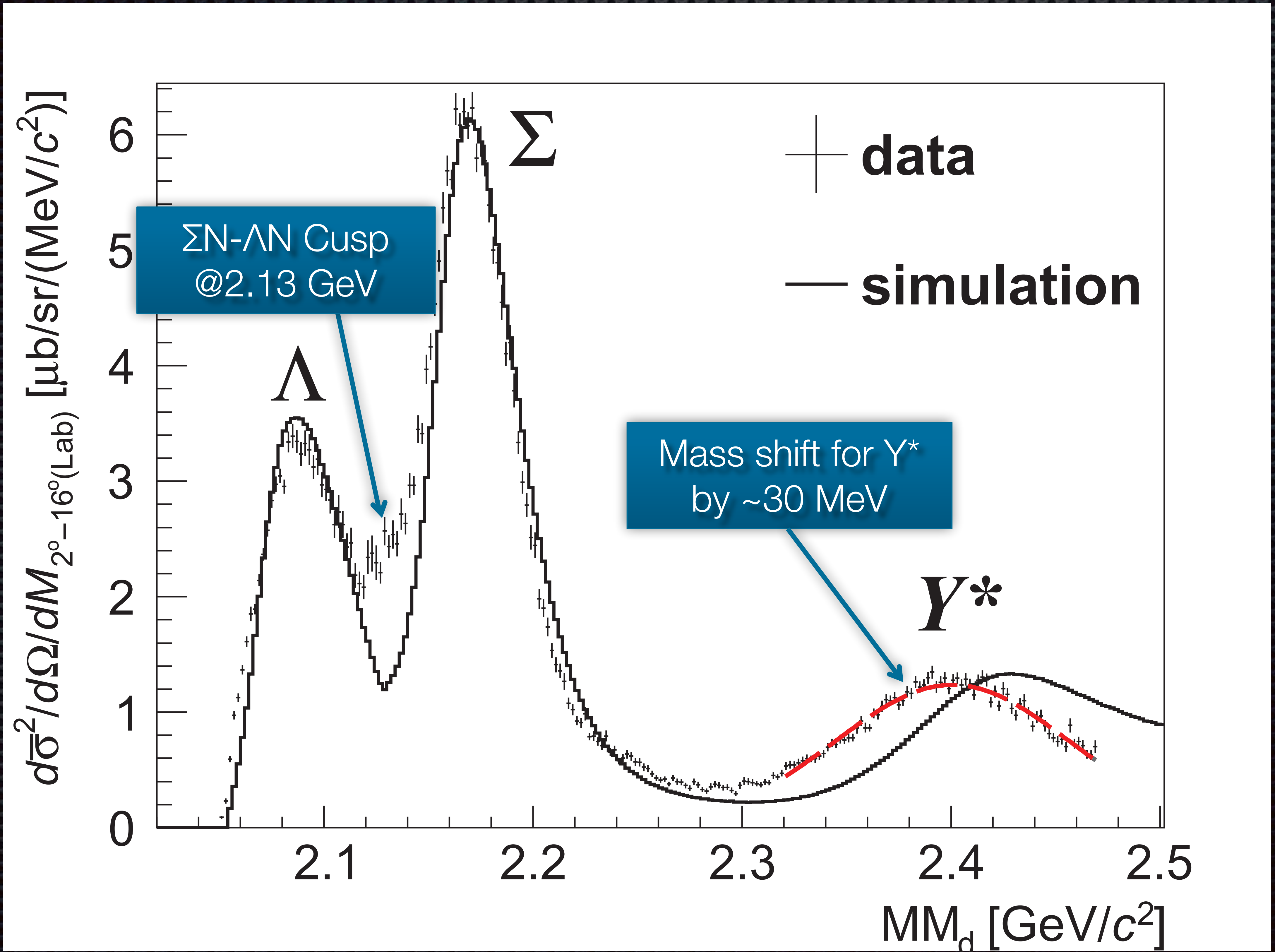


data
simulation
Λ
Σ
Y*
0
1
2
3
4
5
6
2.1
2.2
2.3
2.4
2.5
MM_d [GeV/c²]
dσ̄²/dΩ/dM_{2°−16°(Lab)} [μb/sr/(MeV/c²)]

d(π^+, K^+) @1.69 GeV/c

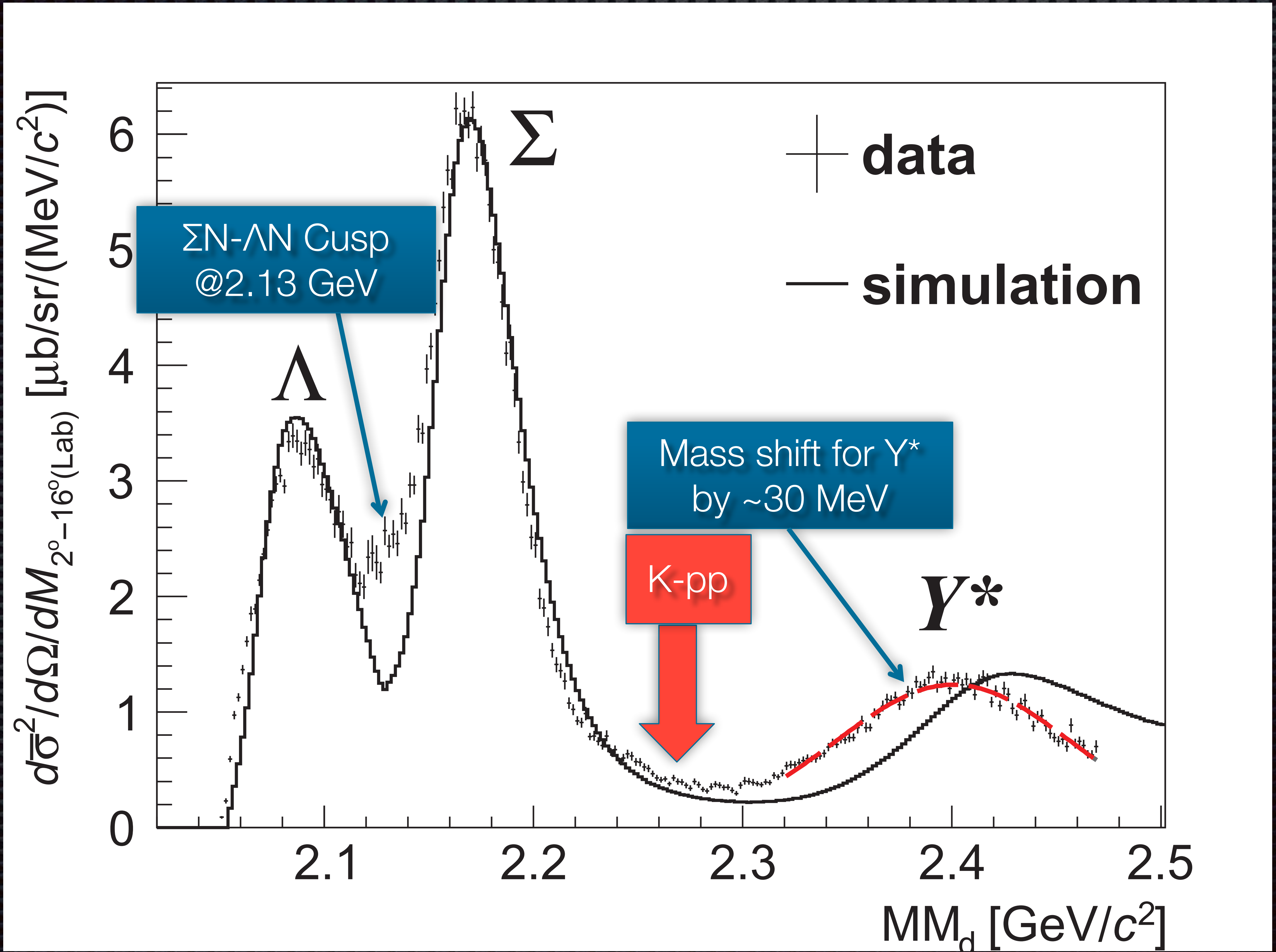


d(π⁺, K⁺) @1.69 GeV/c



Σ
data
simulation
ΣN-ΛN Cusp
@2.13 GeV
Λ
Mass shift for Y*
by ~30 MeV
Y*
$d\bar{\sigma}^2/d\Omega/dM_{2^\circ-16^\circ(\mathrm{Lab})}$ [μb/sr/(MeV/c^2)]
MM$_d$ [GeV/c^2]
0
1
2
3
4
5
6
2.1
2.2
2.3
2.4
2.5

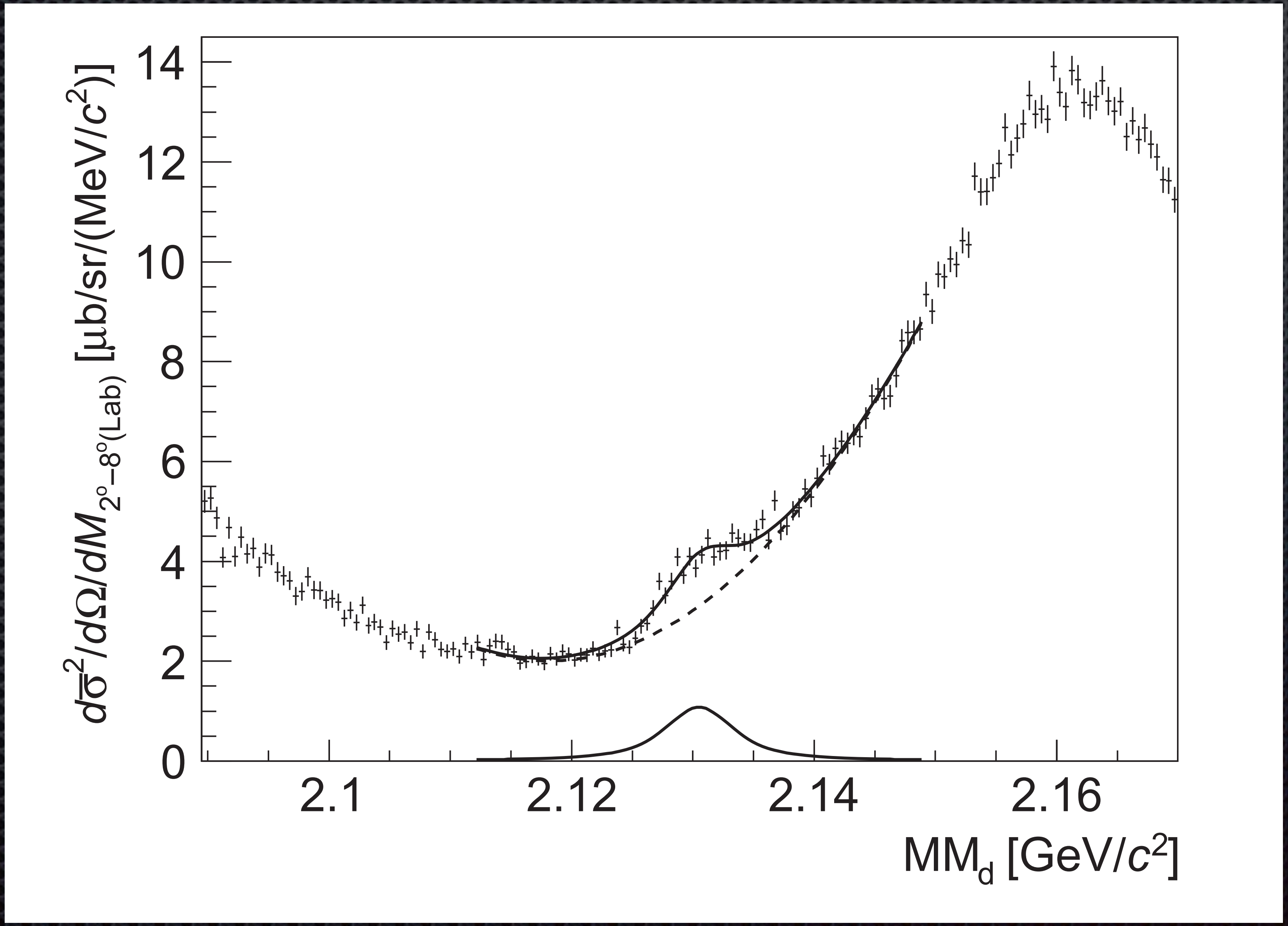
d(π⁺, K⁺) @1.69 GeV/c



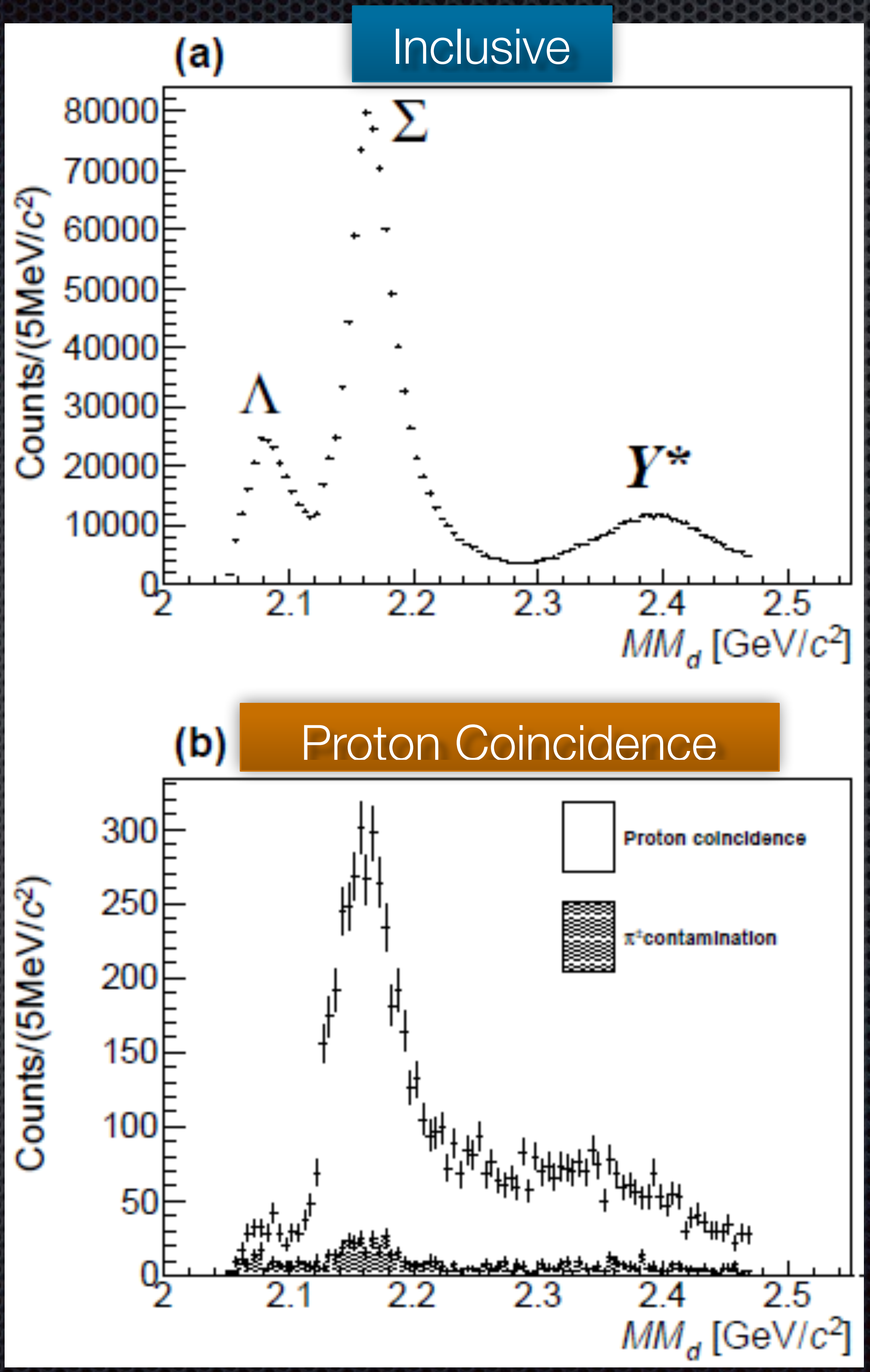
data
simulation
ΣN-ΛN Cusp
@2.13 GeV
Mass shift for Y*
by ~30 MeV
K-pp
Λ
Σ
Y*
d$\bar{\sigma}^2$/dΩ/d$M_{2°-16°(Lab)}$ [μb/sr/(MeV/c^2)]
MM$_d$ [GeV/c^2]
0
1
2
3
4
5
6
2.1
2.2
2.3
2.4
2.5

ΣN→ΛN cusp

- Peak at 2130.5±0.4±0.9 MeV
- Width = 5.3+1.4/-1.2+0.6/-0.3 MeV

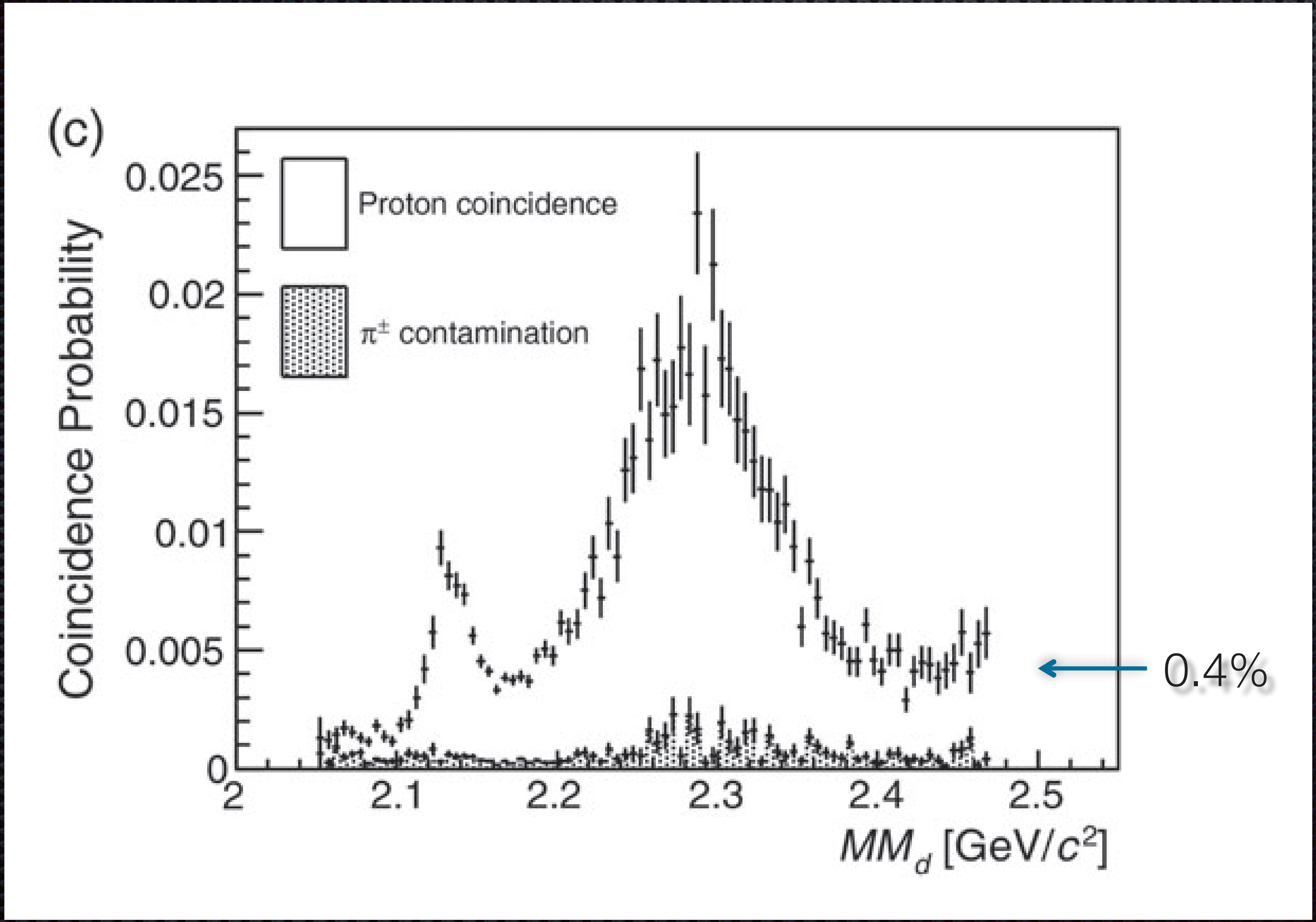


Coincidence study

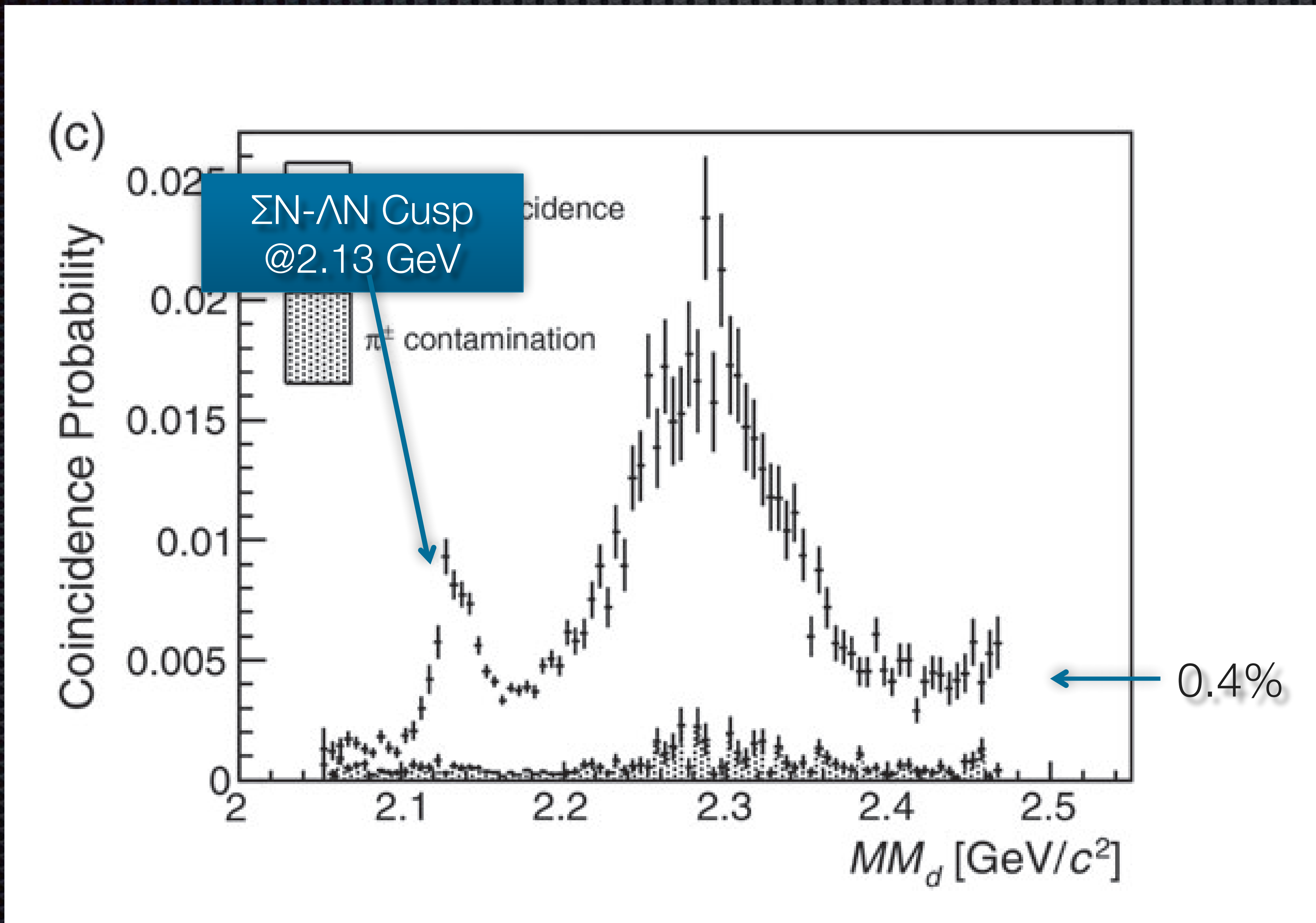


“proton”=p>250 MeV/c

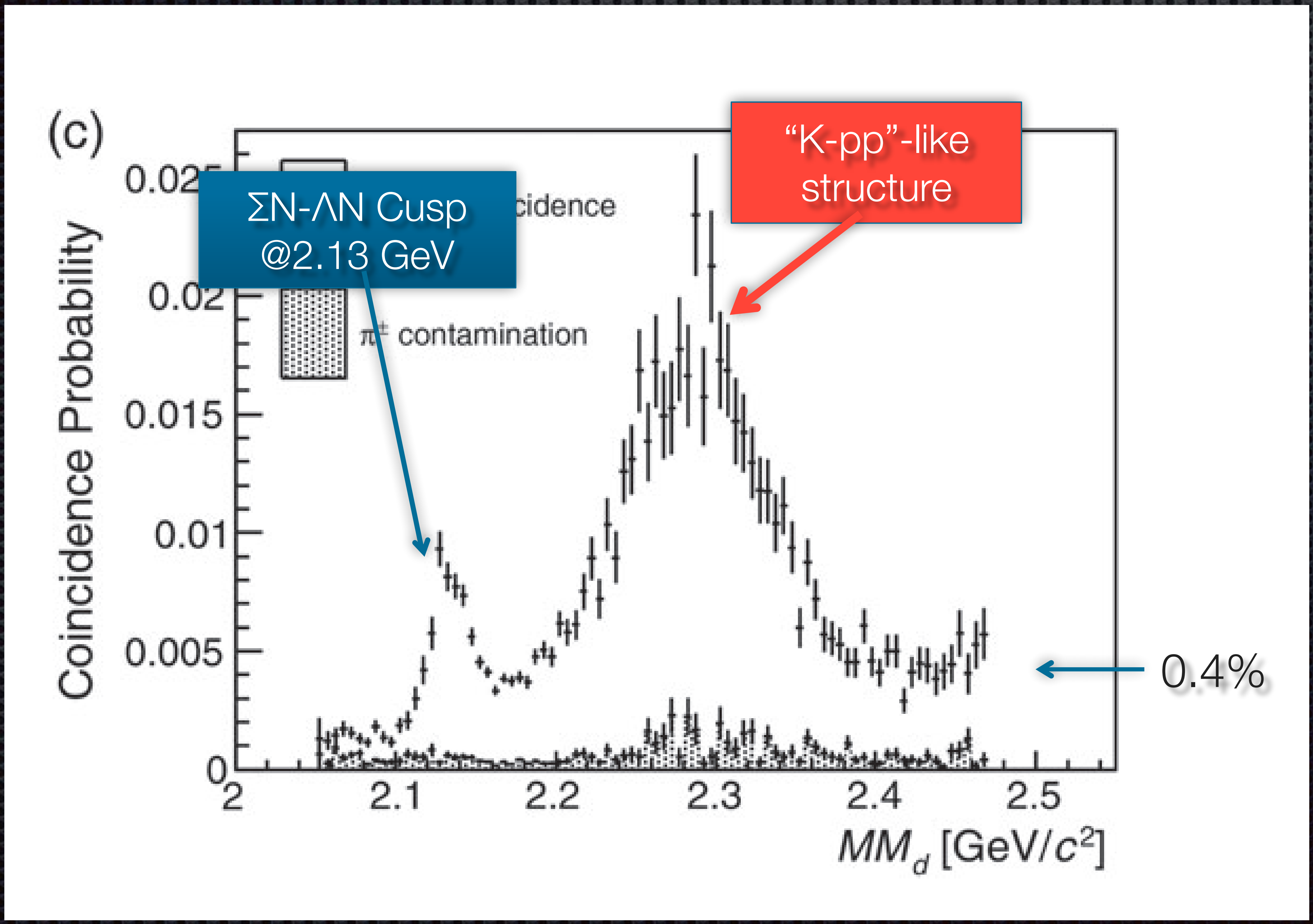
Proton Coincidence Rate



Proton Coincidence Rate



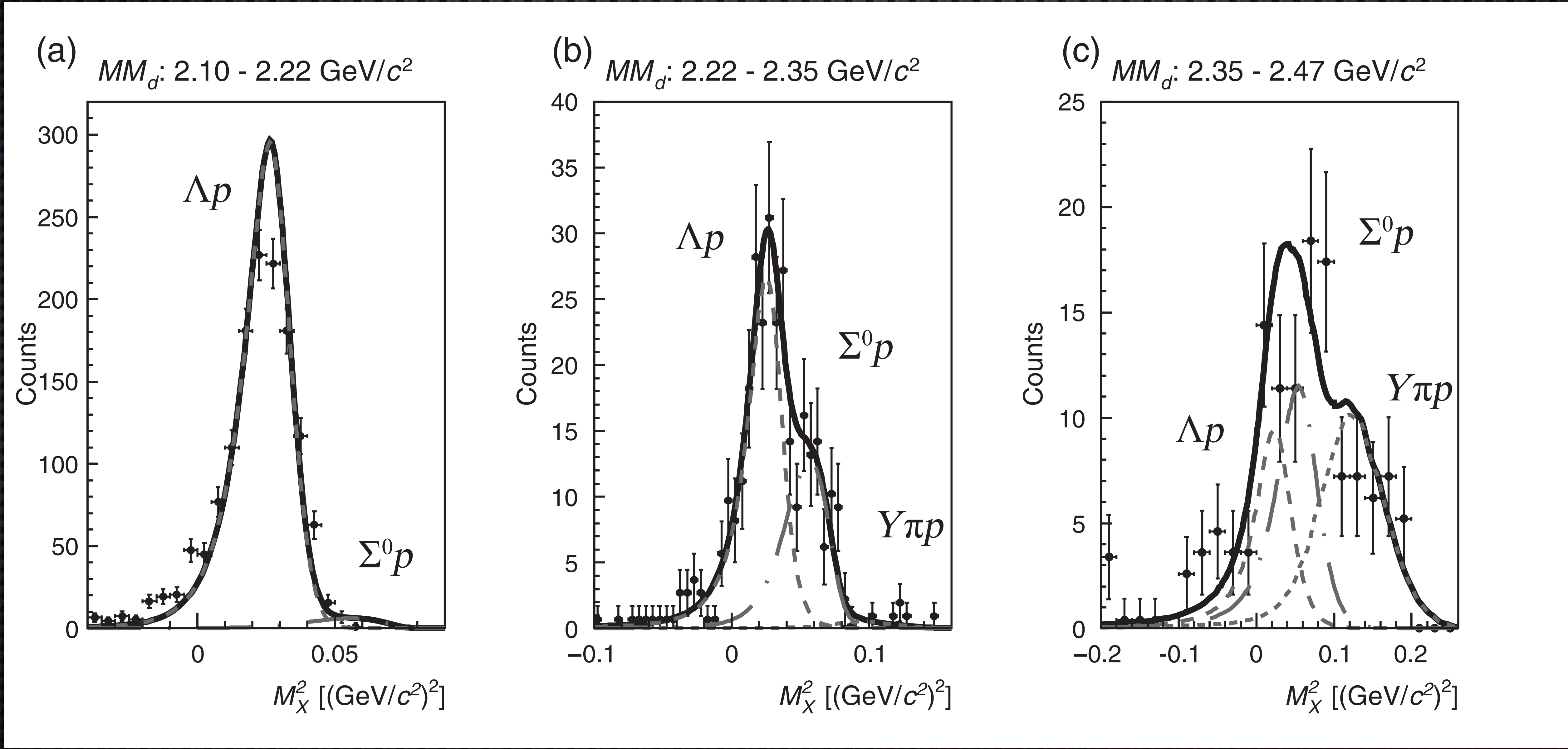
Proton Coincidence Rate



0.4%

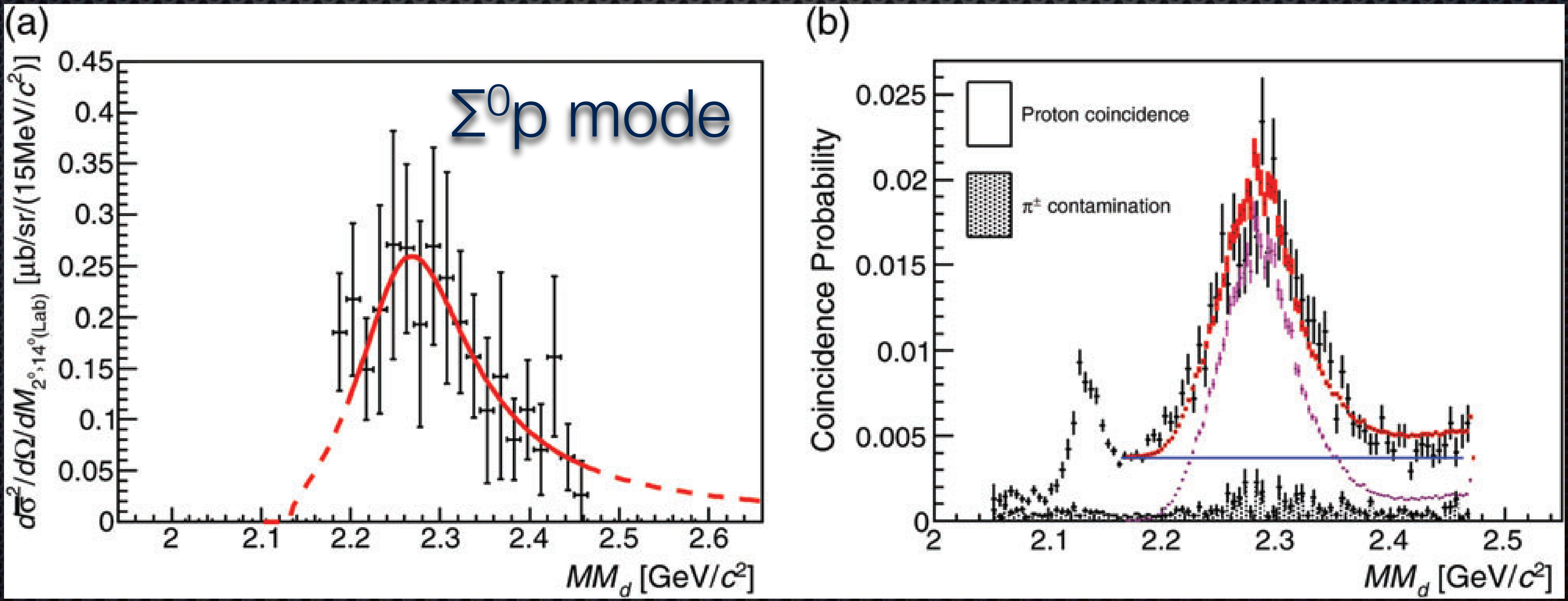
Decay modes classification with two protons

- d(π^+,K^+pp)X
  - ppX = pp-π^- for Λp mode, pp-$\pi^-\gamma$ for Σ^0p mode, pp-ππ for Yπp mode



"$K^{-}pp$"-like structure

- Mass : $2275\ ^{+17}_{-18}\ \text{(stat.)}\ ^{+21}_{-30}\ \text{(syst.)}\ \text{MeV}/c^2$
- Width : $162\ ^{+87}_{-45}\ \text{(stat.)}\ ^{+66}_{-78}\ \text{(syst.)}\ \text{MeV},$
- Binding Energy : $95\ ^{+18}_{-17}\ \text{(stat.)}\ ^{+30}_{-21}\ \text{(syst.)}\ \text{MeV}$



Experiments at New High-p beam line

E16 : ϕ meson in nuclei

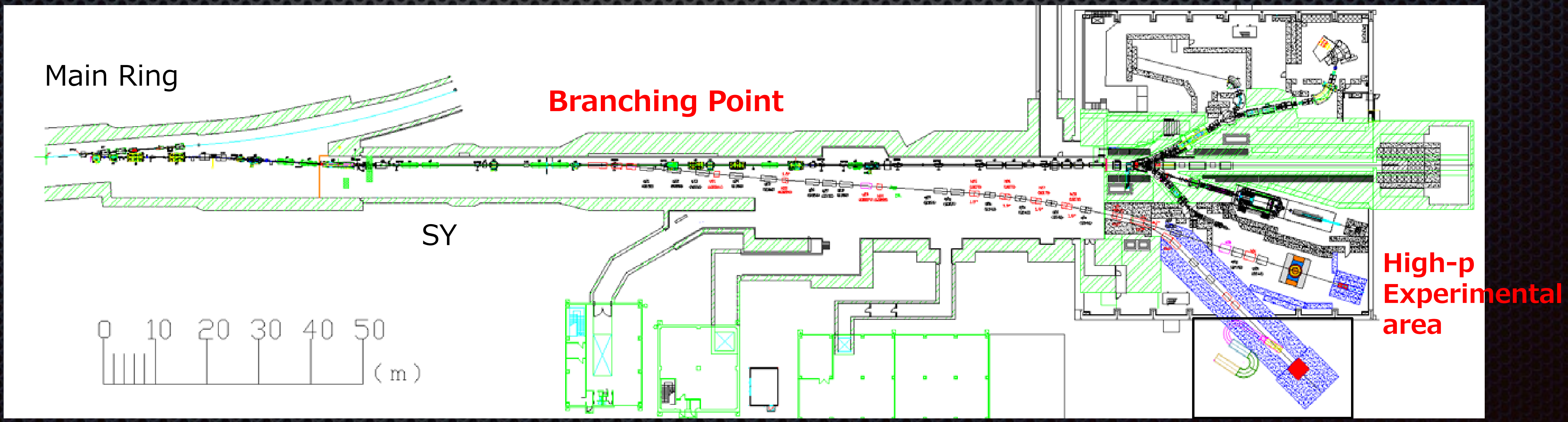
Spokesperson : S. Yokkaichi (RIKEN)

E50 : Charmed Baryon Spectroscopy

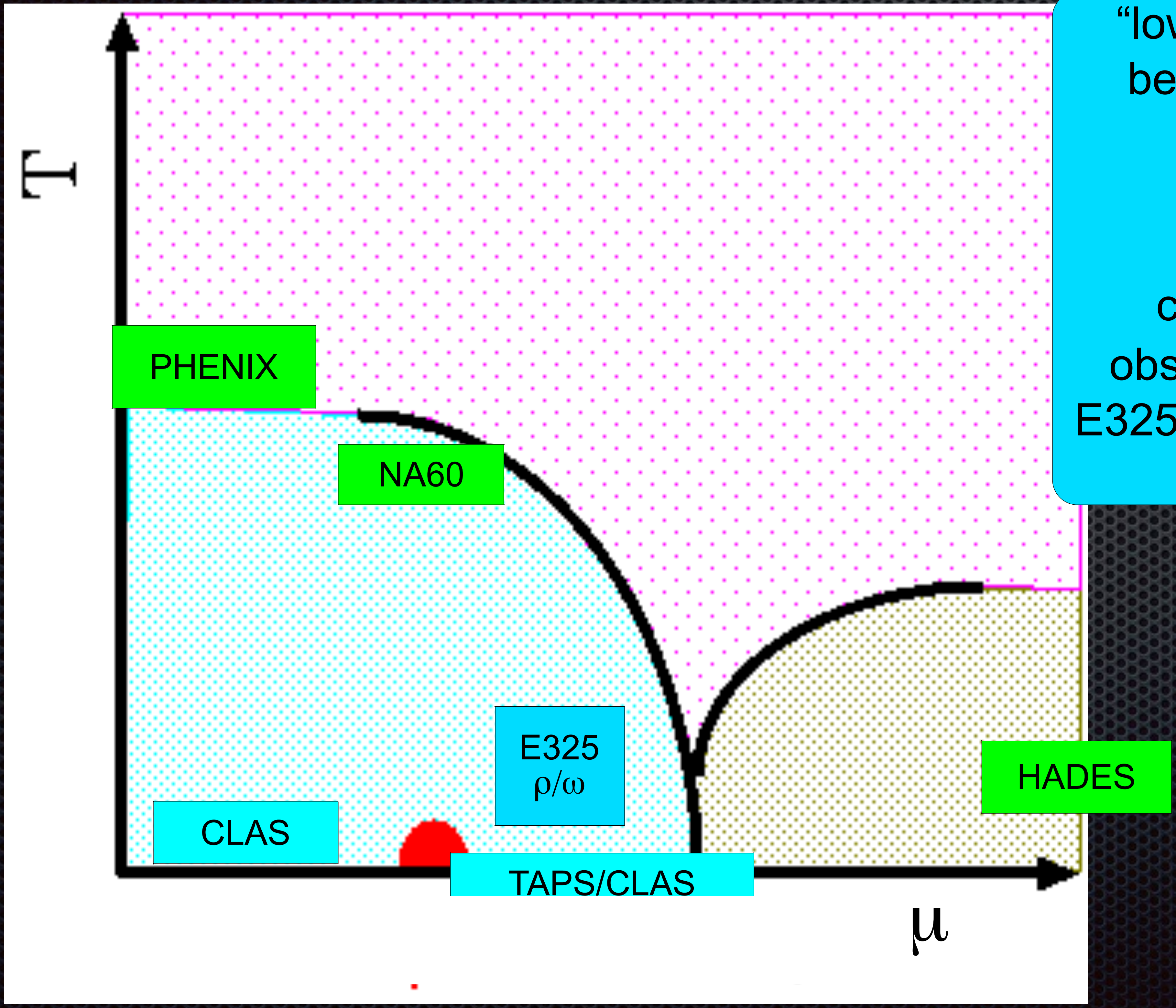
Spokesperson : H. Noumi (RCNP, Osaka)

New high-p beam line

- Under construction in 2013 ~ 2016
  - 30 GeV primary beam @10^{10}/spill
  - ~20 GeV/c π beam @10^{7}/spill



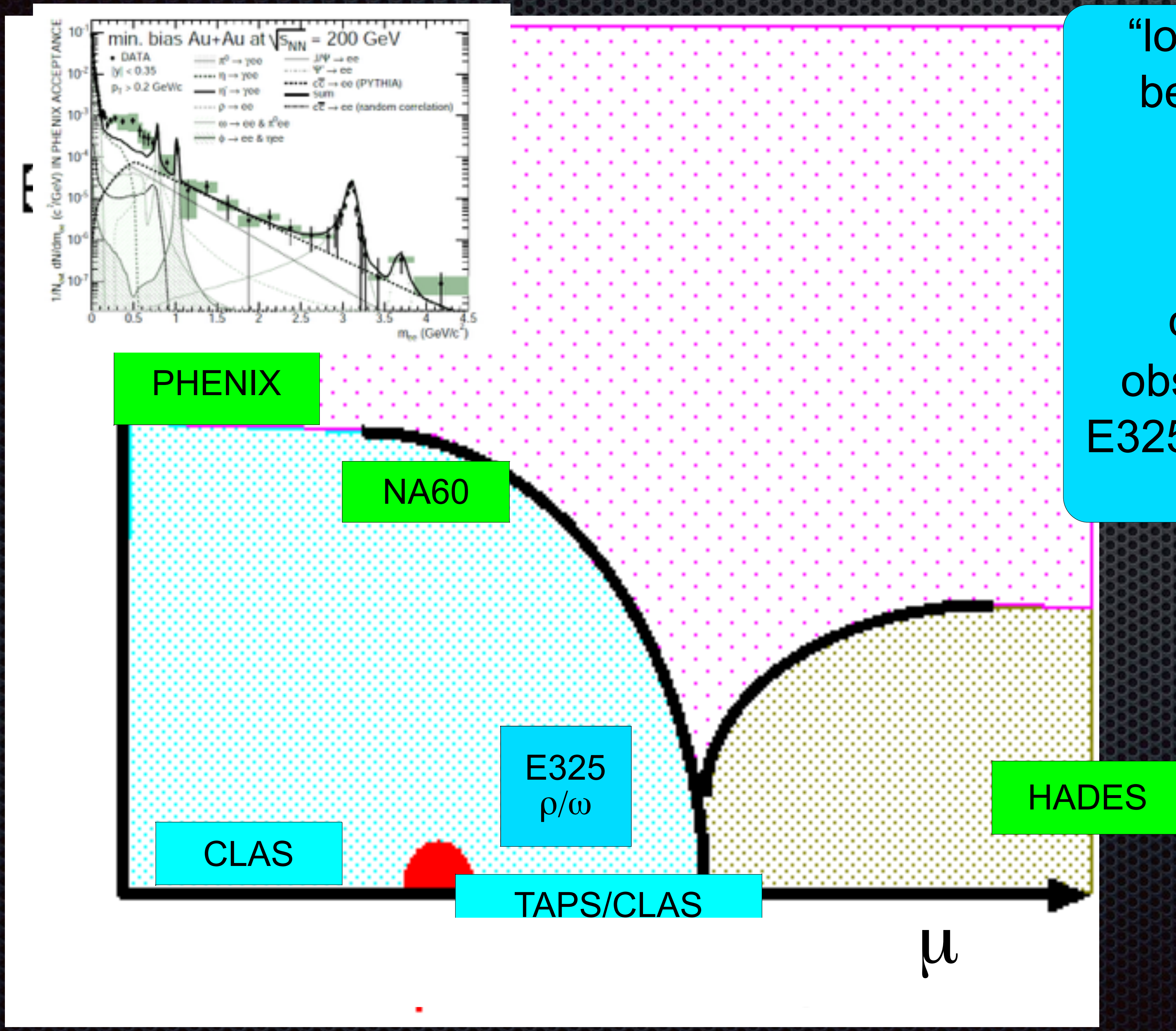
E16: Spectral change of vector mesons with Di-lepton Spectra



"low mass enhancement" below the ω meson peak in HI collisions and HADES p+Nb

change of ϕ meson is observed only by KEK-PS E325 w/ best mass resolution & high statistics

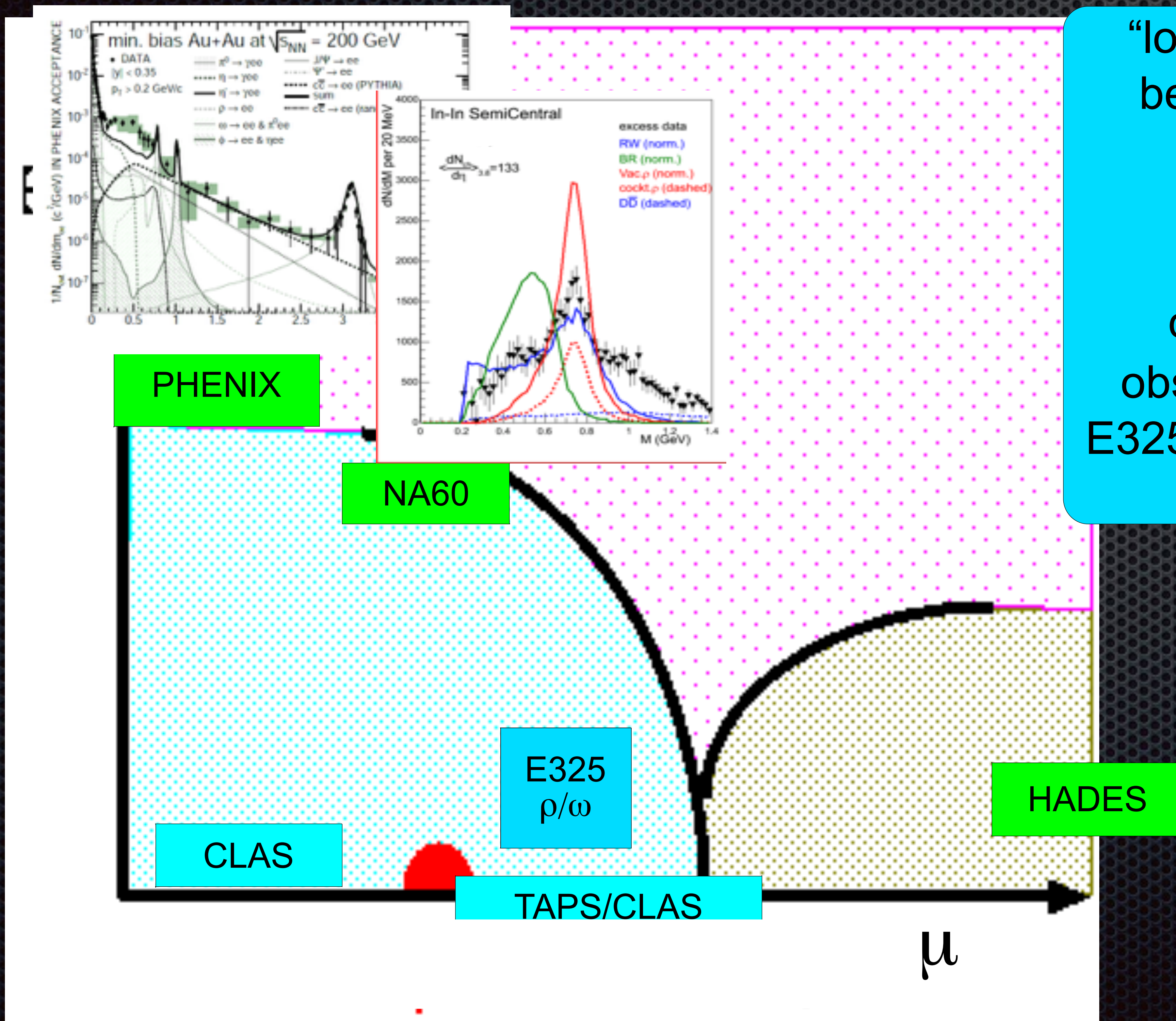
E16: Spectral change of vector mesons with Di-lepton Spectra



"low mass enhancement" below the ω meson peak in HI collisions and HADES p+Nb

change of φ meson is observed only by KEK-PS E325 w/ best mass resolution & high statistics

E16: Spectral change of vector mesons with Di-lepton Spectra



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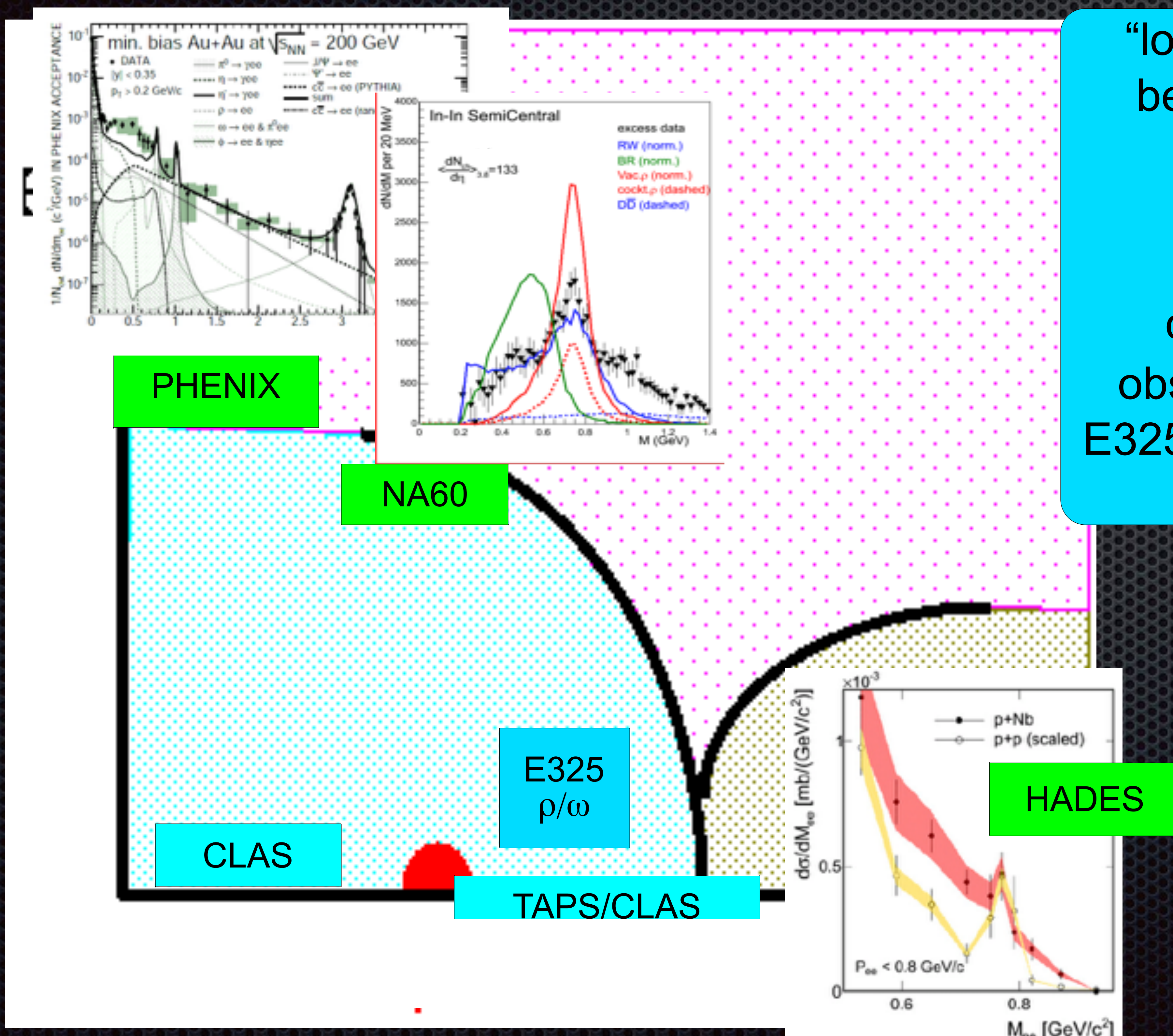

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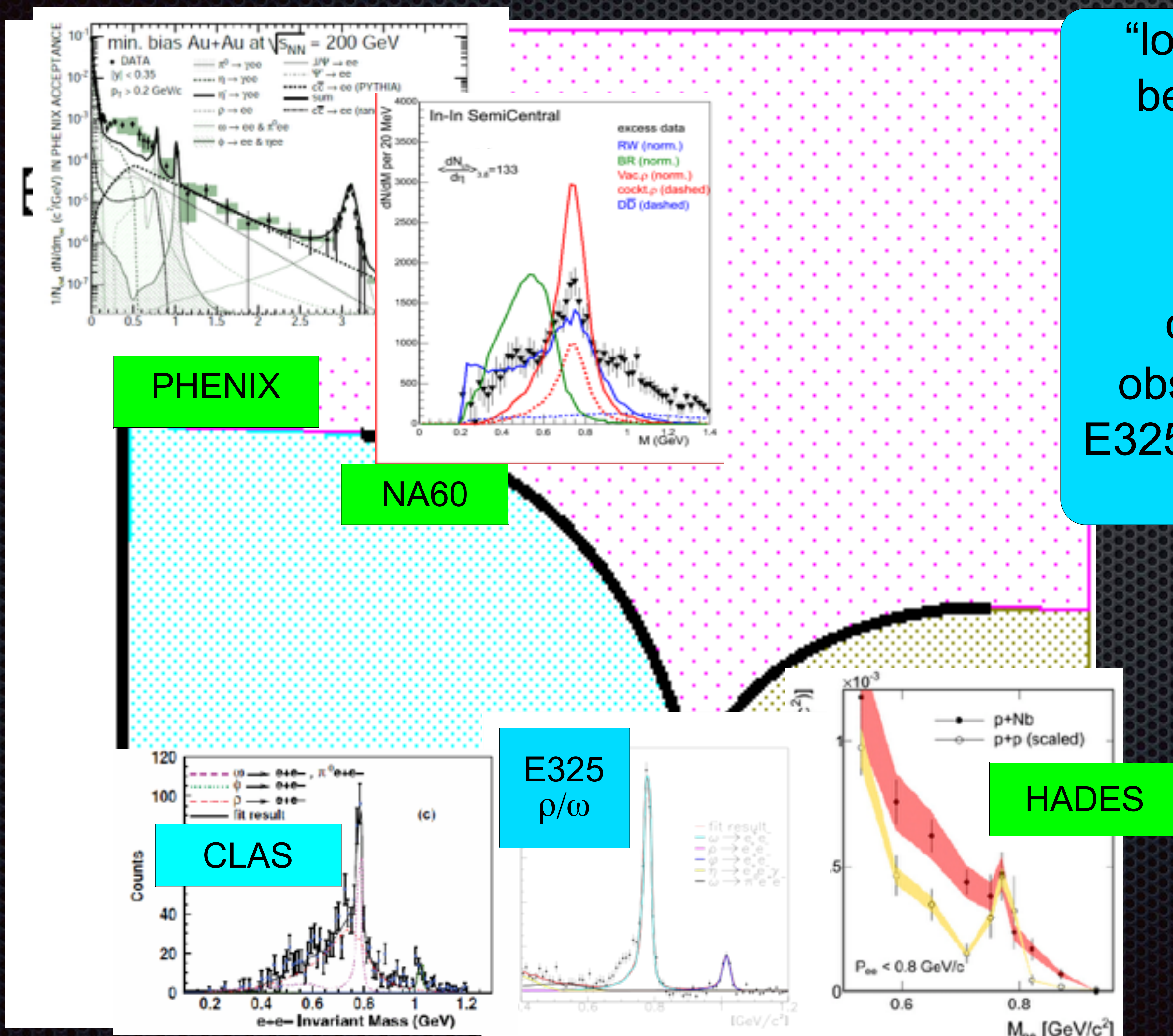
E16: Spectral change of vector mesons with Di-lepton Spectra



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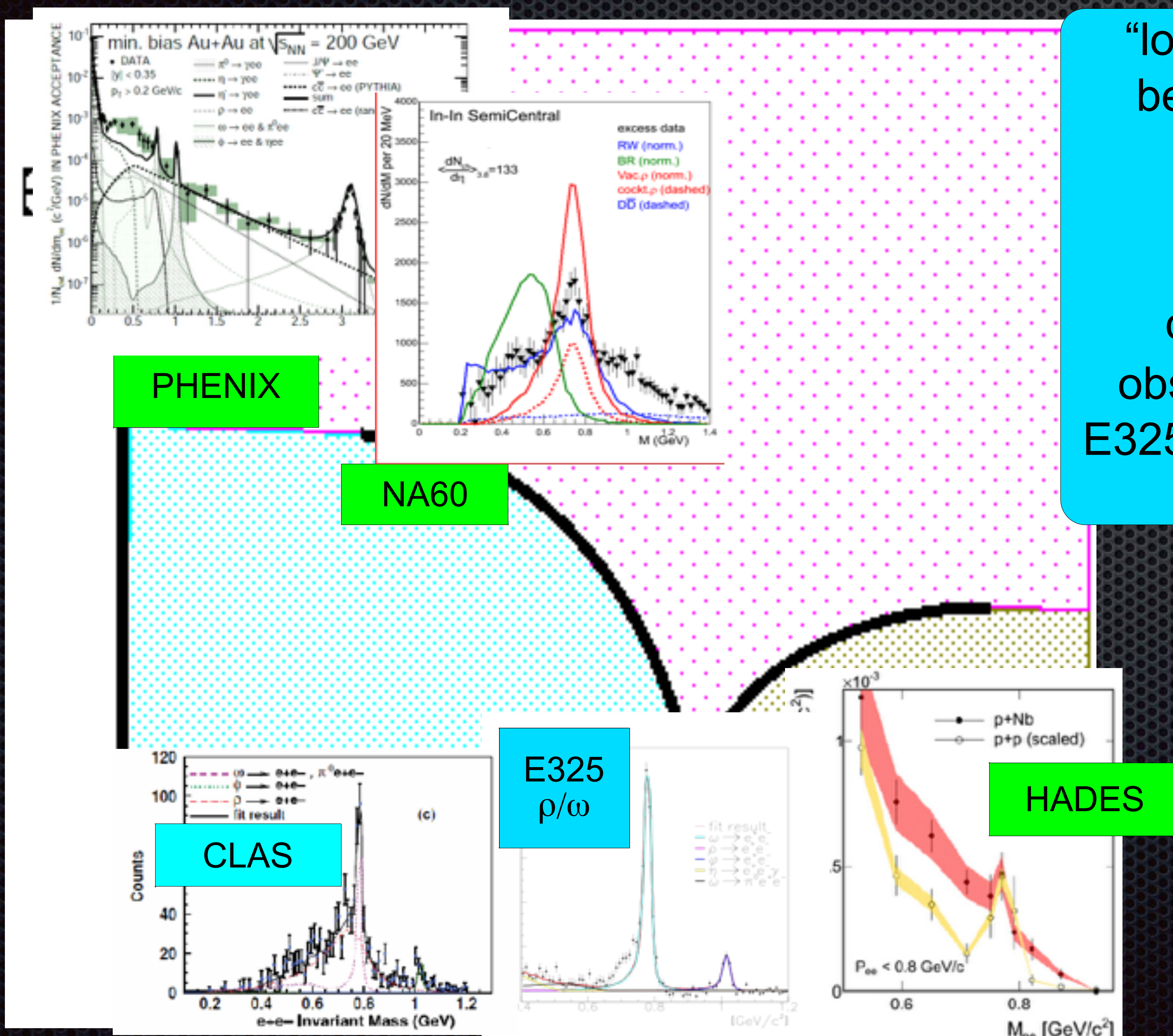
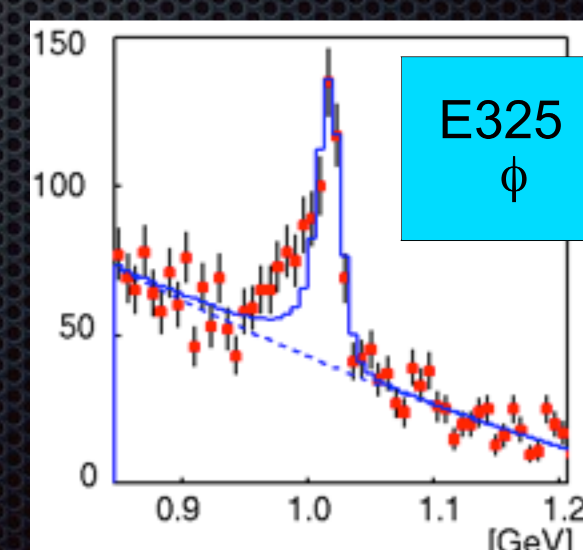
E16: Spectral change of vector mesons with Di-lepton Spectra

“low mass enhancement"
below the ω meson peak
in HI collisions
and HADES p+Nb

change of ϕ meson is
observed only by KEK-PS
E325 w/ best mass resolution
& high statistics



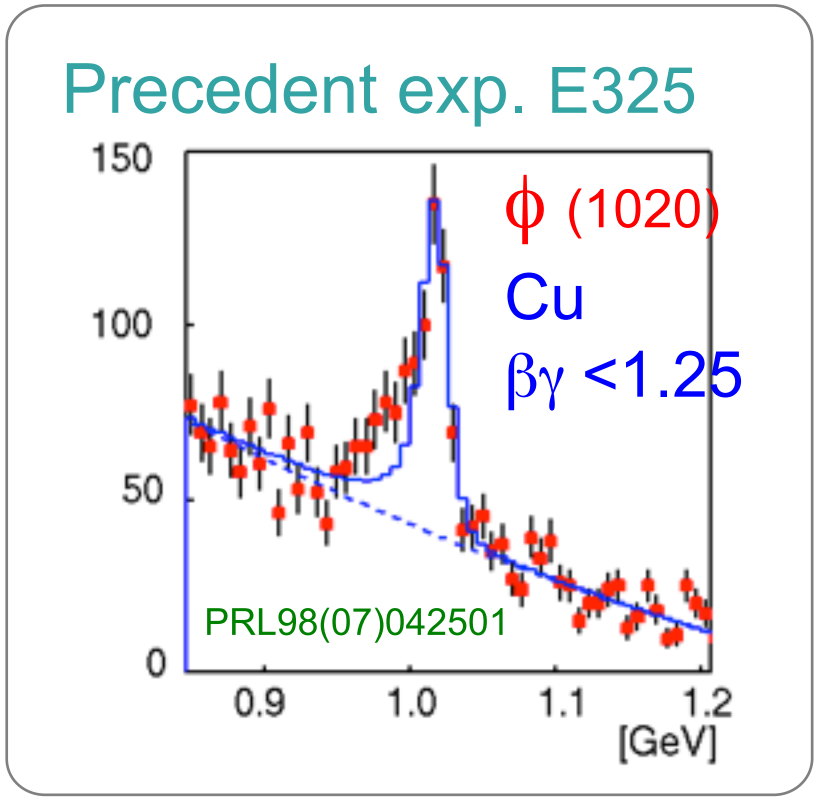


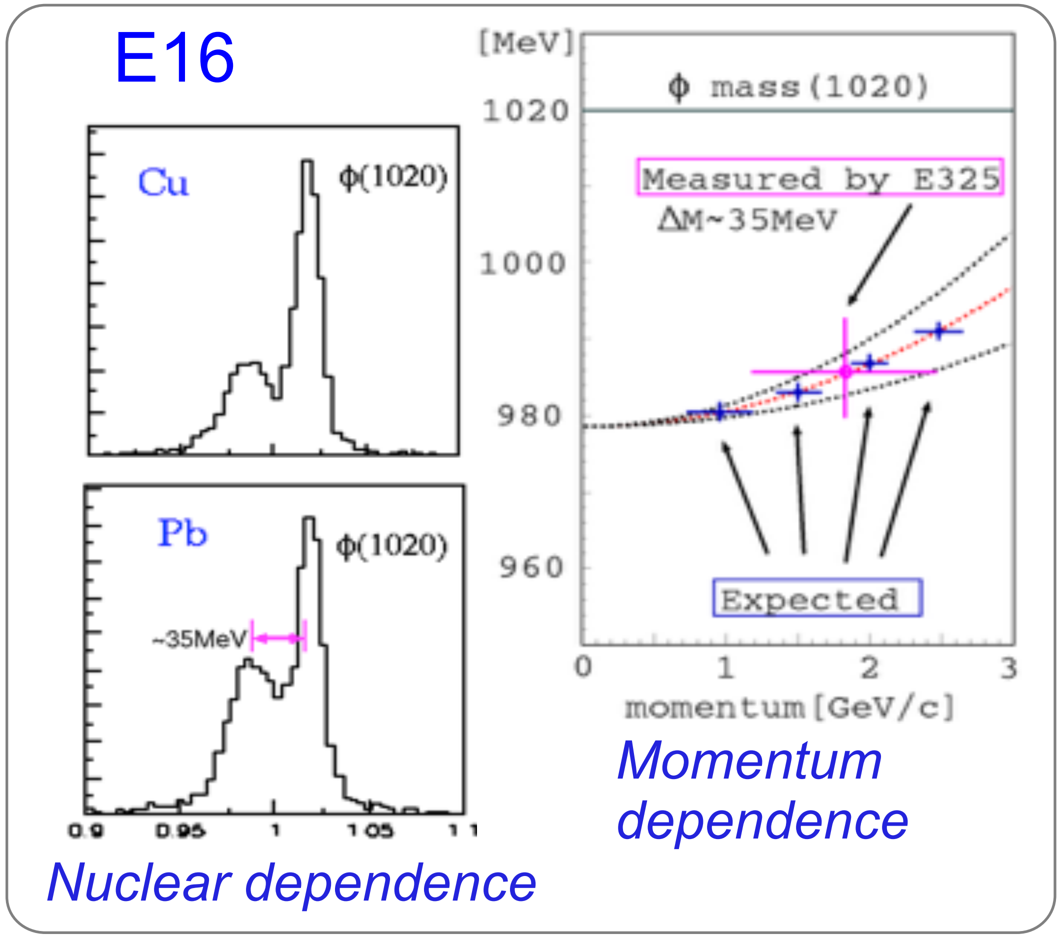
Goal of E16

- Systematic measurements of the spectral change of ϕ(and ρ/ω) in nuclei
  - High statistics : 100,000 ϕ's
  - Best mass resolution : 5 MeV

  - Confirm the E325 results
  - Nuclear size dependence (H, C, Cu, Pb)
  - Momentum dependence (dispersion relation in nuclear matter)

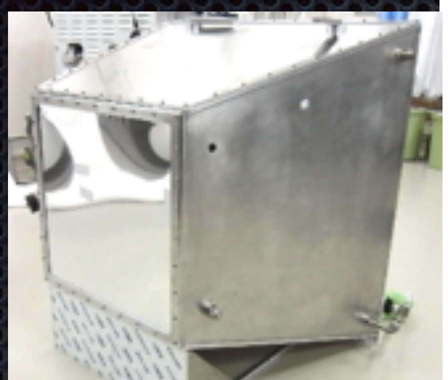
- Need New spectrometer :
  10 MHz interactions, with 30-GeV primary proton beam of $\sim 10^{10}$ pps

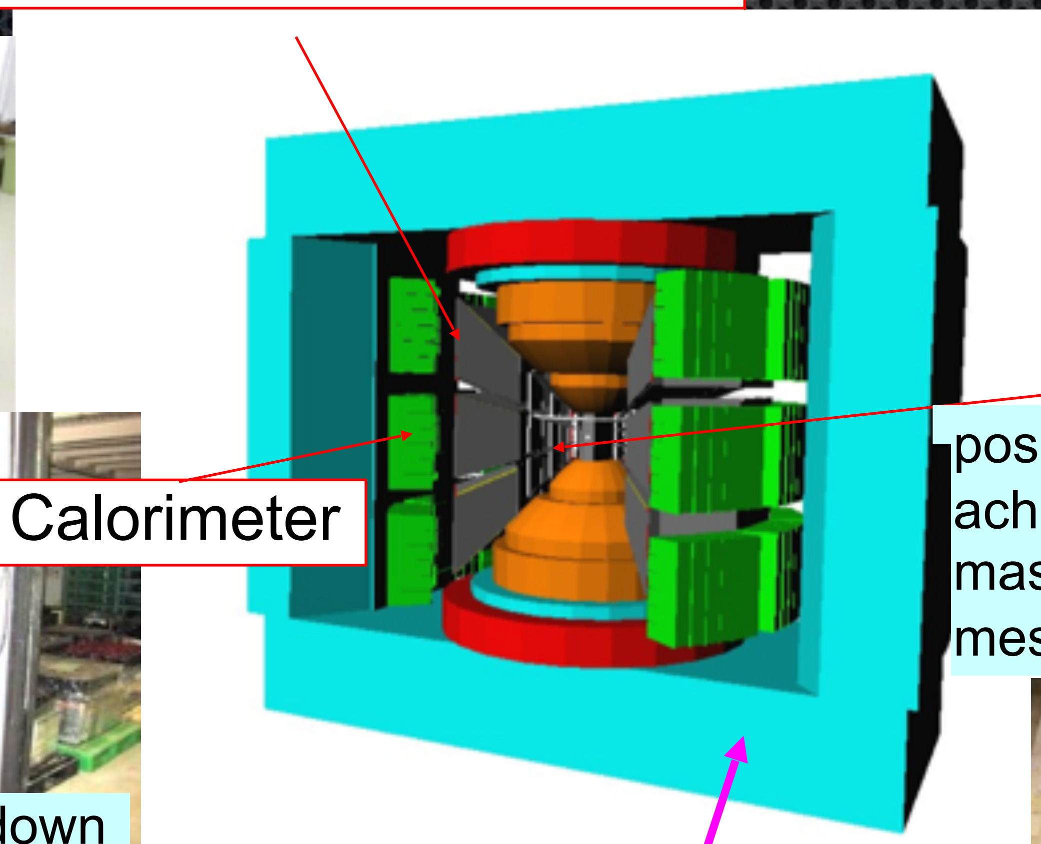


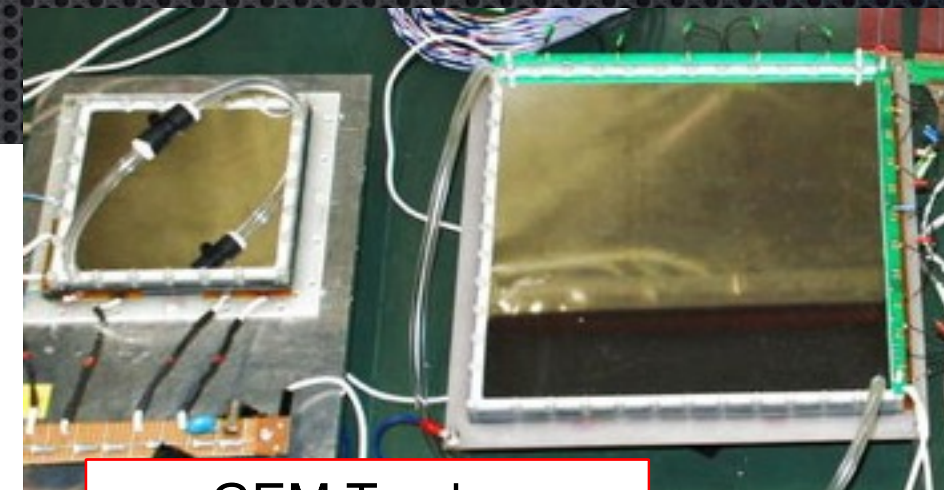


Detector developments and construction

Hadron Blind Cherenkov Detector (HBD)

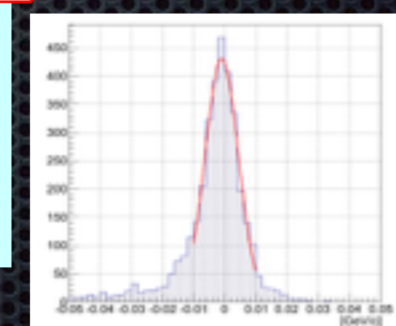




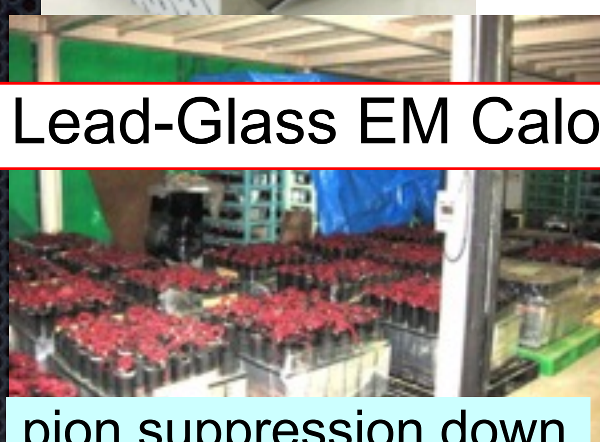


GEM Tracker

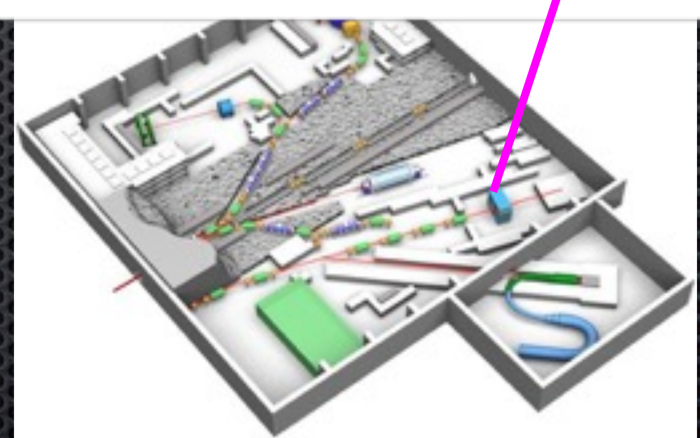
position resolution 100 μm is achieved to keep the ~5 MeV mass resolution for the ϕ mesons.



Lead-Glass EM Calorimeter



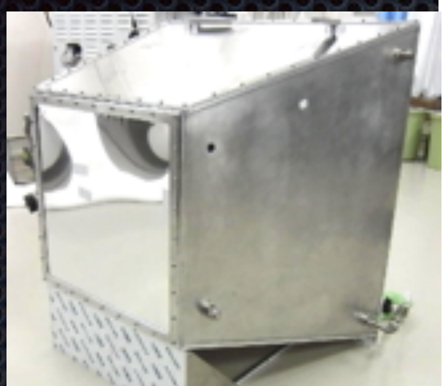
pion suppression down to ~0.1% is achieved with the combination of the two stage of electron-ID counters; HBD & LG

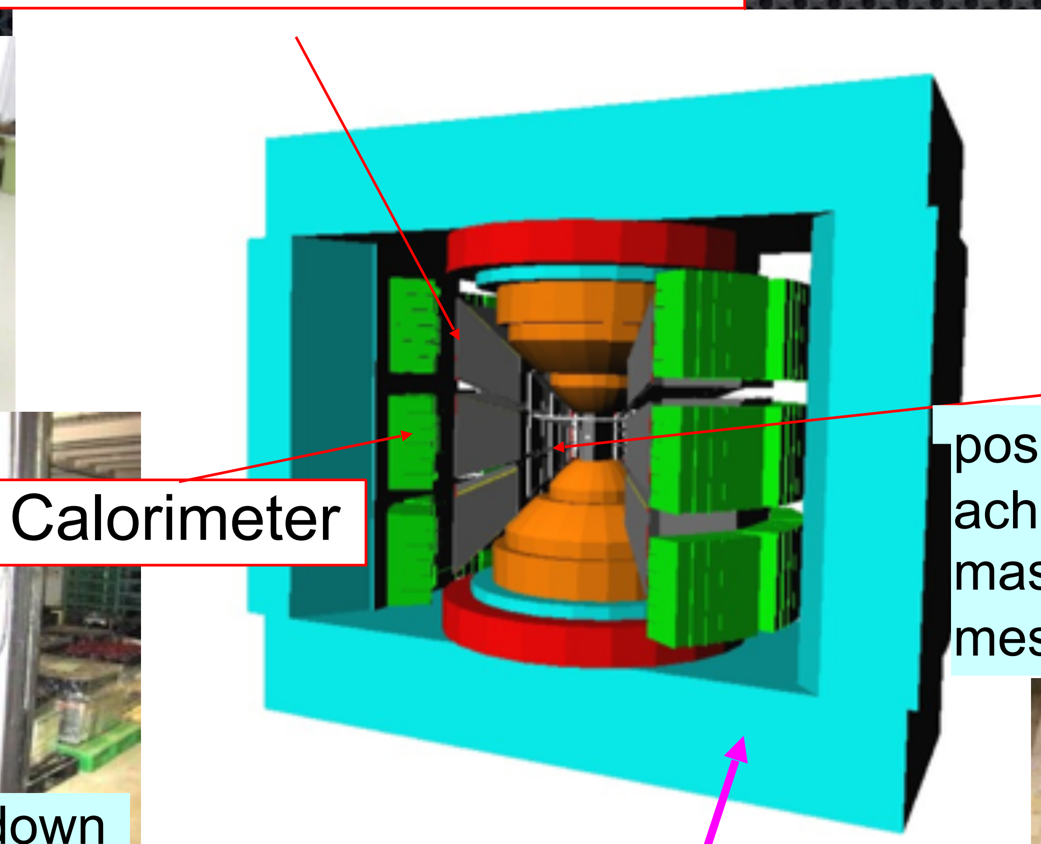


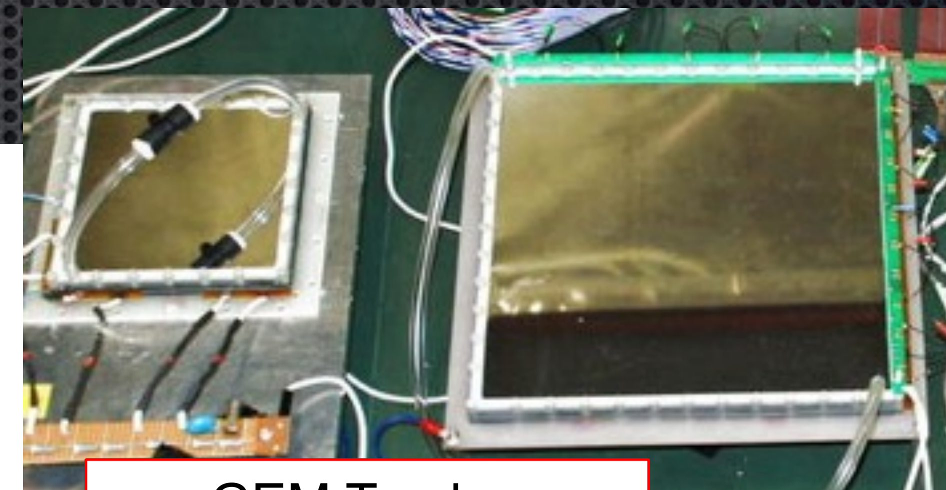
The spectromter magnet should be re-constructed and located at the new High-momentum beam line, which is under construction and completed in JFY 2016.

Detector developments and construction

Hadron Blind Cherenkov Detector (HBD)







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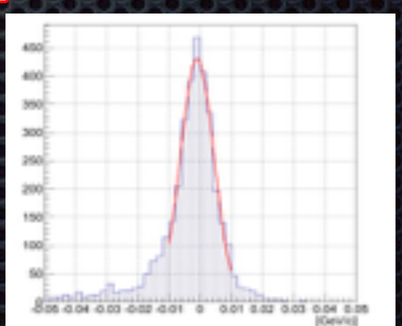
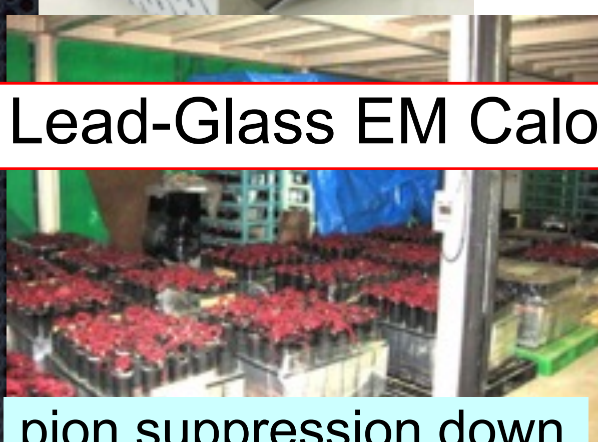


Lead-Glass EM Calorimeter



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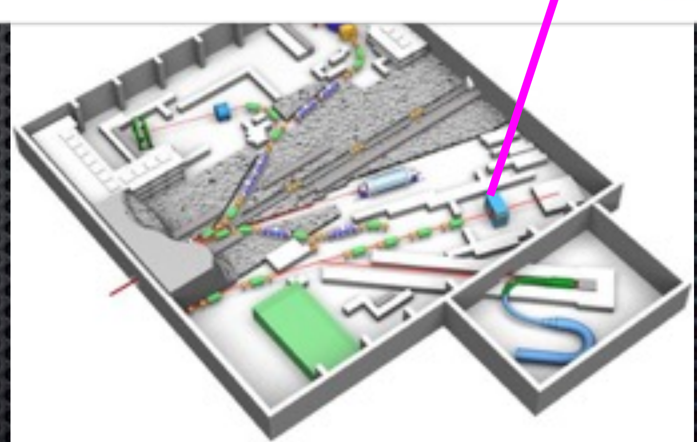
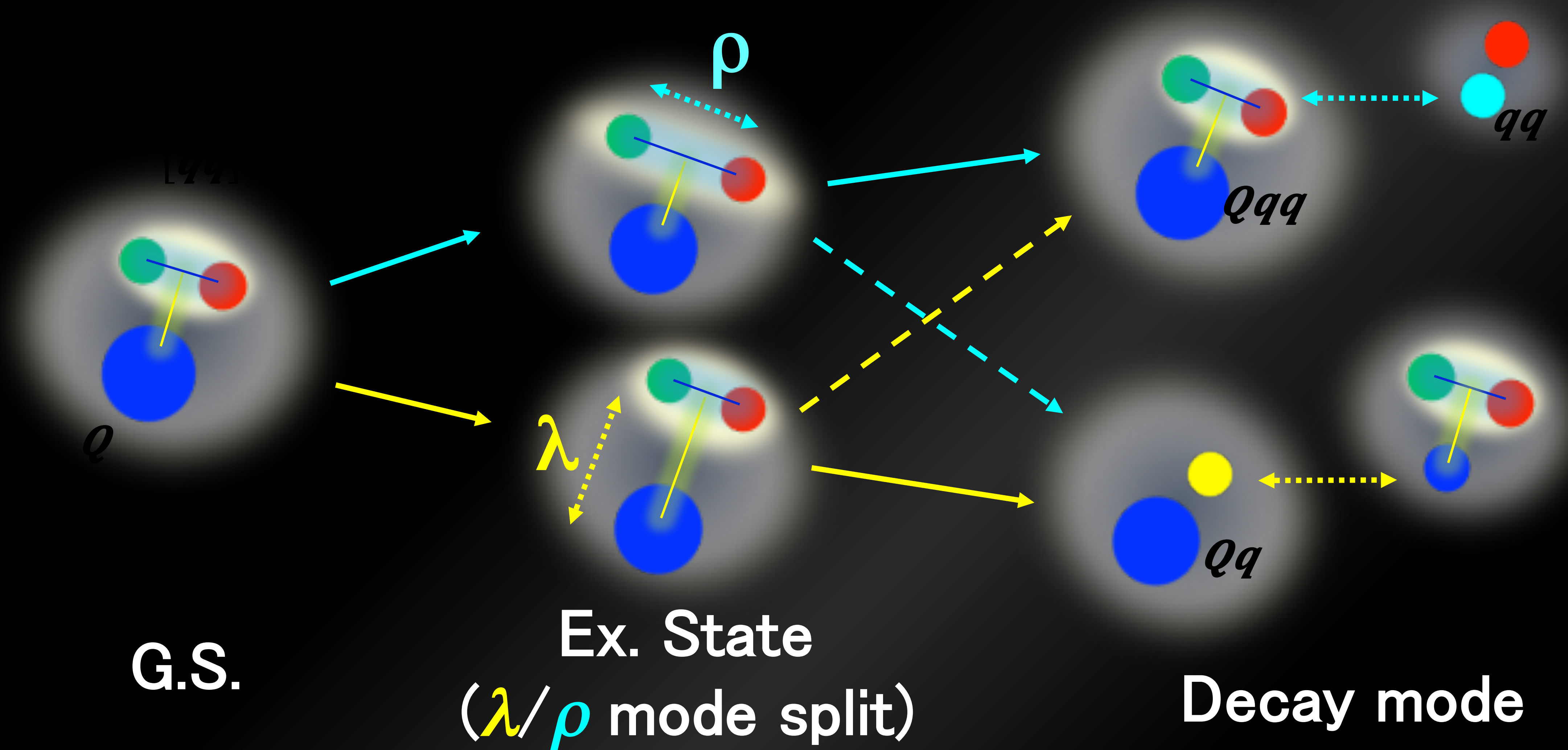


The spectromter magnet should be re-constructed and located at the new High-momentum beam line, which is under construction and completed in JFY 2016.

Experiment will start in early 2017.

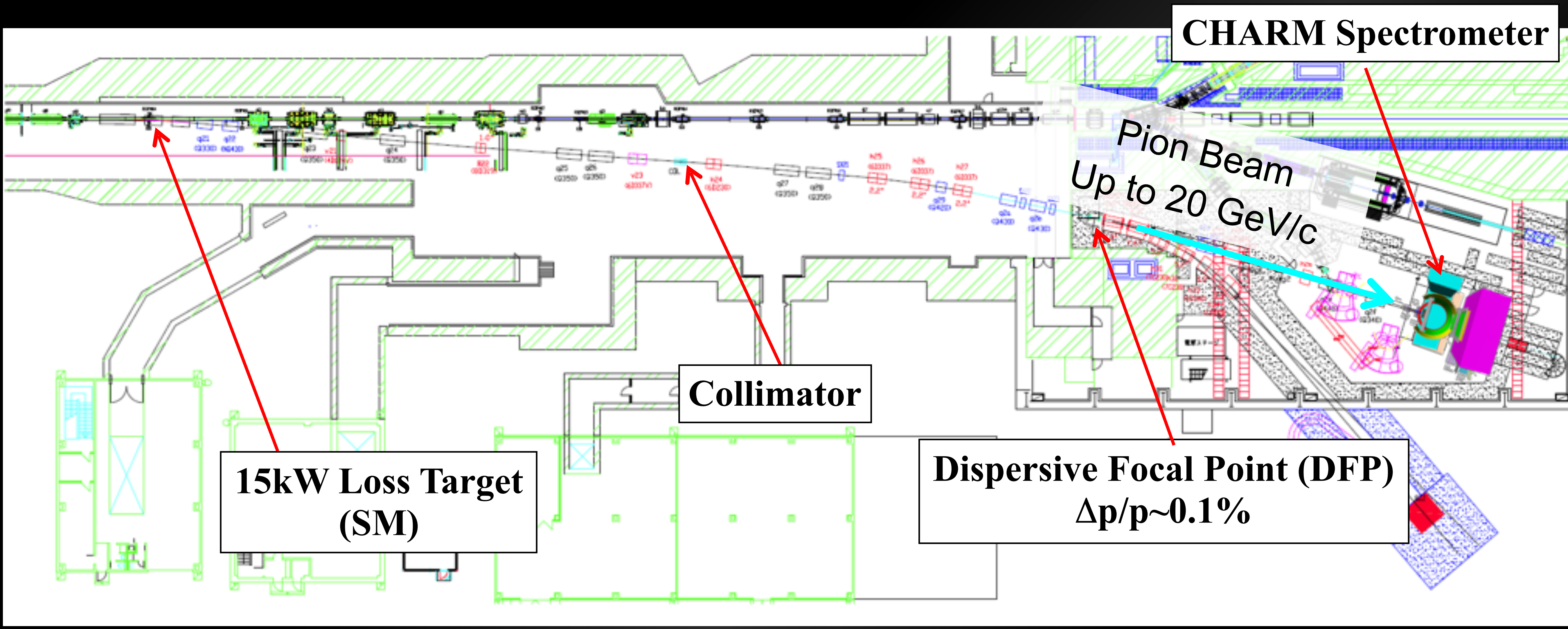
E50: Charmed Baryon Spectroscopy

- Quark-Diquark $[qq]$ structure of charmed baryons
- Characteristic features appear in
  Level Structure, *Prod. Rate*, and *Decay Branch'g Ratio*

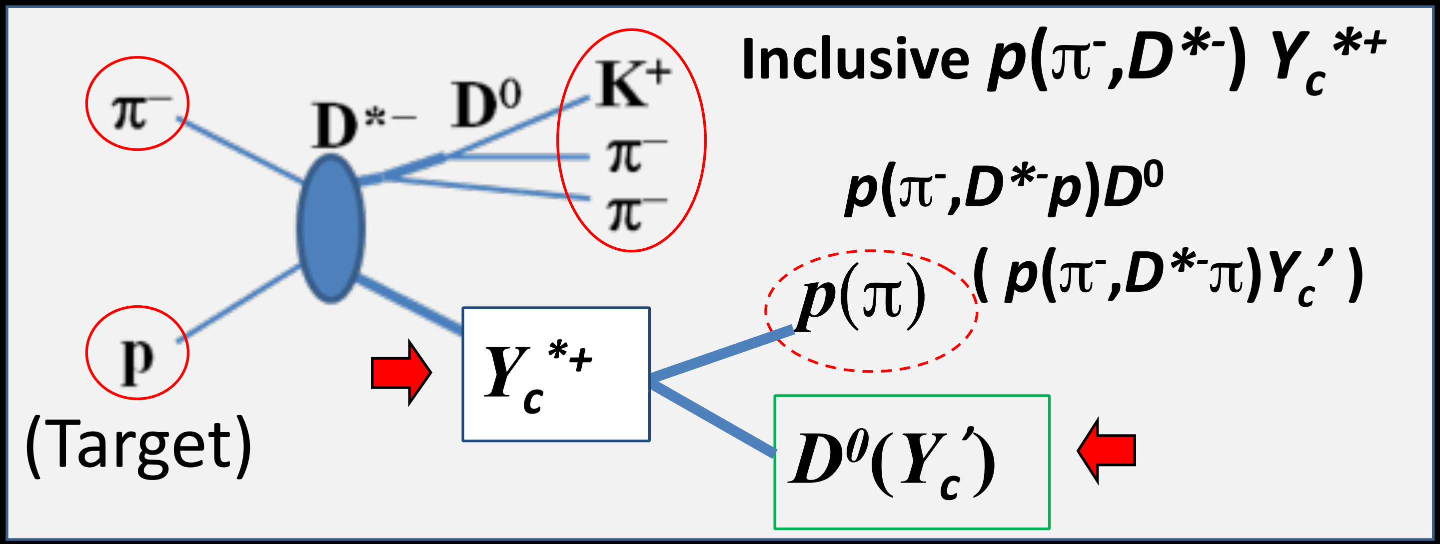


Charmed Baryon Spectroscopy at the High-momentum Beam Line

- High-intensity secondary Pion beam
  >1.0 x 10^7 pions/sec @ 20GeV/c
- High-resolution beam: $\Delta p/p$~0.1%



CHARM Spectrometer



Cross Section:

$\sigma\ (\Lambda_c) \sim 1$ nb (no meas.)

Acceptance:

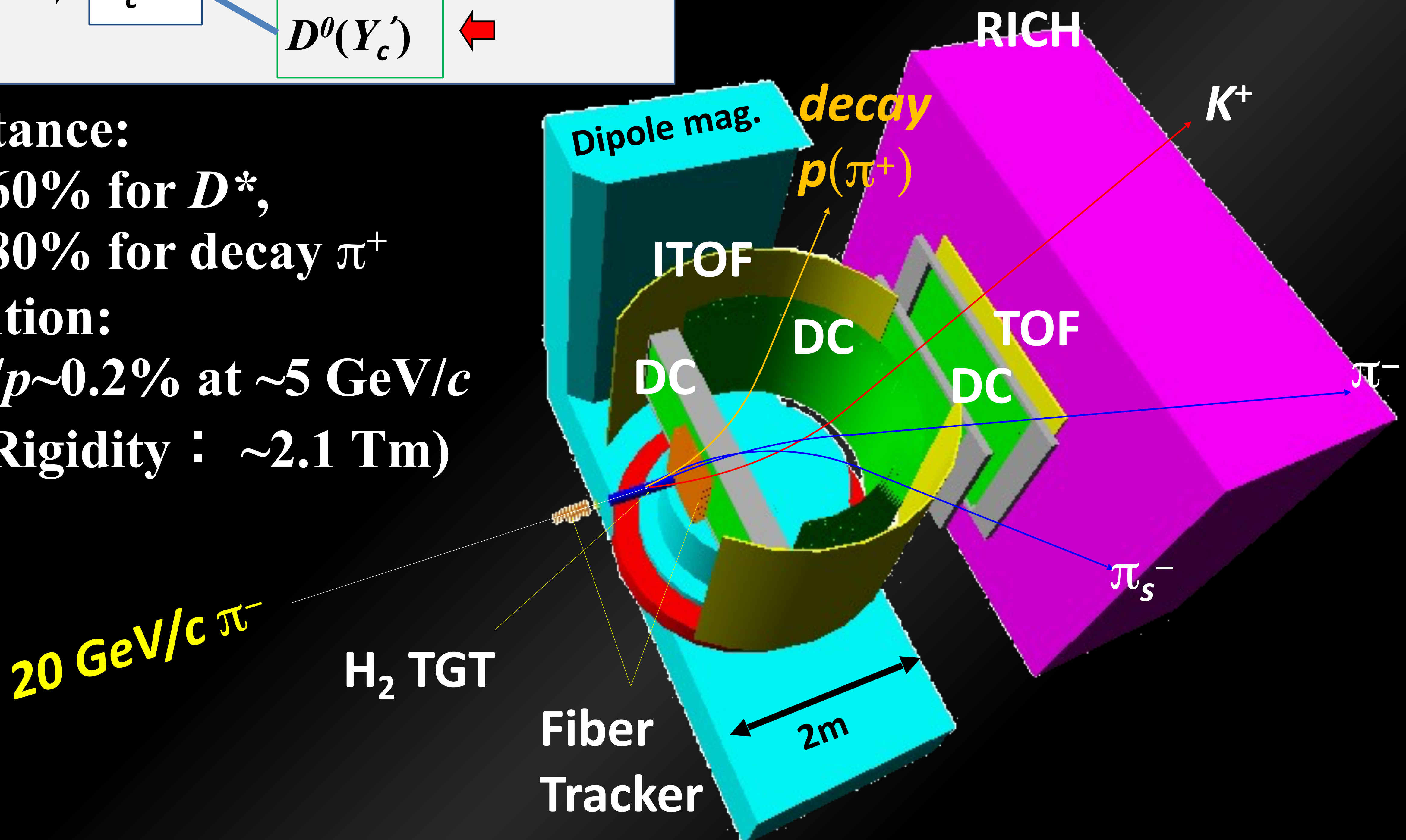
~ 60% for D^*,

~ 80% for decay π^+

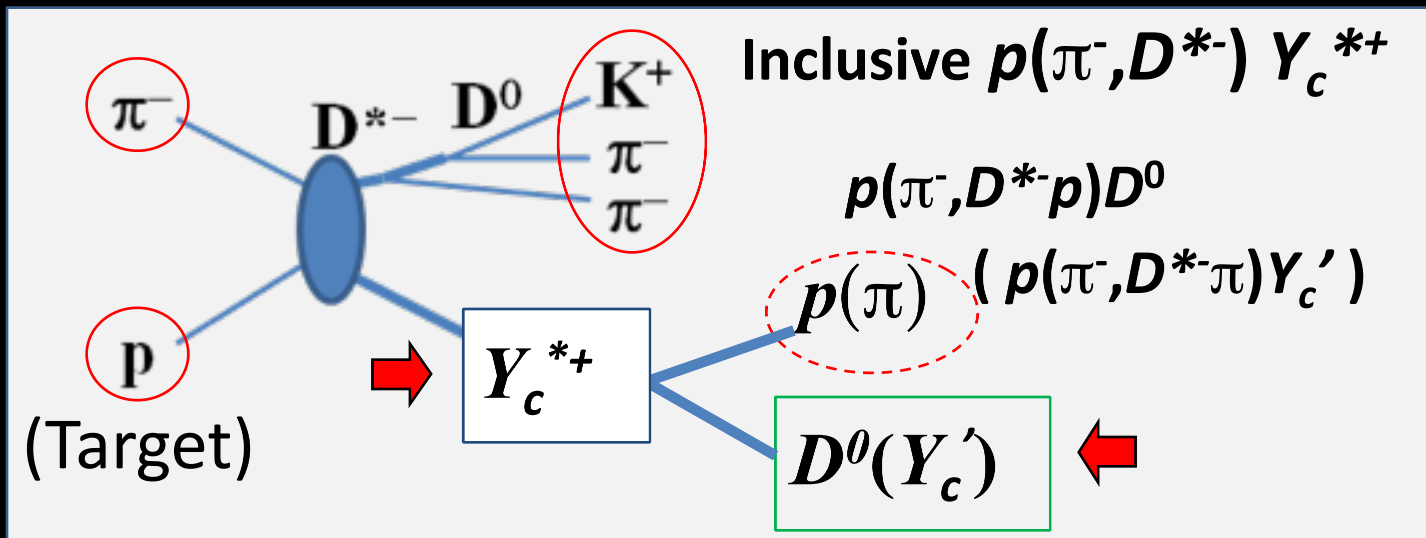
Resolution:

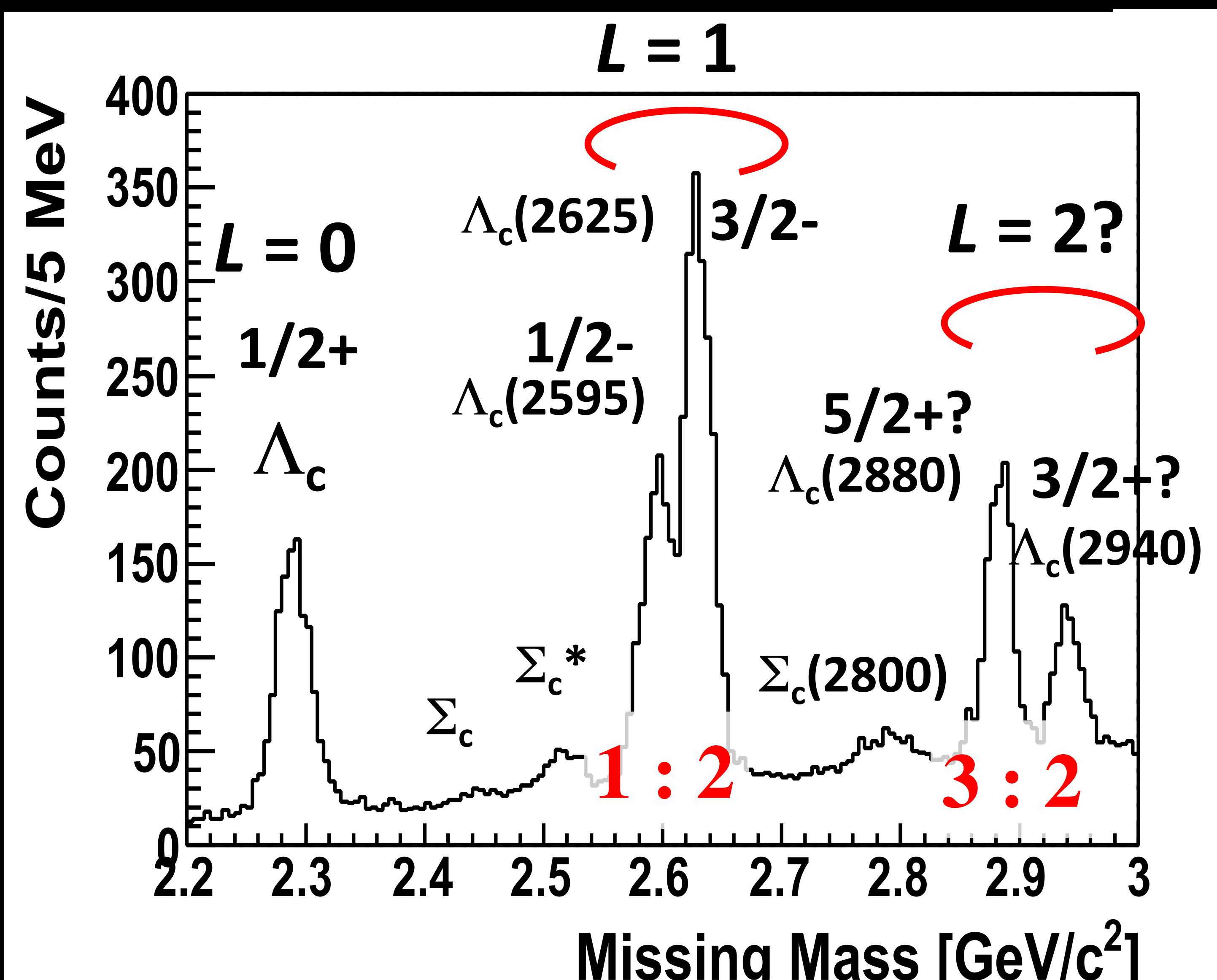
$\Delta p/p$~0.2% at ~5 GeV/c

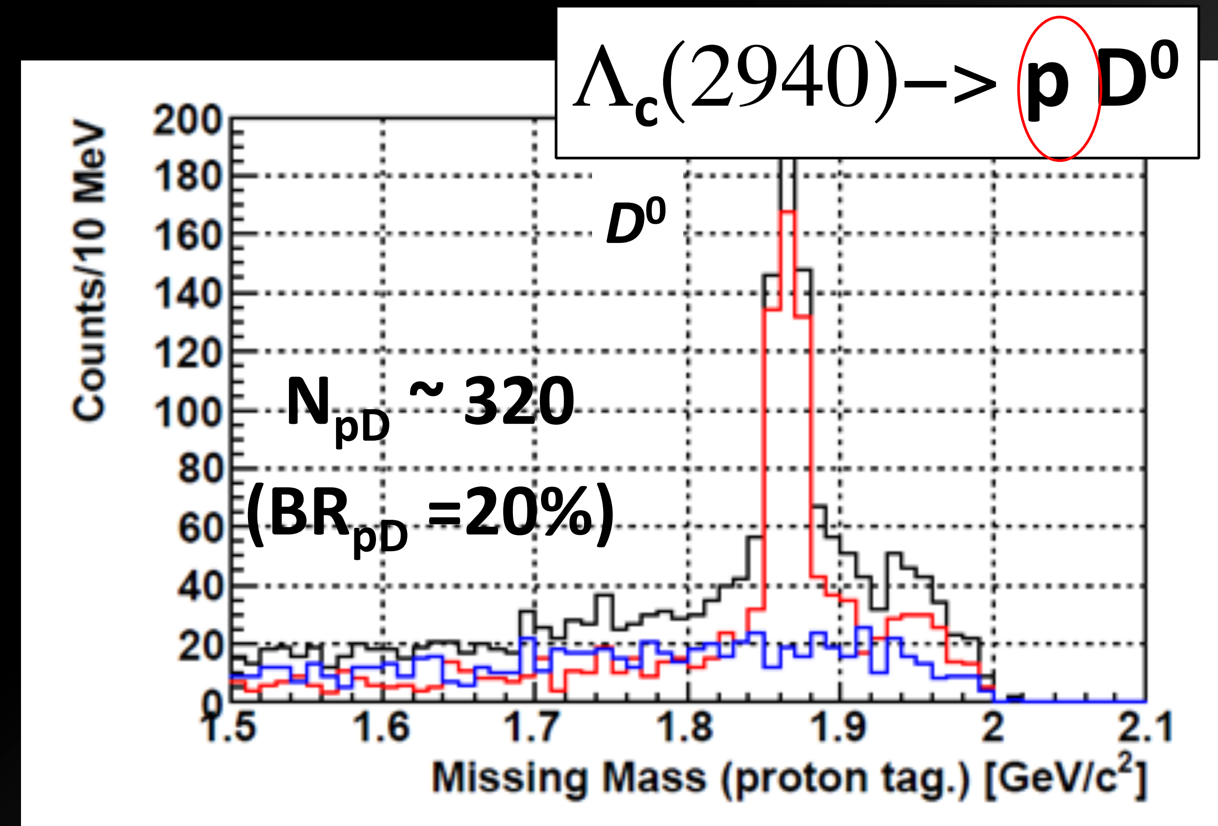
(Rigidity： ~2.1 Tm)

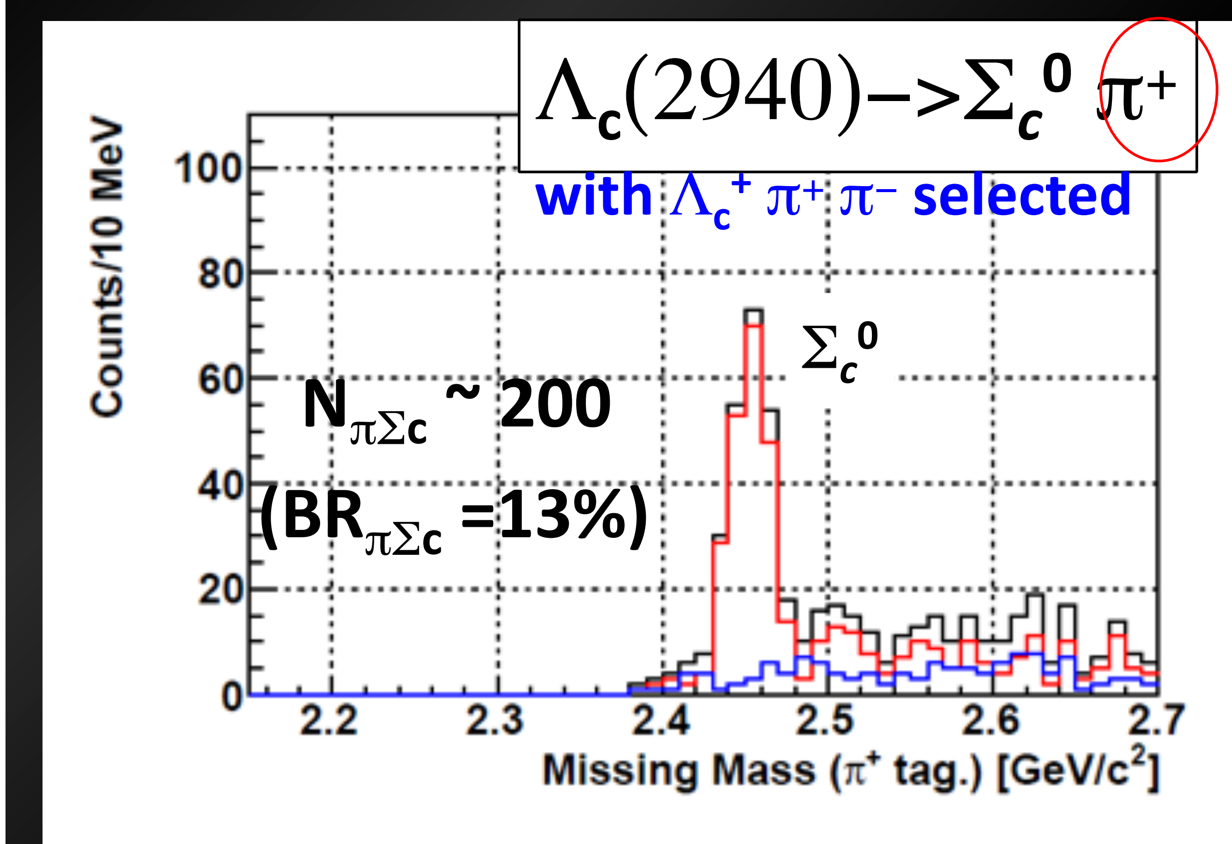


Inclusive Spectrum and Decay Mode ID (Sim.)





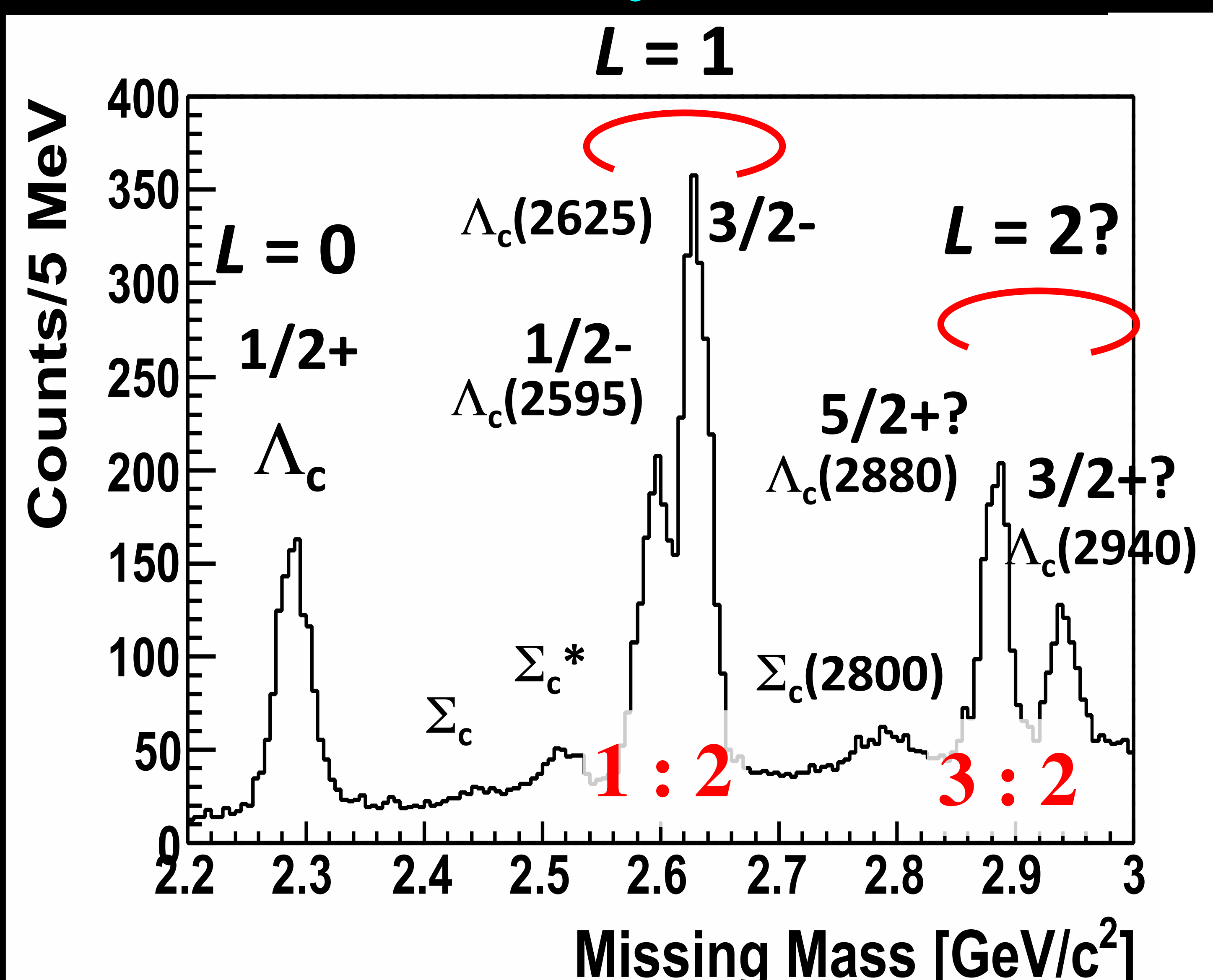


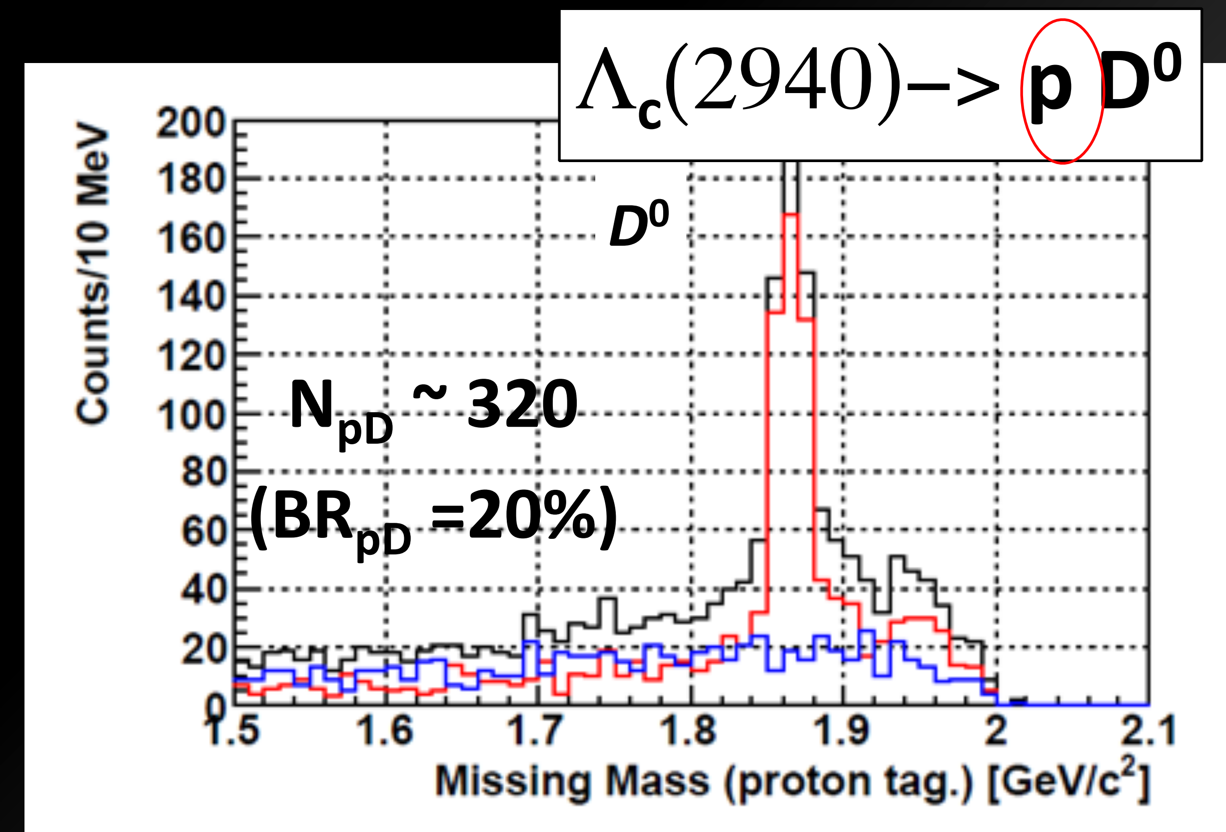


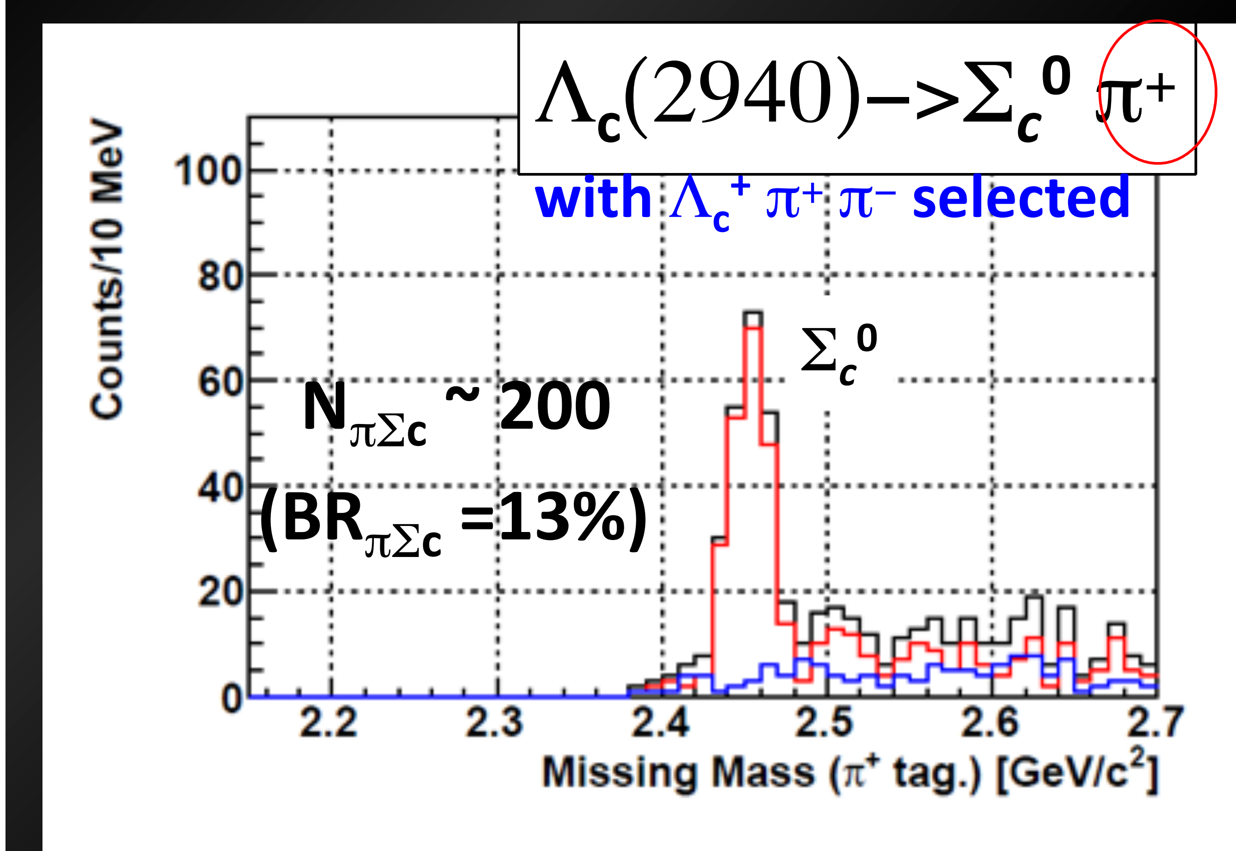
Inclusive Spectrum and Decay Mode ID (Sim.)

- Level Structure
- Production Rate
- Decay Branching Ratio

Yield: ~1000 Y_c^*/nb/100 day







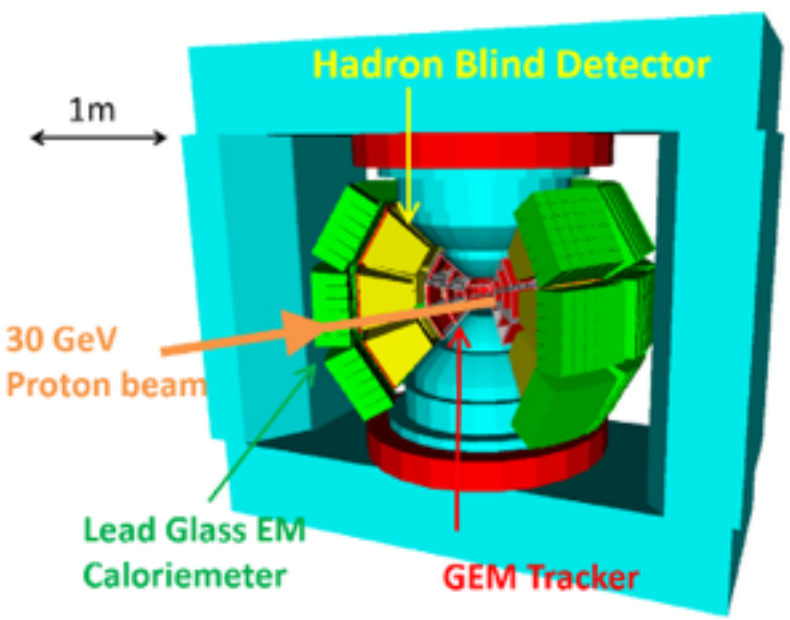
Summary

- J-PARC : π era → Kaon era in 2015
- Θ^+ was not observed in $\pi^- p \rightarrow K^- X$ reactions at 1.92 and 2.01 GeV/c.   < 0.28 μb/sr
- Observation of "K^-pp"-like structure in $d(\pi^+, K^+pp)X$ at 2.275 GeV/c^2 (B=2, S=-1)
- New high-p beam line under construction will open new opportunities at J-PARC

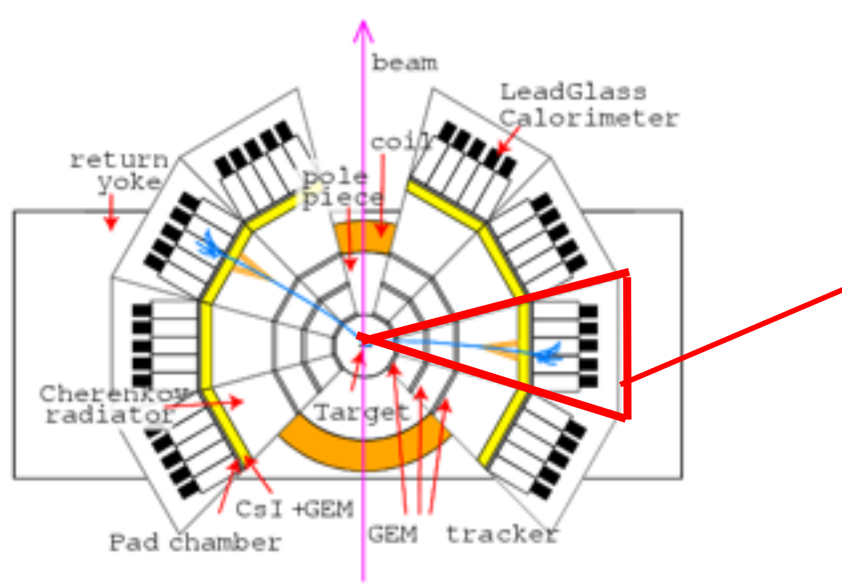
To collect high statistics

- For the statistics 100 times as large as E325, a new spectrometer and a primary beam in the High-p line are required.
  - To cover larger acceptance : x~ 5
  - Higher energy beam (12 → 30/50 GeV) : x ~2 of production
  - Higher intensity beam ($10^9 \rightarrow 10^{10}$ /spill (1sec)) : x 10 (→ 10MHz interaction on targets)
  - to cope with the high rate, new detectors (GEM Tracker & HBD) are required.

Proposed Spectrometer

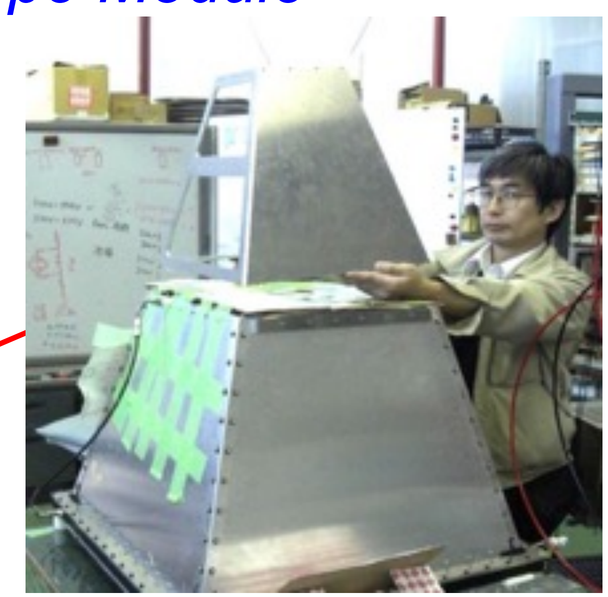


Plan View



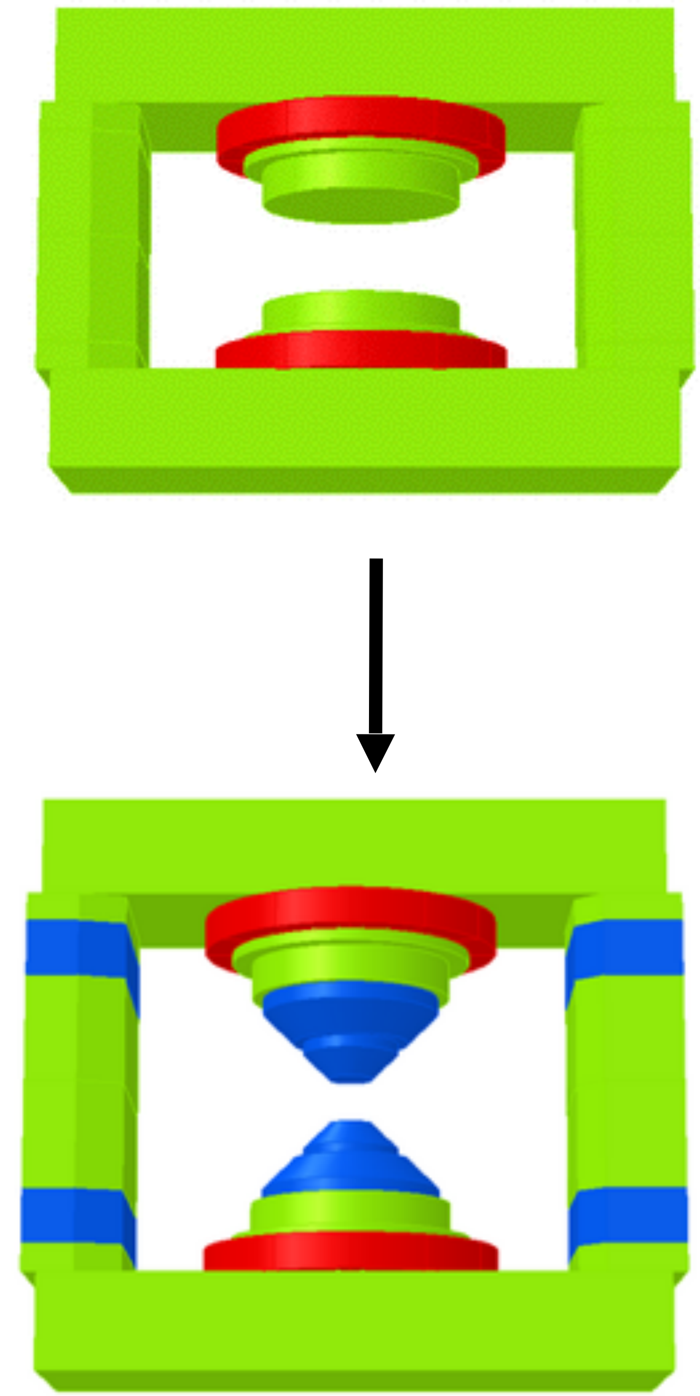
26 detector modules

Prototype Module



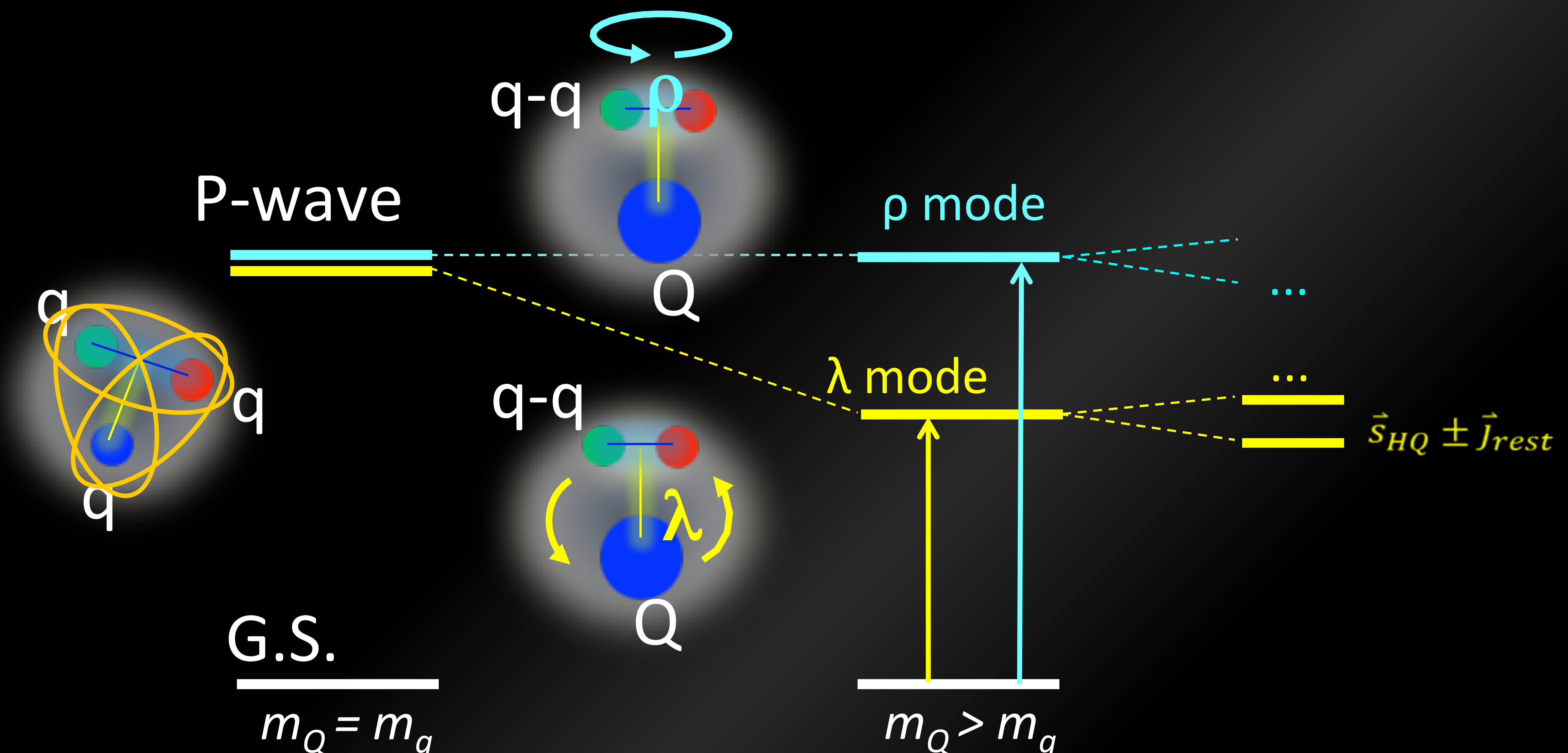
Spectrometer Magnet

delivered in 2012
(by R. Muto)



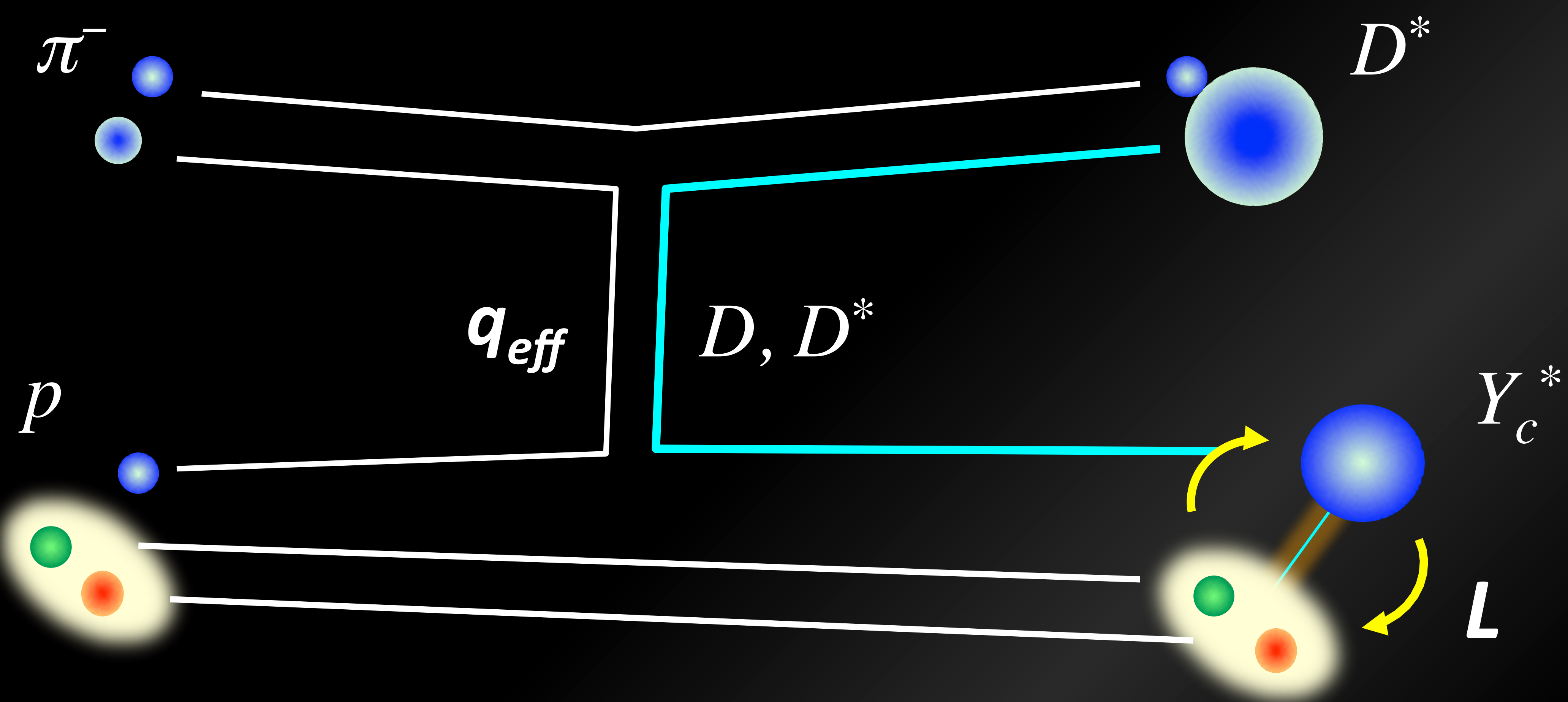
Schematic Level Structure of Heavy Baryons

- λ and ρ motions split (Isotope Shift)
- HQ spin multiplet $(\vec{s}_{HQ} \pm \vec{j}_{rest})$



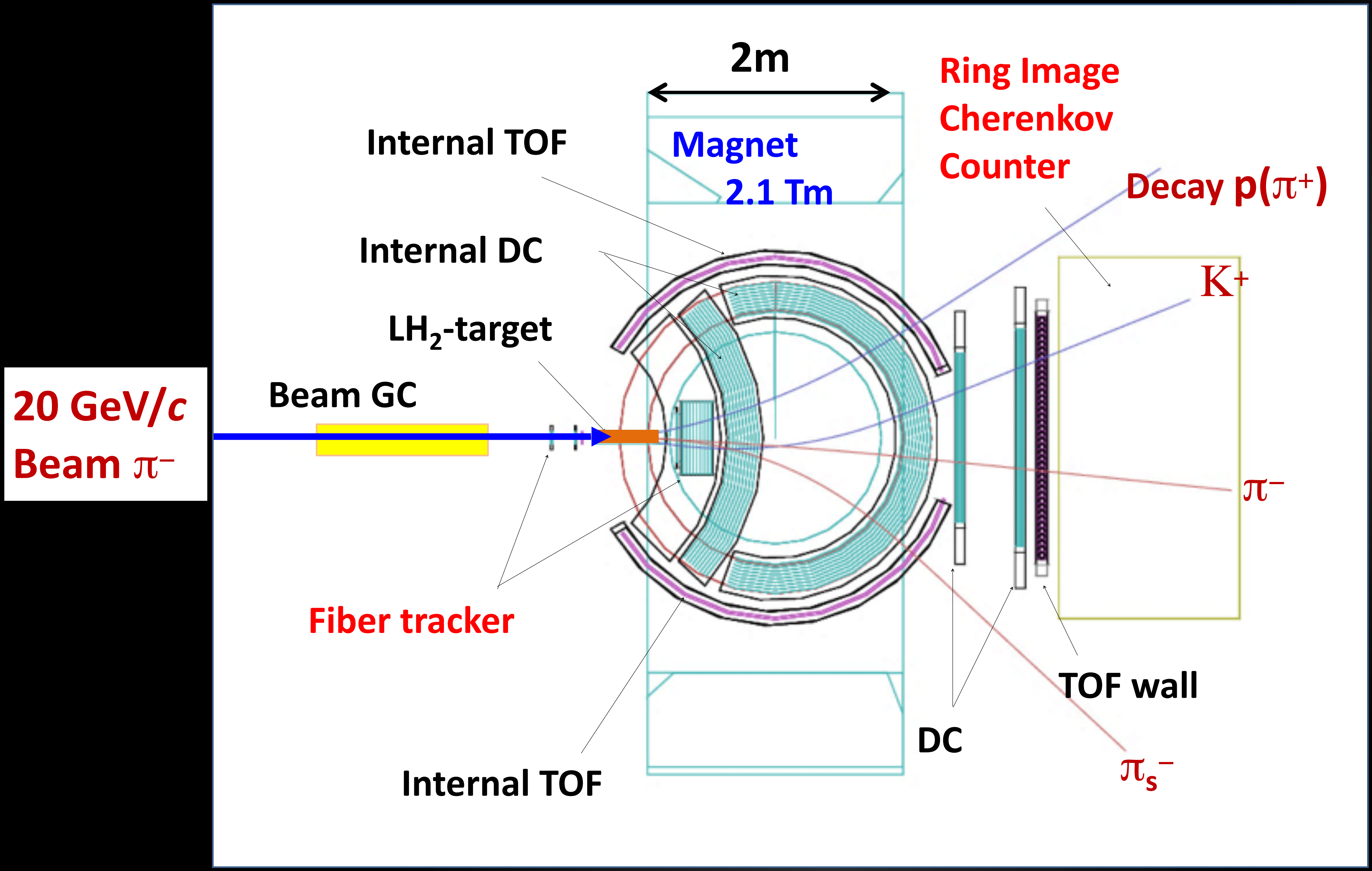
Production Rate

S.H. Kim, A. Hosaka, H.C. Kim, HN, K. Shirotori, PTEP, 103D01, 2014.



- ✓ C.S. DOES NOT go down at higher L when q_{eff}>1 GeV/c
- ✓ λ modes are excited by a simple mechanism

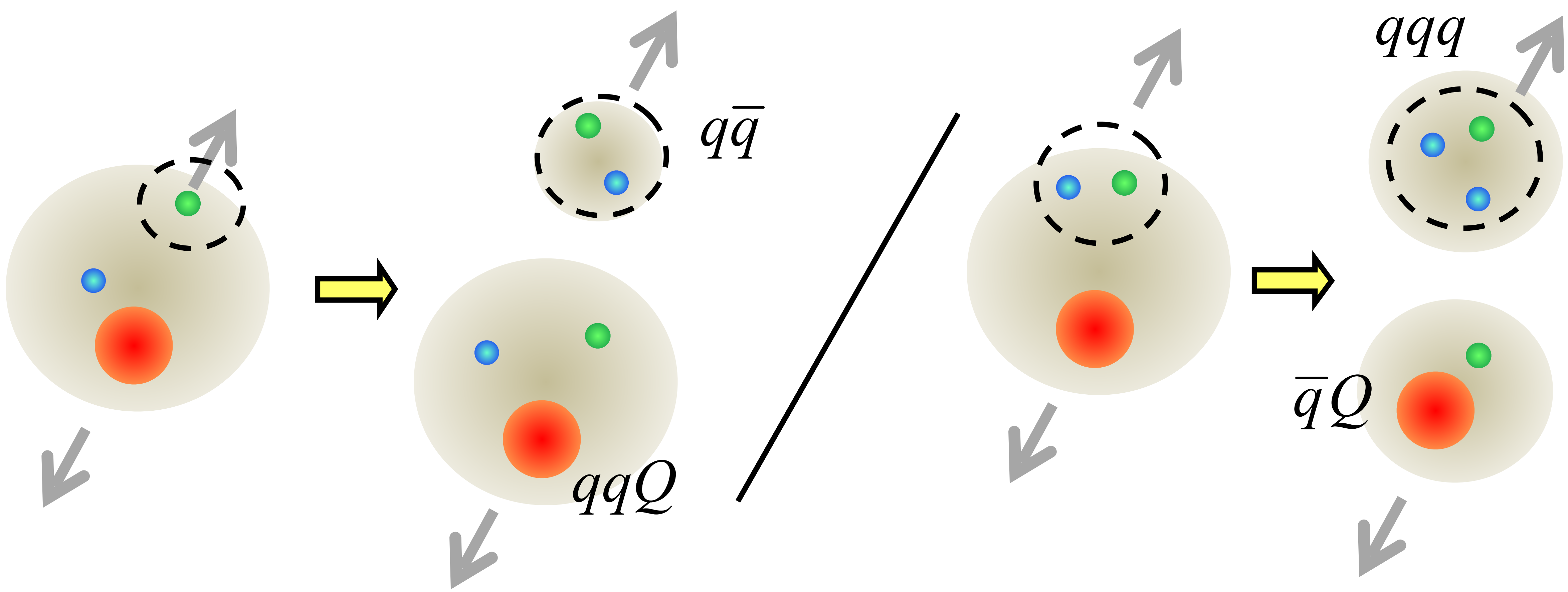
Large Acceptance Spectrometer



Acceptance: ~ 60% for D^*, ~80% for decay π^+

Resolution: $\Delta p/p$~0.2% at ~5 GeV/c （Rigidity： ~2.1 Tm)

Decay Properties



ρ mode (qq)

$\Gamma(\Sigma_c\pi) > \Gamma(pD)$

λ mode [qq]

$\Gamma(\Sigma_c\pi) < \Gamma(pD)$

Future Extension

High-resolution (~100keV) spectroscopy of Λ hypernuclei by the ($\pi^{\pm}$,K^{+}) reactions

medium-/heavy- Λ hypernuclei

neutron-rich Λ hypernuclei

HIHR

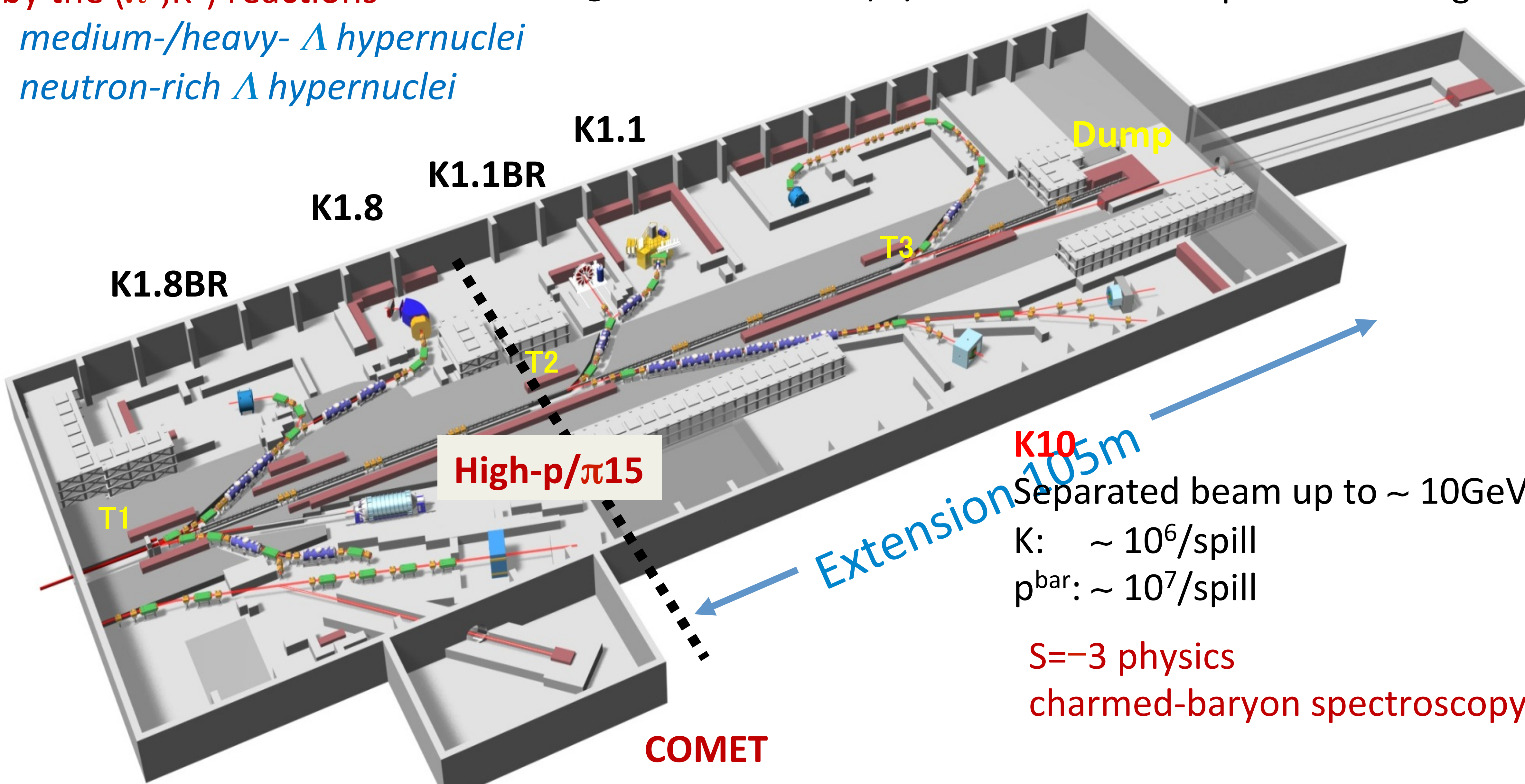
π beam up to 2GeV/c

High-intensity ~10^{9}/spill

High-resolution $\Delta p/p$ ~10^{-5}

KL

5°production angle



K10

Separated beam up to ~ 10GeV/c

K: ~ 10^{6}/spill

p^{bar}: ~ 10^{7}/spill

S=−3 physics

charmed-baryon spectroscopy