Meson2014@Krakow,
May 31, 2014

K^-pp search experiments at J-PARC

Tomofumi NAGAE (Kyoto University),
for J-PARC E15 & E27 collaborations

J-PARC E15 Collaboration

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[8] *High Energy Accelerator Research Organization (KEK), Tsukuba, 305-0801, Japan*
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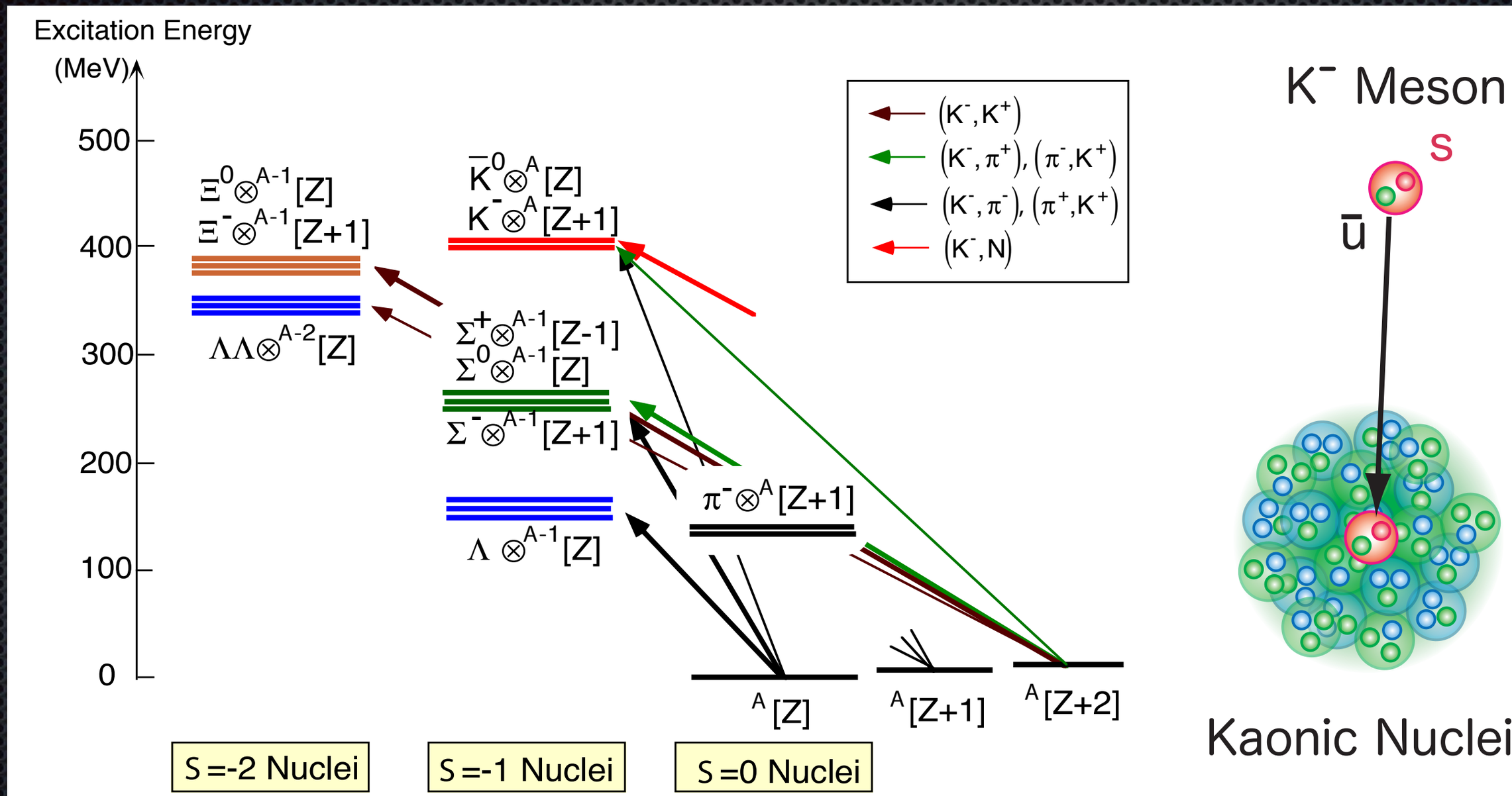
- E15 experiment : ^{3}He(K^-,n)"K^-pp" at 1 GeV/c
- E27 experiment : d(π^+,K^+)"K^-pp" at 1.69 GeV/c
- Summary

New type of Strange matter

- Strange Mesons ($\bar{K}$, K^-) in nuclei

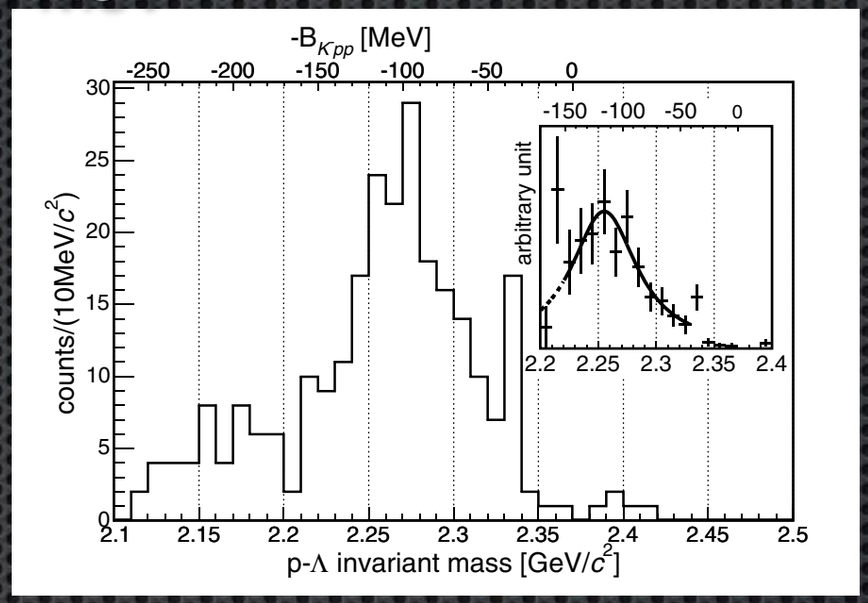


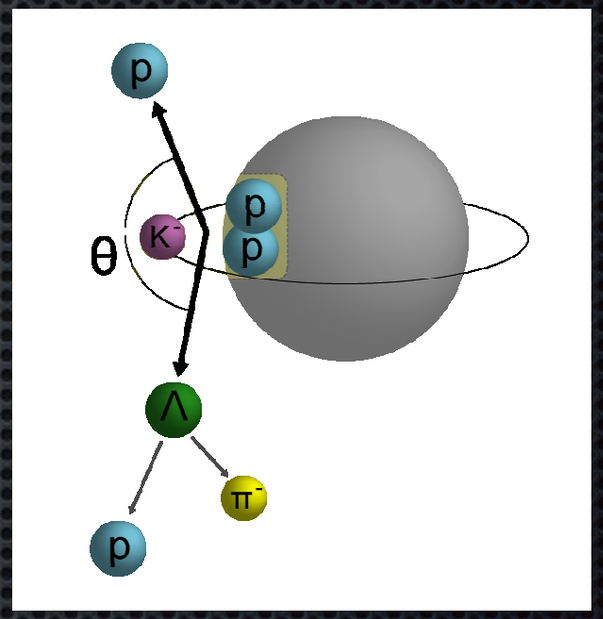
K^-pp

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

Experiments on K^-pp

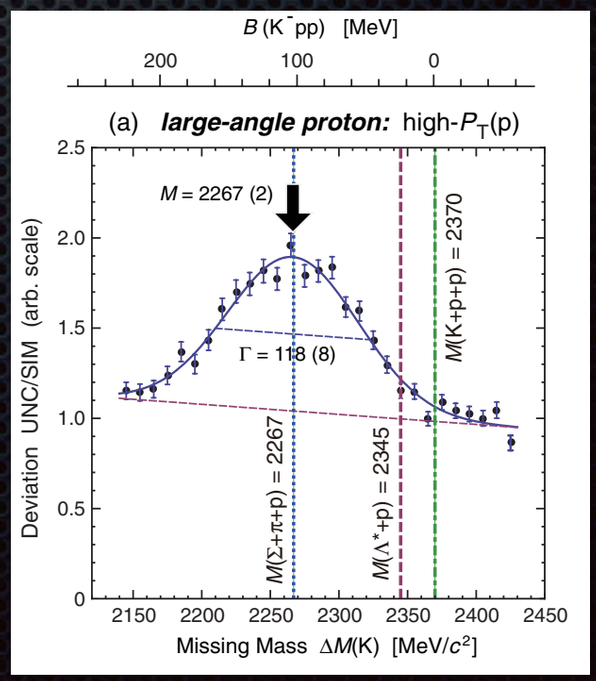
- First evidence of K^-pp with ^{6}Li+^{7}Li+^{12}C by FINUDA
  M. Agnello et al., PRL94, (2005) 212303
  B=115+6/-5+3/-4 MeV
  Γ= 67+14/-11+2/-3 MeV





- 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.
- Λ*N bound state ? ; T. Uchino et al., NPA 868-869 (2011) 53.

K^-pp Searches at J-PARC

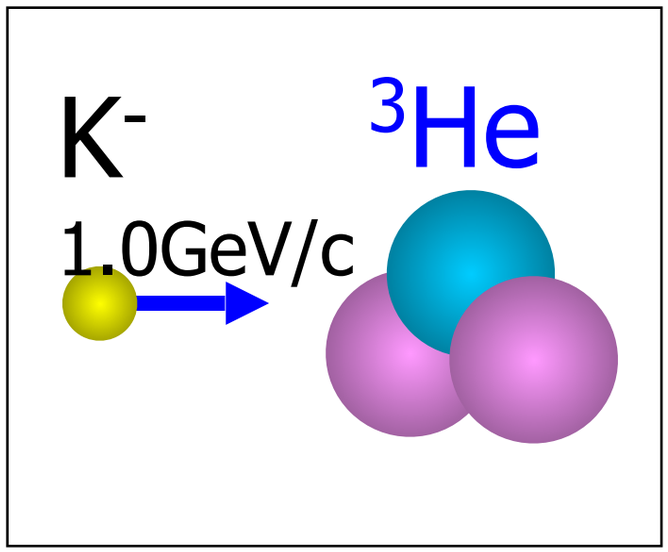
- E15 : ^{3}He(K^-,n/p)"K^-pp", "K^-pp"→Λp, Σ^0p at 1 GeV/c
  - K^-"n"→n+"K^-", "K^-"+"pp"→K^-pp
  - Exclusive measurement
    - K^-pp→Λp, Σ^0p
  - Isospin dependence
- E27 : d(π^+,K^+) with proton(s) coin. at 1.69 GeV/c
  - Λ(1405) as a doorway; π^+"n"→K^+Λ*(1405), Λ*p→K^-pp
  - Semi-exclusive
    - K^-pp→p+Y, p+p+π+(γ, π)

E15 Experiment

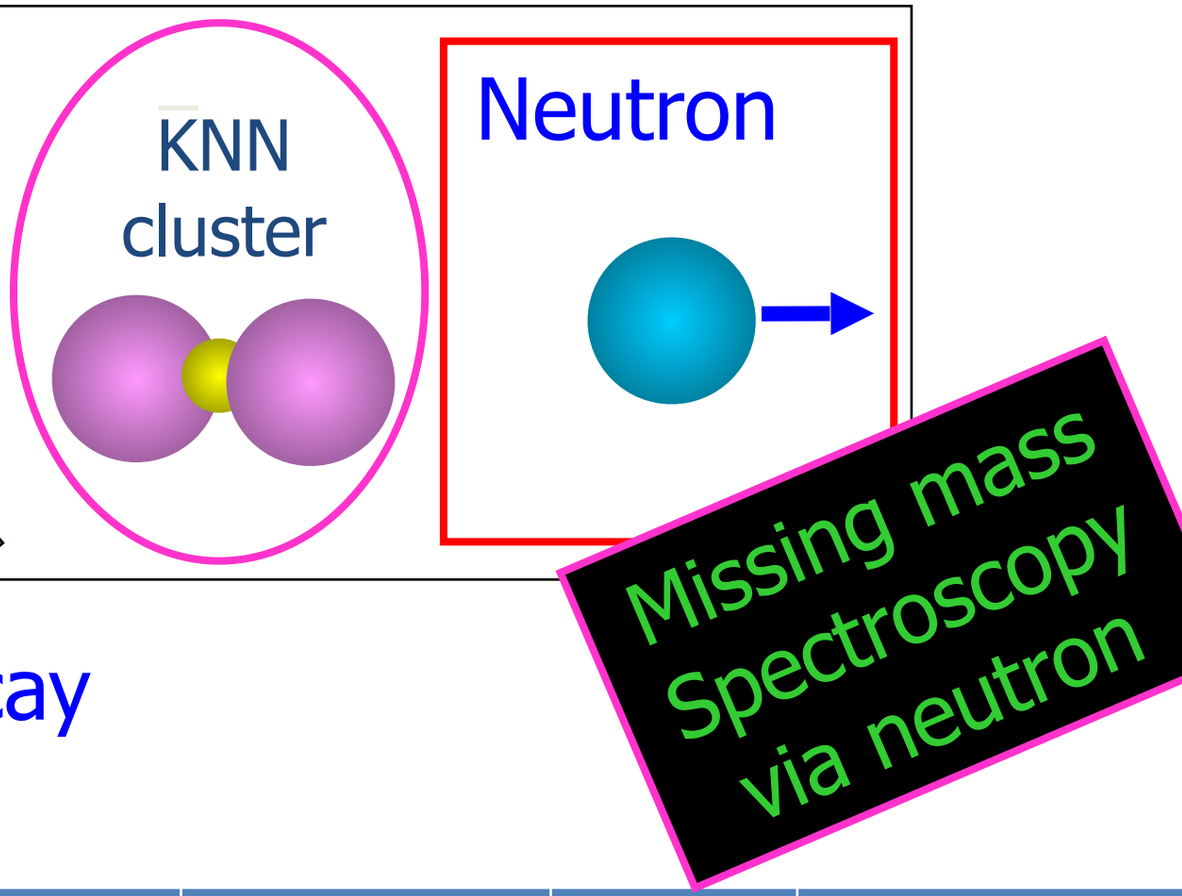
Y. Sada on June 2 (A3)

in-flight ^{3}He(K^-, n) reaction & its exclusive measurement

→ Search for KNN bound states both via formation & Decay

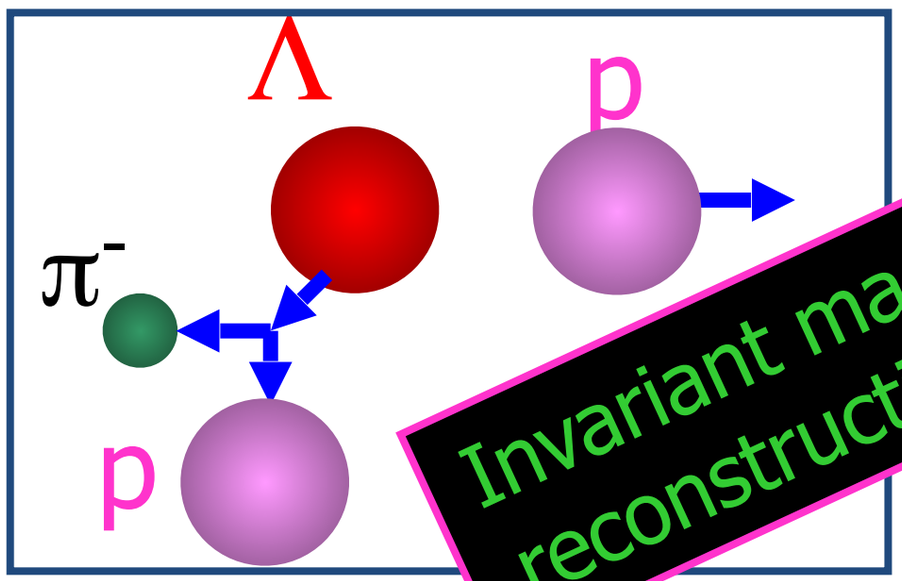


Formation



Decay

Mode to decay charged particles



Invariant mass reconstruction

	Primary-beam intensity	Duration	Kaons on target (w/ tgt selection)
March, 2013 ***(Run#47)***	***14.5 kW*** ***(18 Tppp, 6s)***	***30 h***	***1.1 x 10***
May, 2013 ***(Run#49c)***	***24 kW*** ***(30 Tppp, 6s)***	***88 h***	***5.1 x 10***

J-PARC K1.8BR spectrometer

beam dump

beam sweeping magnet

liquid ^{3}He-target system

CDS

beam line spectrometer

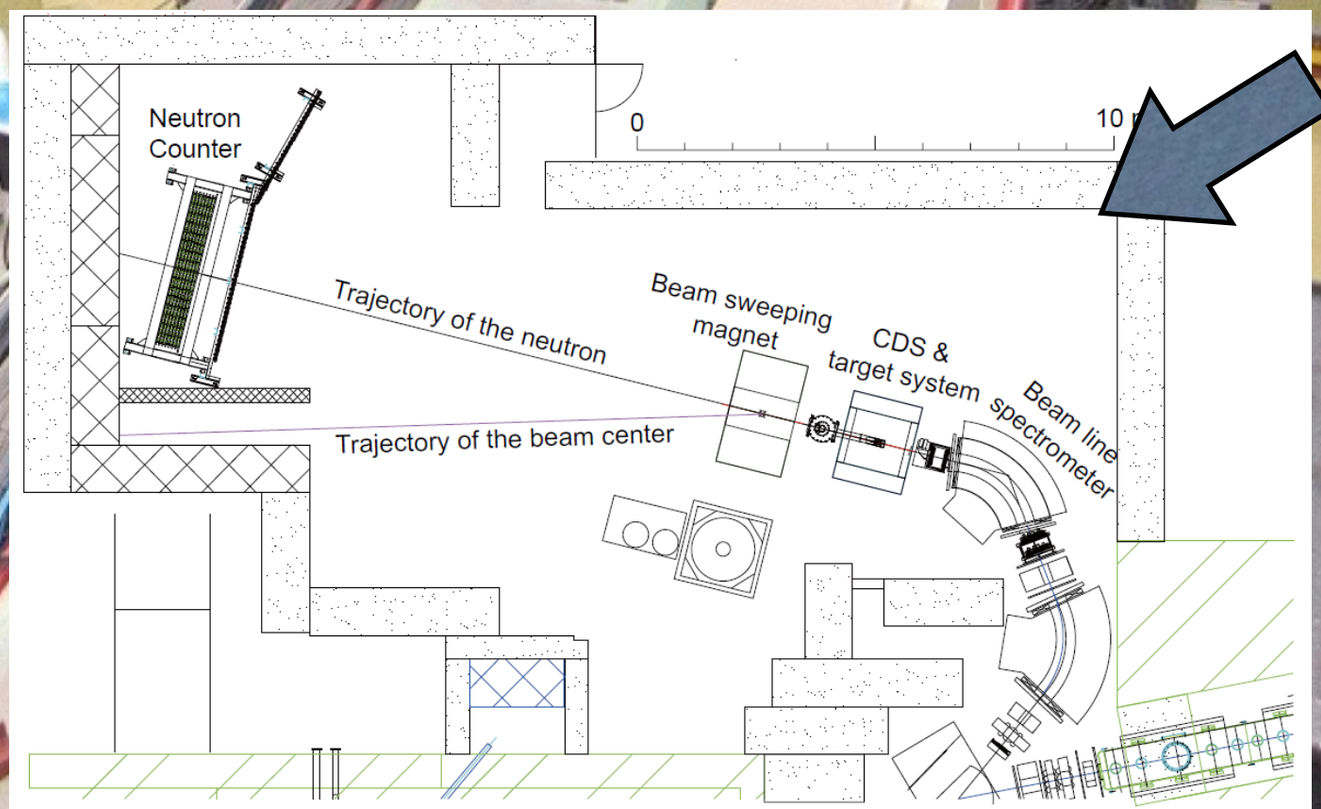
K-

γ, n

p

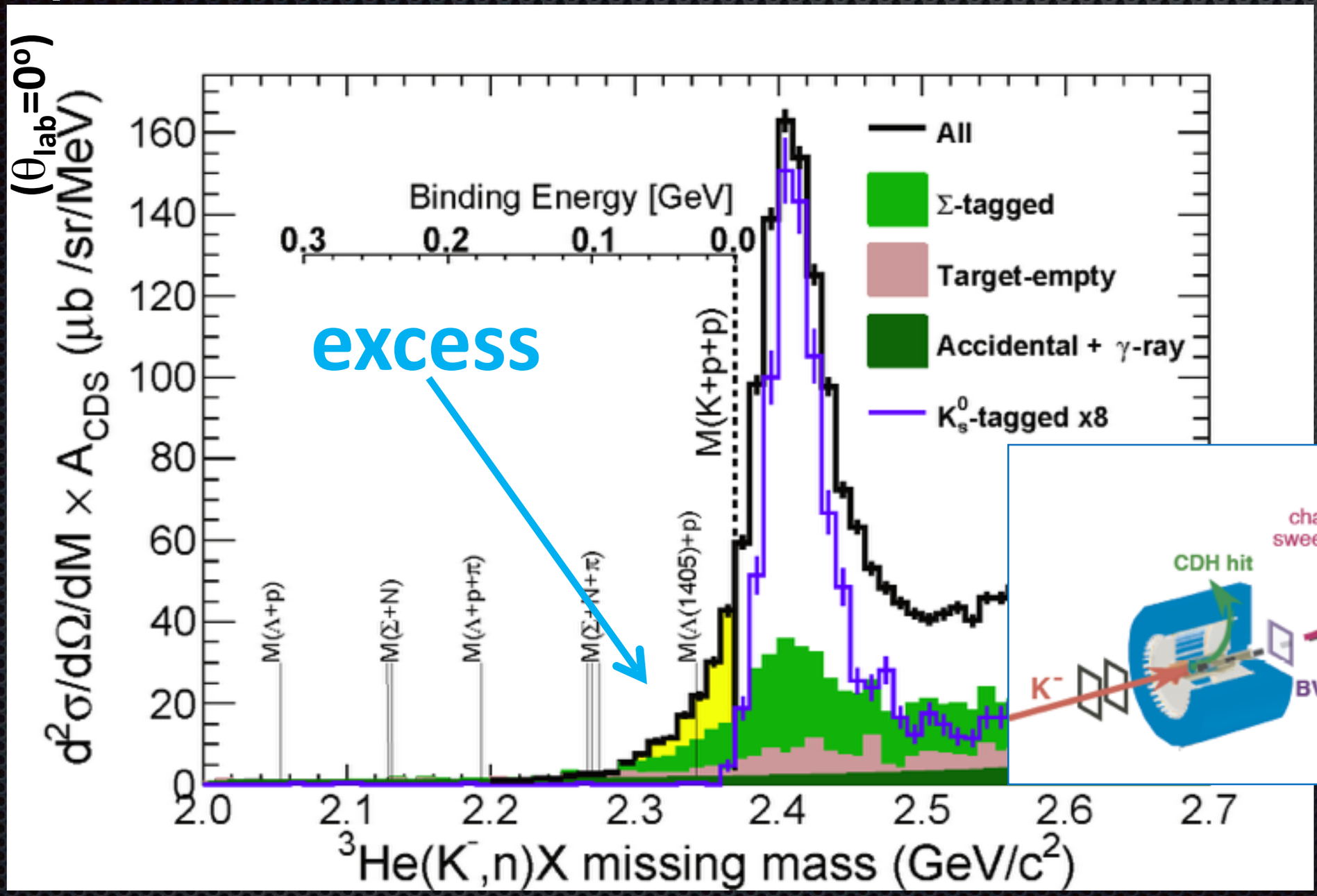
15m

neutron counter
charge veto counter
proton counter



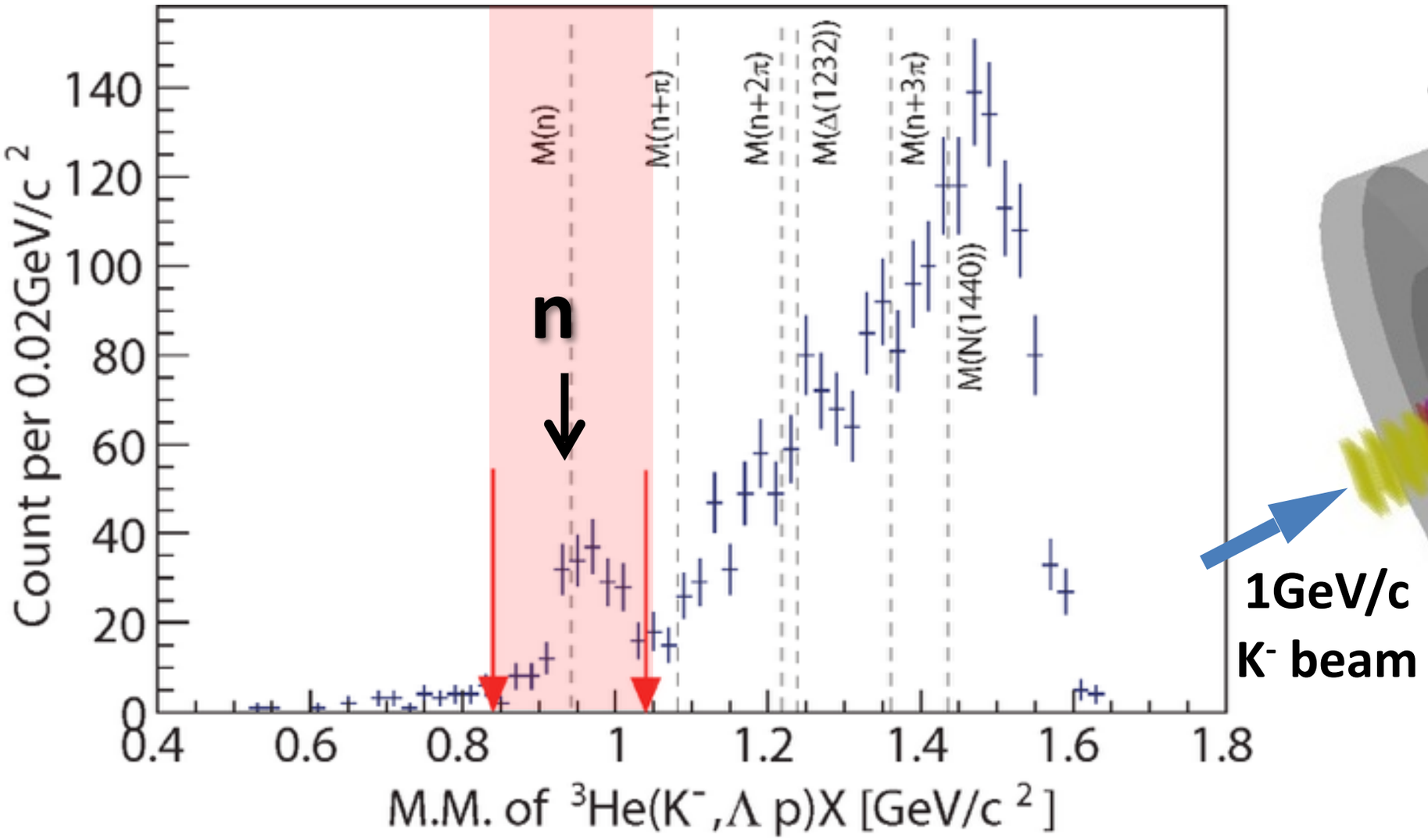
K. Agari et. al., PTEP 2012, 02B011

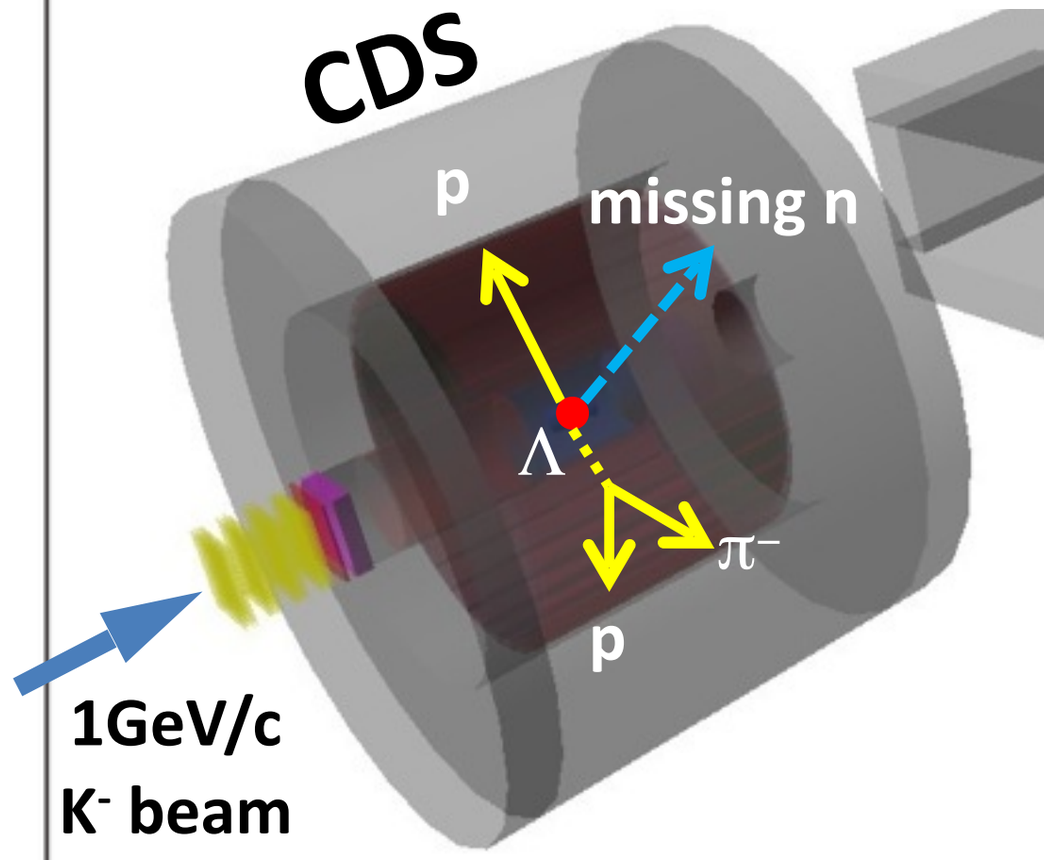
Semi-inclusive ^{3}He(K^-,n)X M.M. spectrum



- CANNOT be explained by any experimental effects nor well-known elementary processes

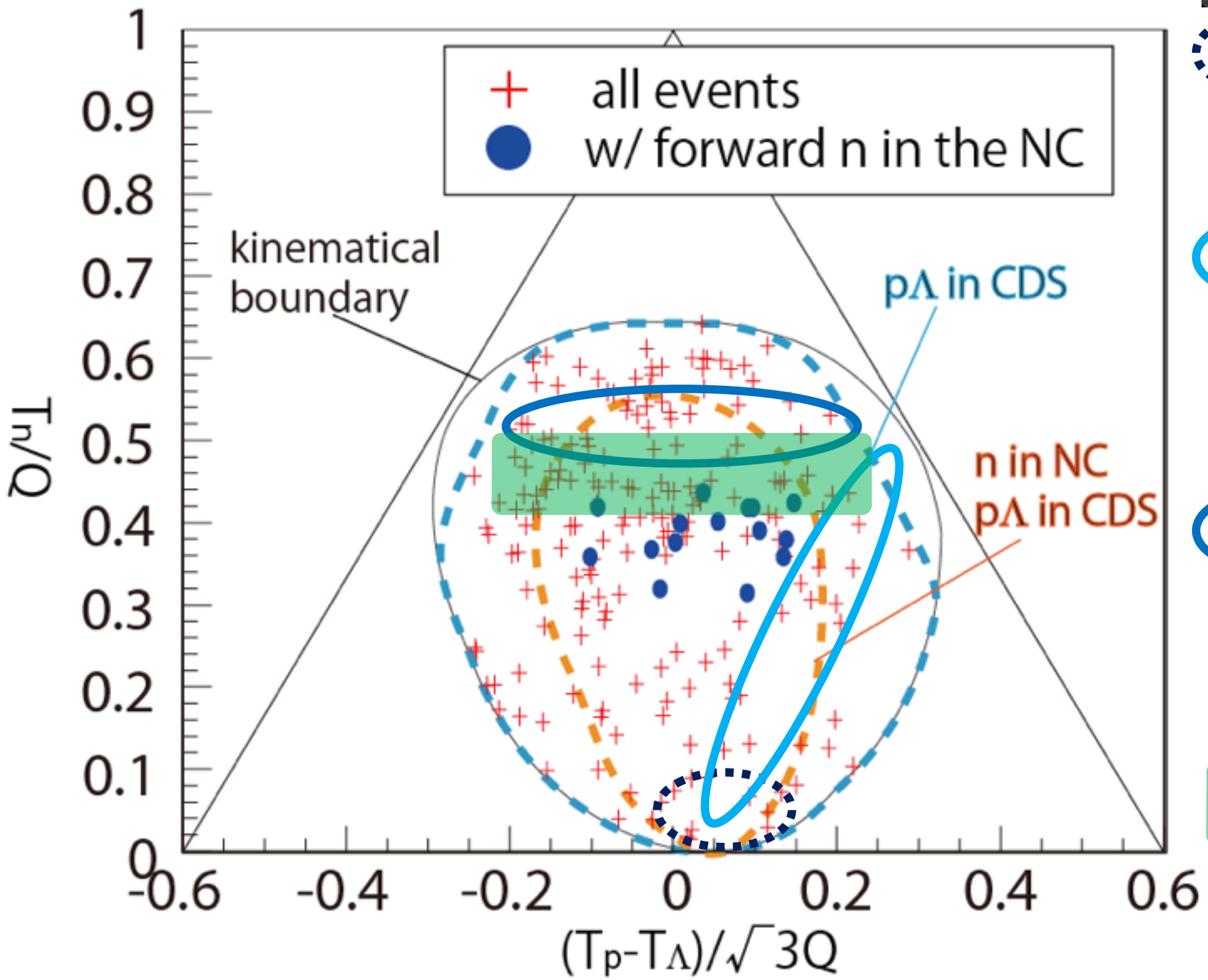
Exclusive ^{3}He(K^{-},Λp)n events





- $K^{-3}He \rightarrow \Lambda(\Sigma^0)pn$ events are exclusively identified ~ 190 events
- $\Sigma^0 pn$ contamination ~ 20%

^{3}He(K^-,Λp)n ; Dalitz plot



2NA:
e.g. $K^{-3}He \rightarrow \Lambda p n_s$

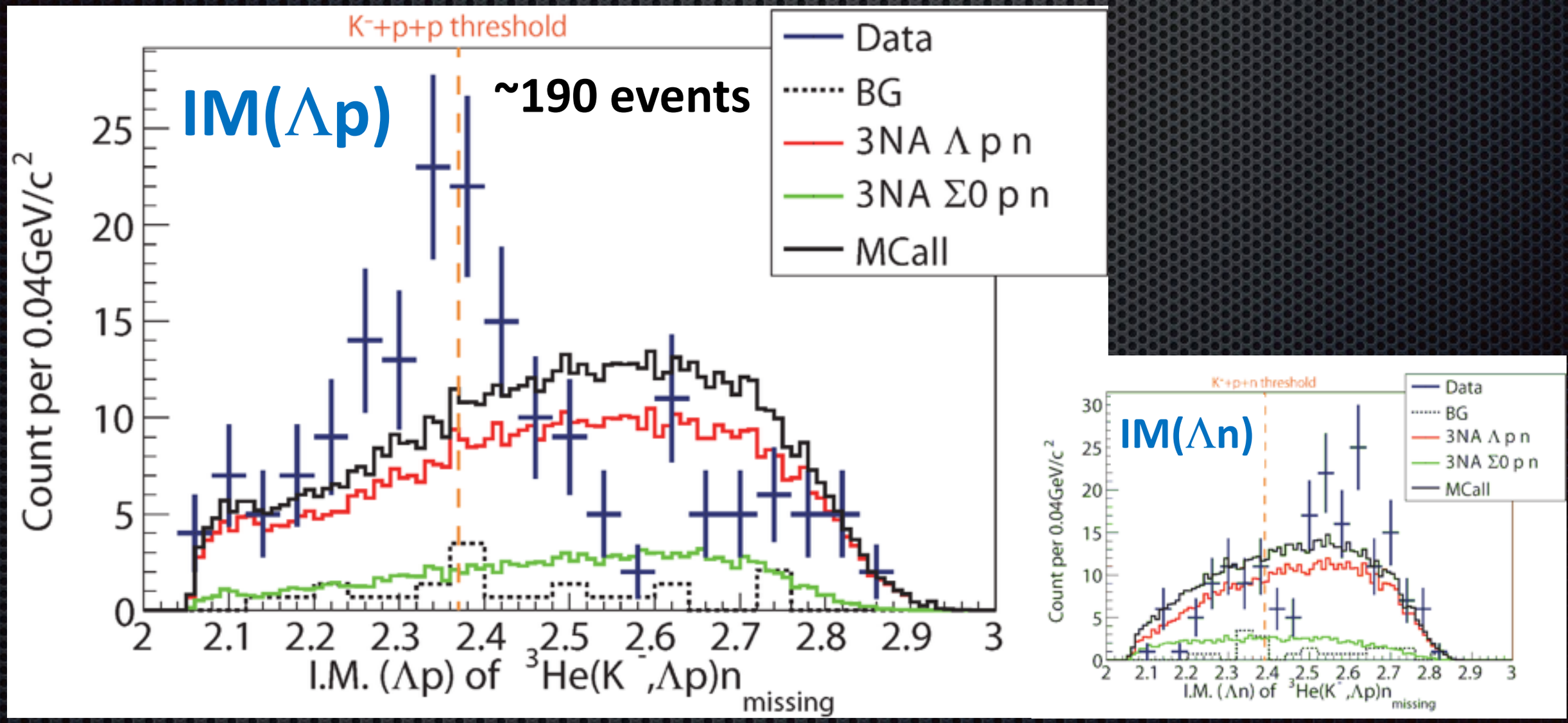
2NA+2step:
e.g. $K^{-3}He \rightarrow \Sigma^0 p n_s$,
$\Sigma^0 n_s \rightarrow \Lambda n$

2NA+2step:
e.g. $K^{-3}He \rightarrow \Sigma^0 n p_s$,
$\Sigma^0 p_s \rightarrow \Lambda p$

K^-pp form.:
$K^{-3}He \rightarrow (K^-pp)n$,
$K^-pp \rightarrow \Lambda p$

- Events are widely scattered in phase-space(Λ-p-n)

^{3}He(K^{-},Λp)n ; Invariant mass



- Total CS :~200μb (assuming phase-space distrib.)

  (~ 0.1% of total cross section of K^{-3}He)

E15 Summary

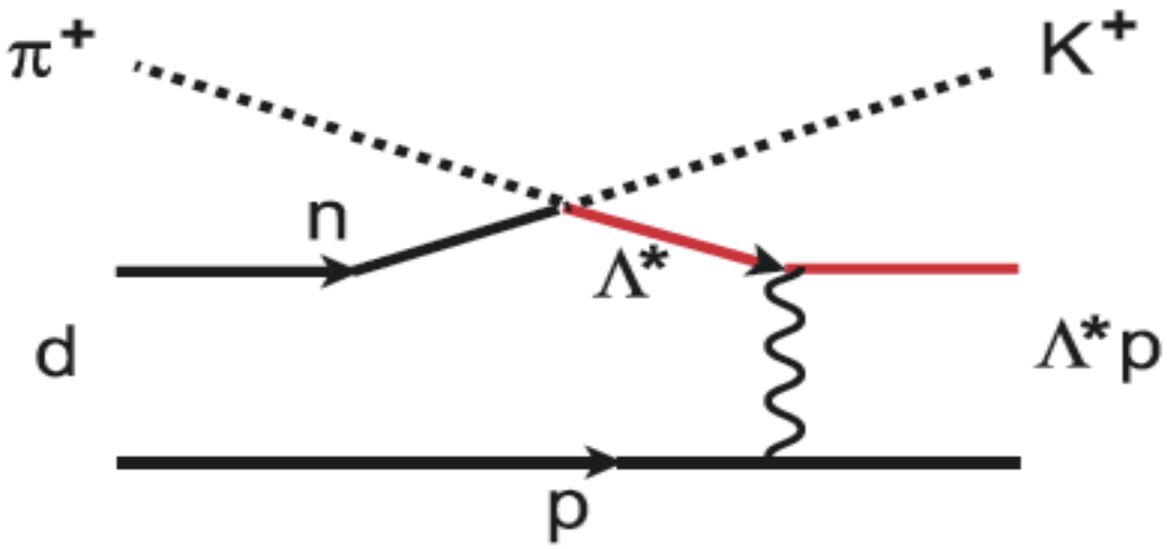
- $K^{-}{}^{3}He$ reaction at 1 GeV/c : 4-days data taking was successful.
  - Excess below the $K^{-}pp$ threshold in (K^{-},n) spectrum.
    - $^{3}He(K^{-},\Lambda p)n$ exclusive process (3-nucleon abs.?) was observed.
- Next physics data taking in 2015 : 10 times more data !

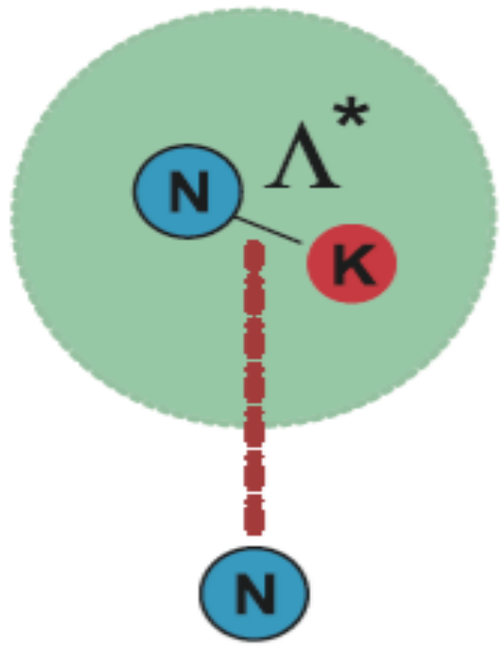
E27: $d(\pi^+,K^+)$ reaction

π^+ + "n" --> "Λ^*" + K^+

"Λ^*" + "p" --> bound K^-pp ***minor***

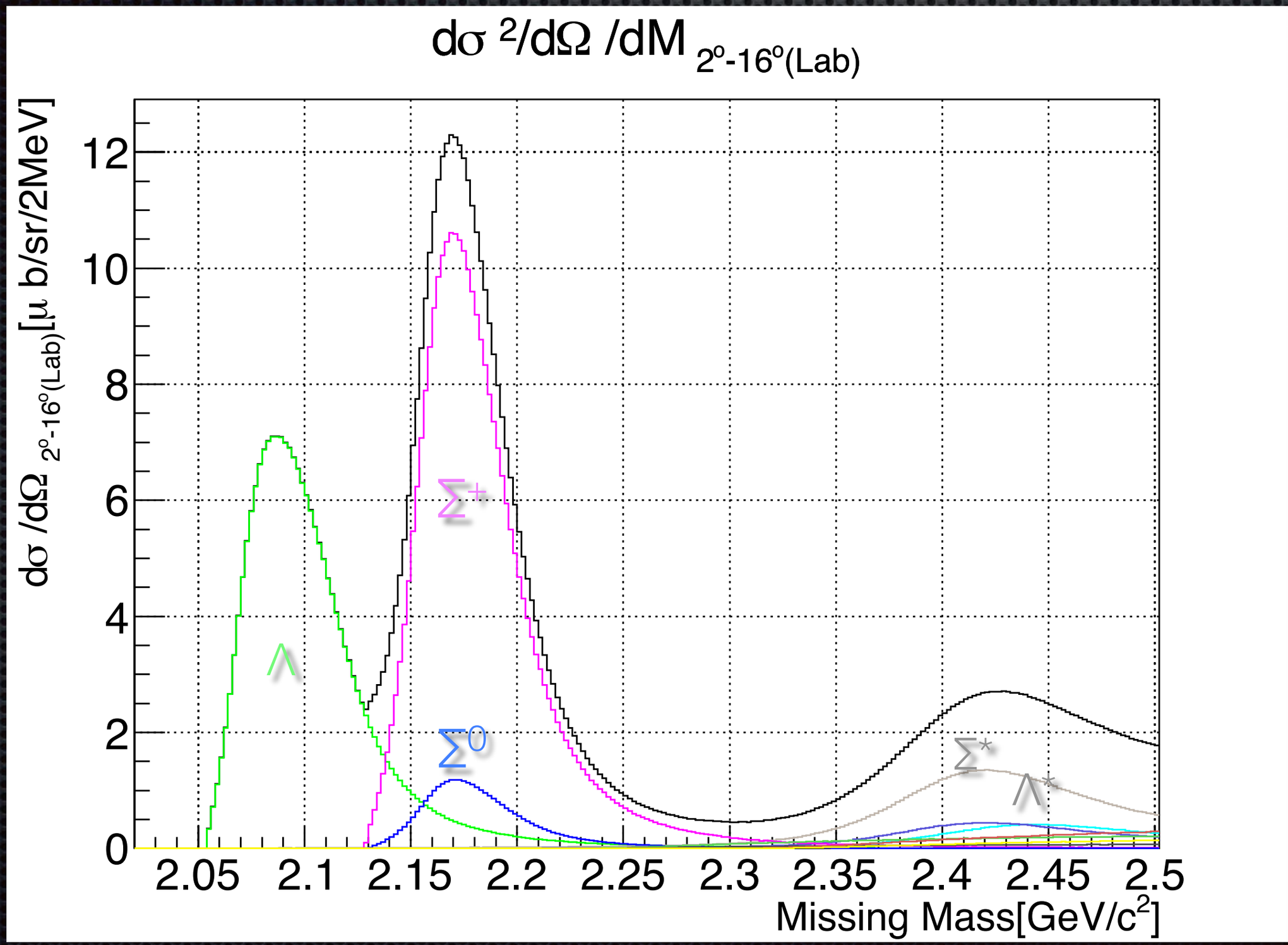
--> quasi-free Λ^* ***dominant***



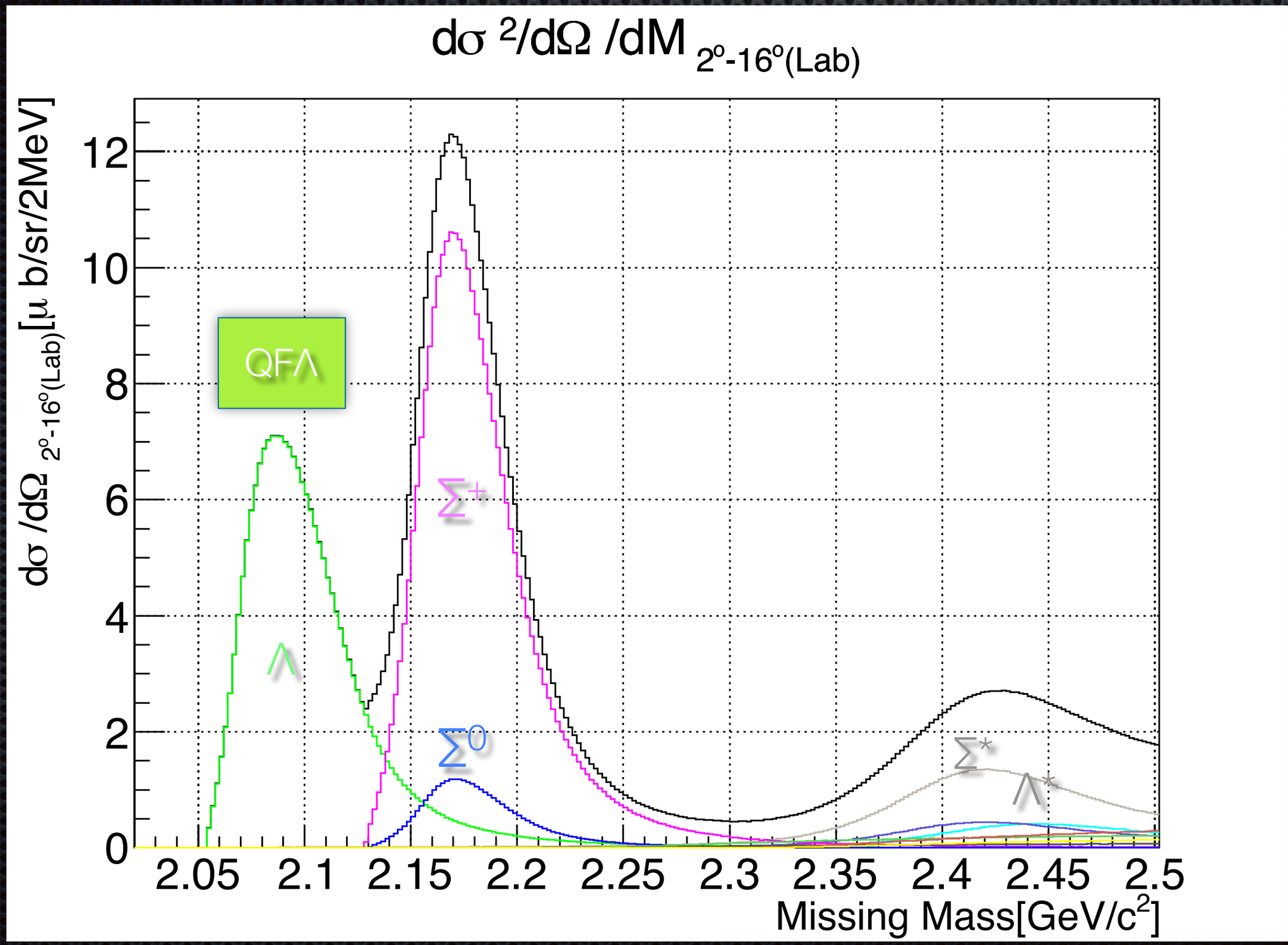


Yamazaki & Akaishi, Phys. Rev. C76 (2007) 045201.

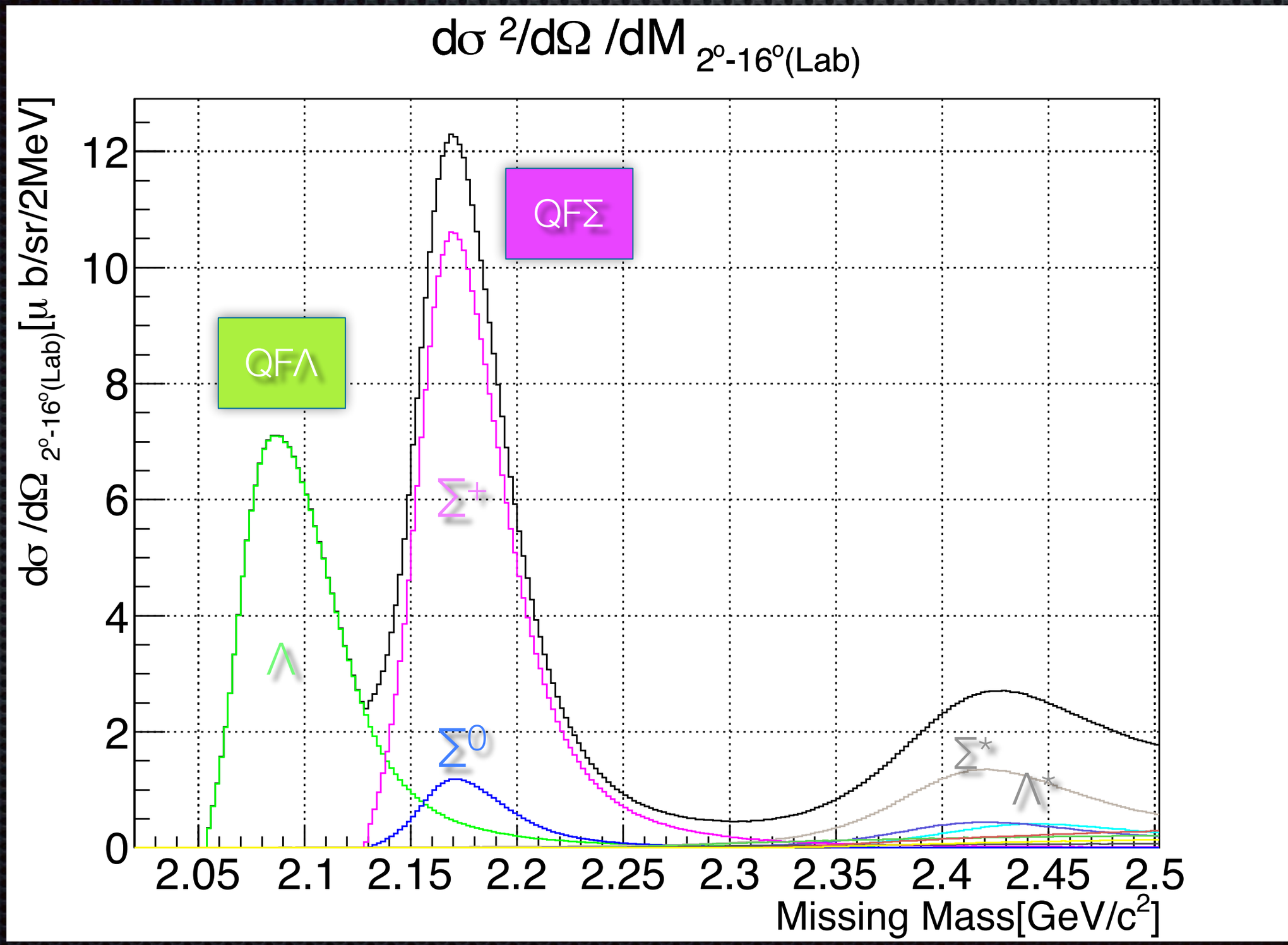
d(π⁺,K⁺) inclusive spectrum; in simulation



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



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



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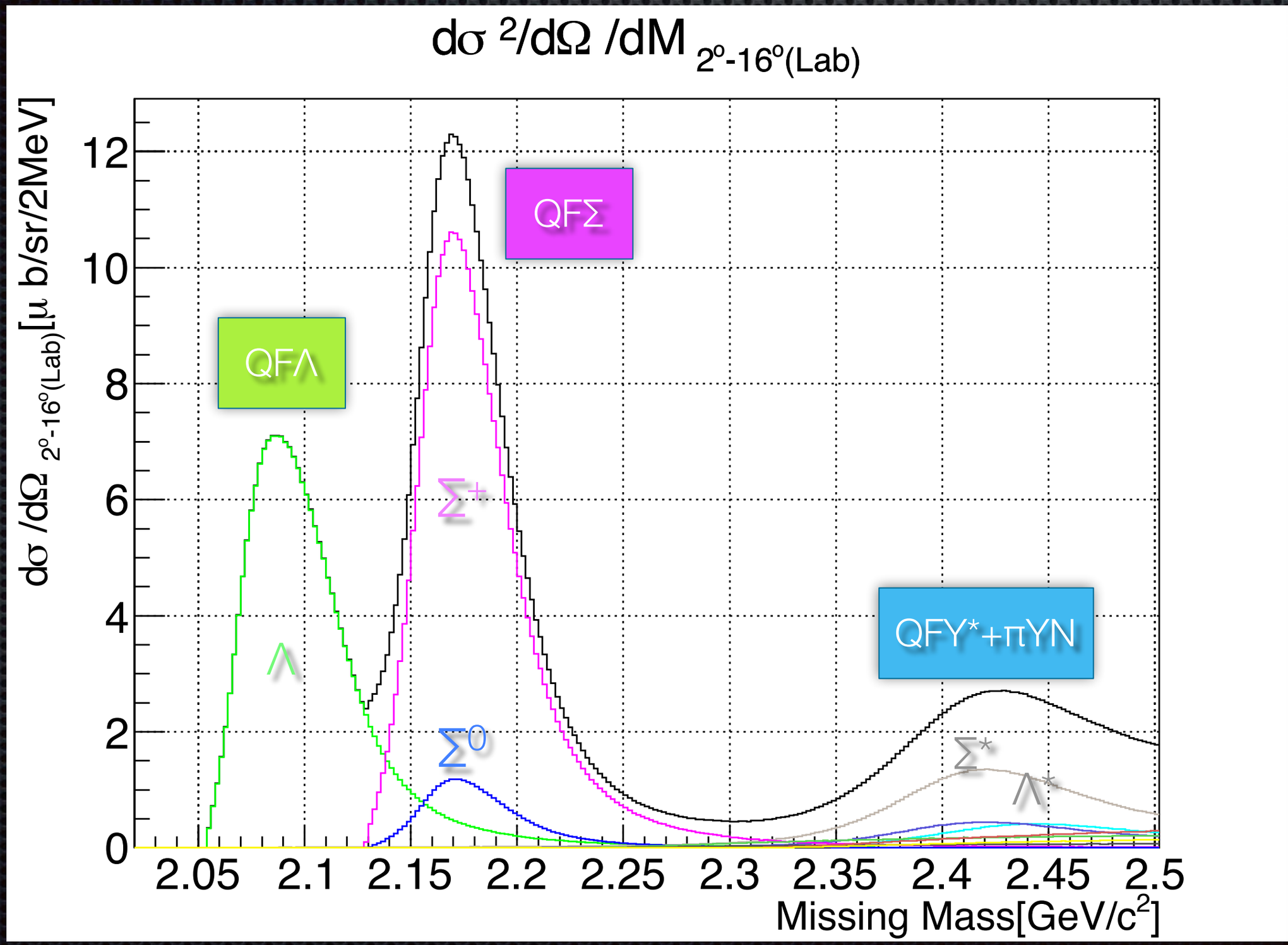
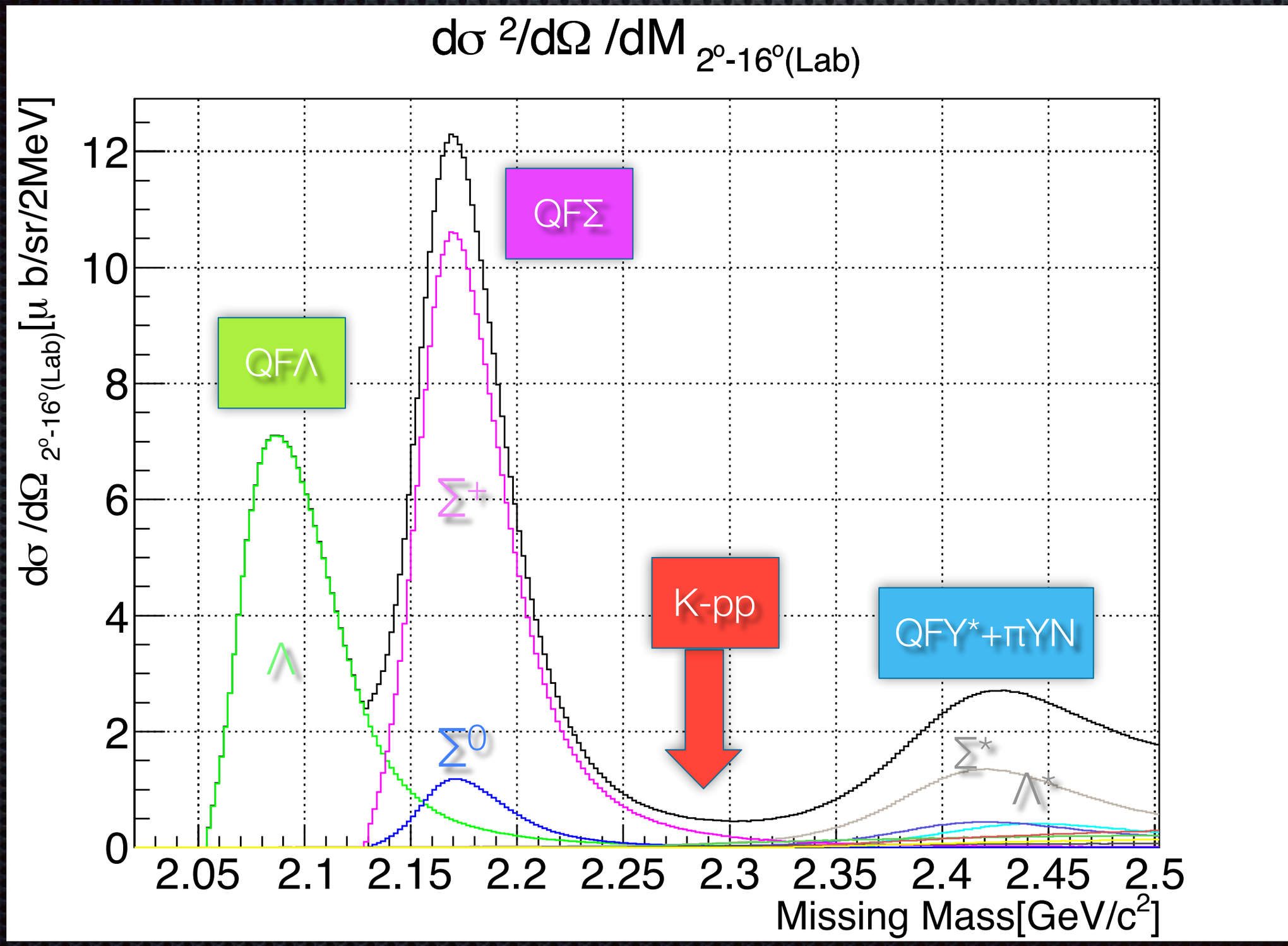
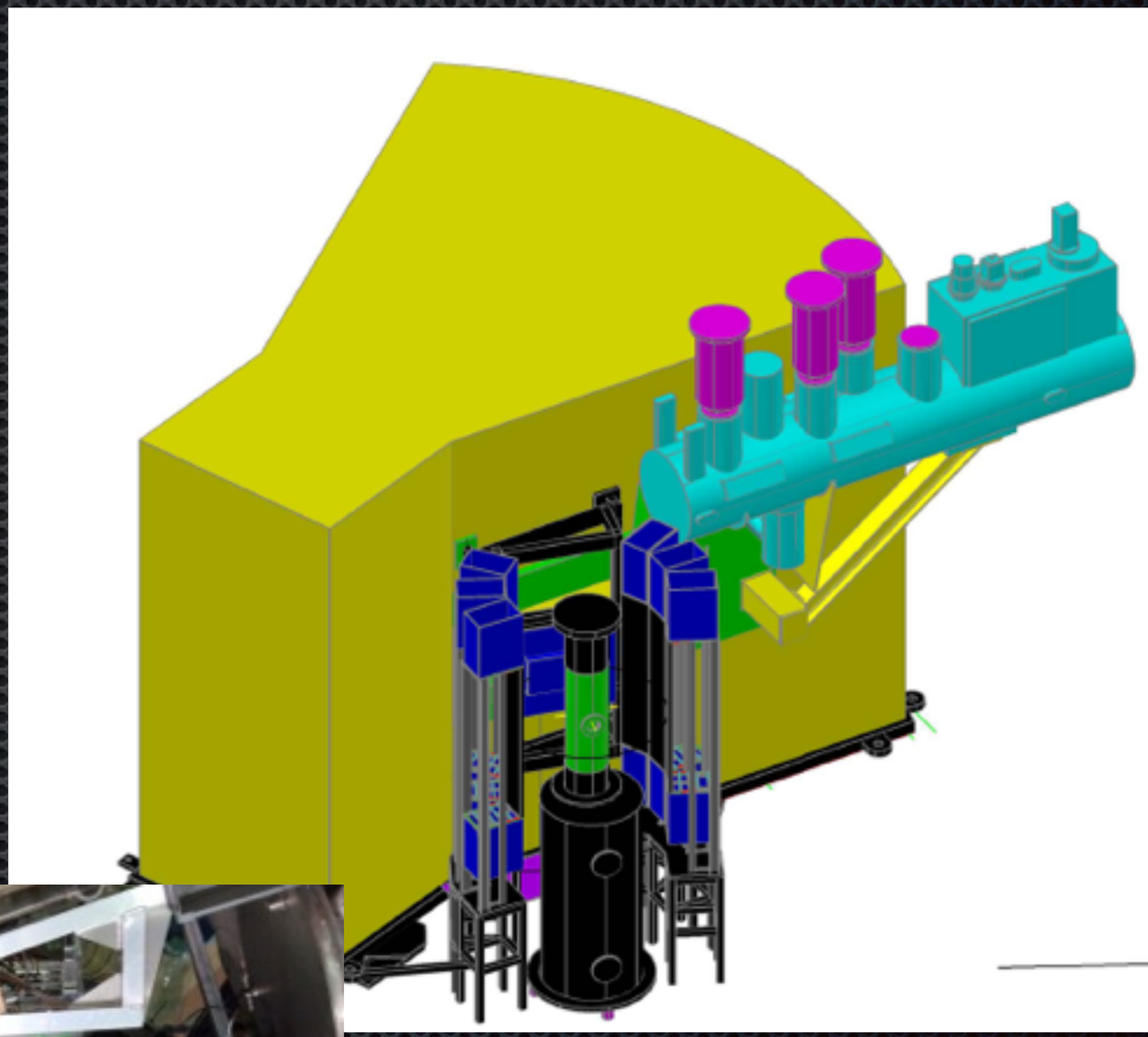


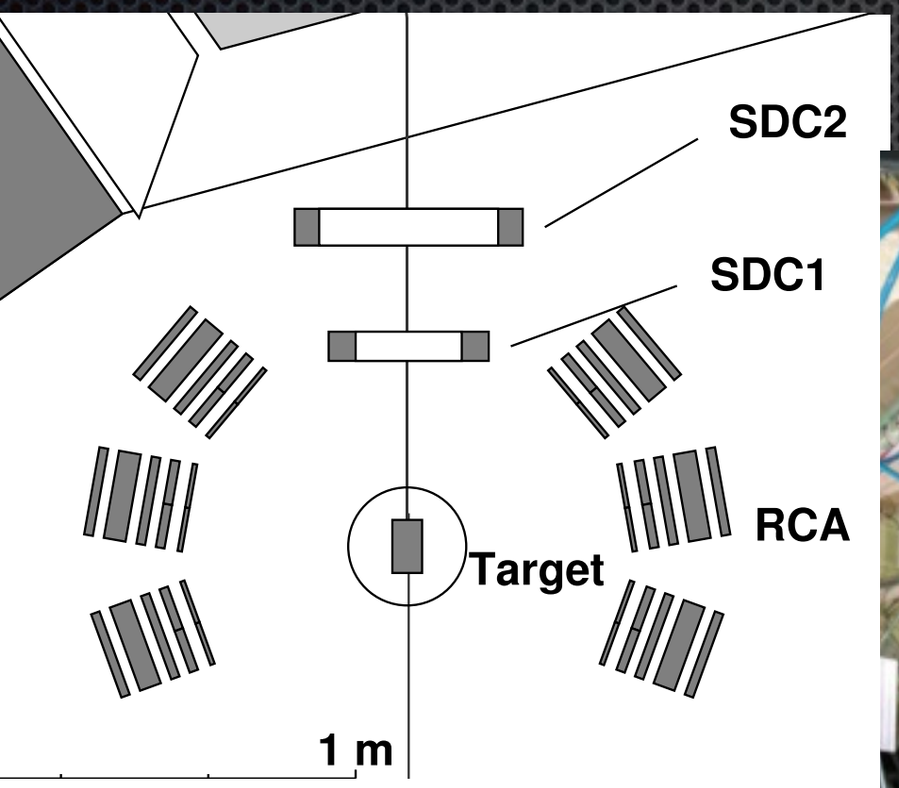
d(π⁺,K⁺) inclusive spectrum; in simulation

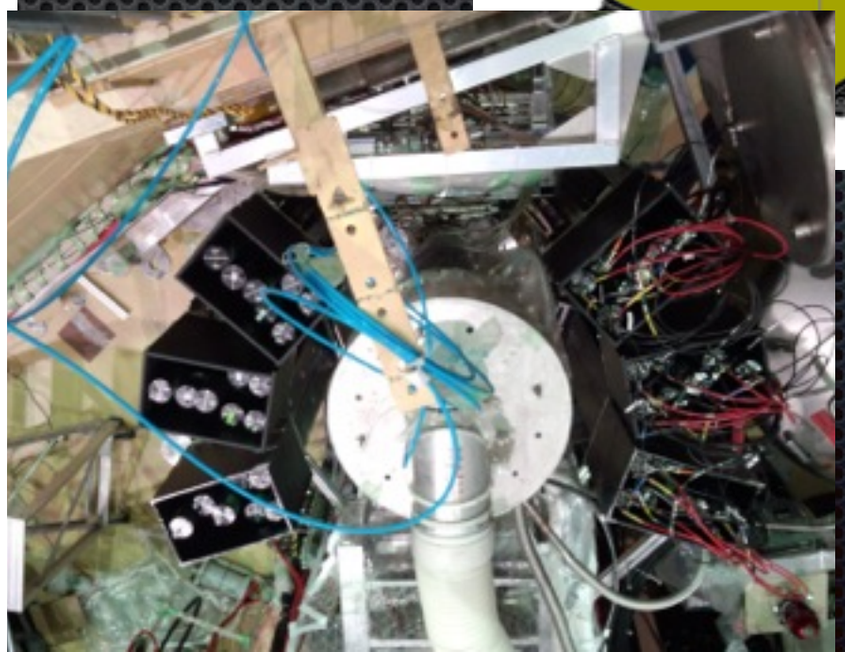


Range Counter System for E27

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

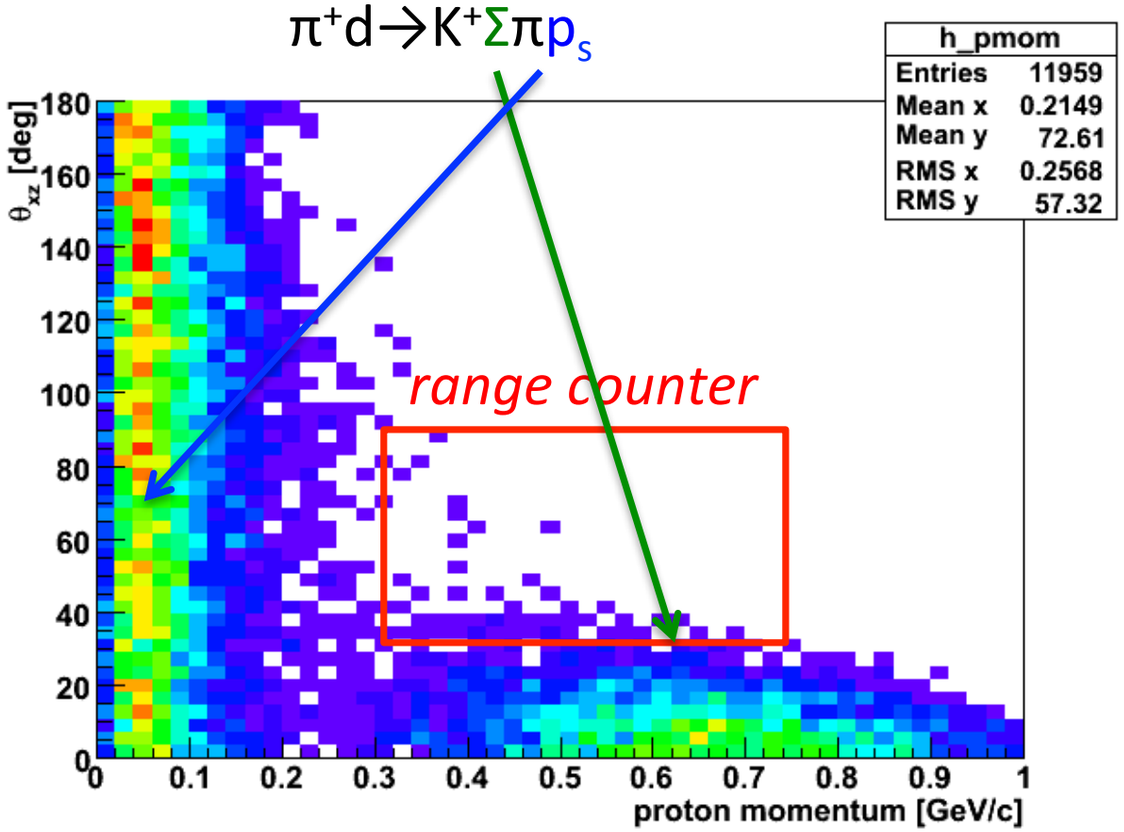




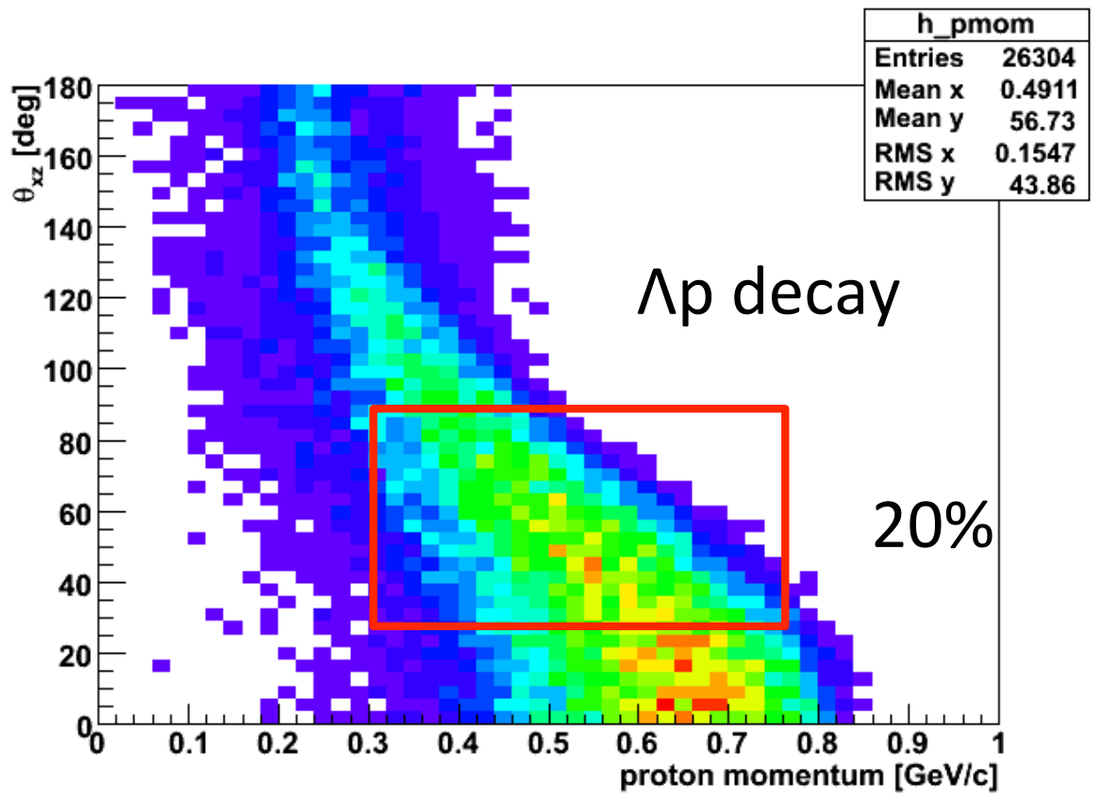


One-proton tagging

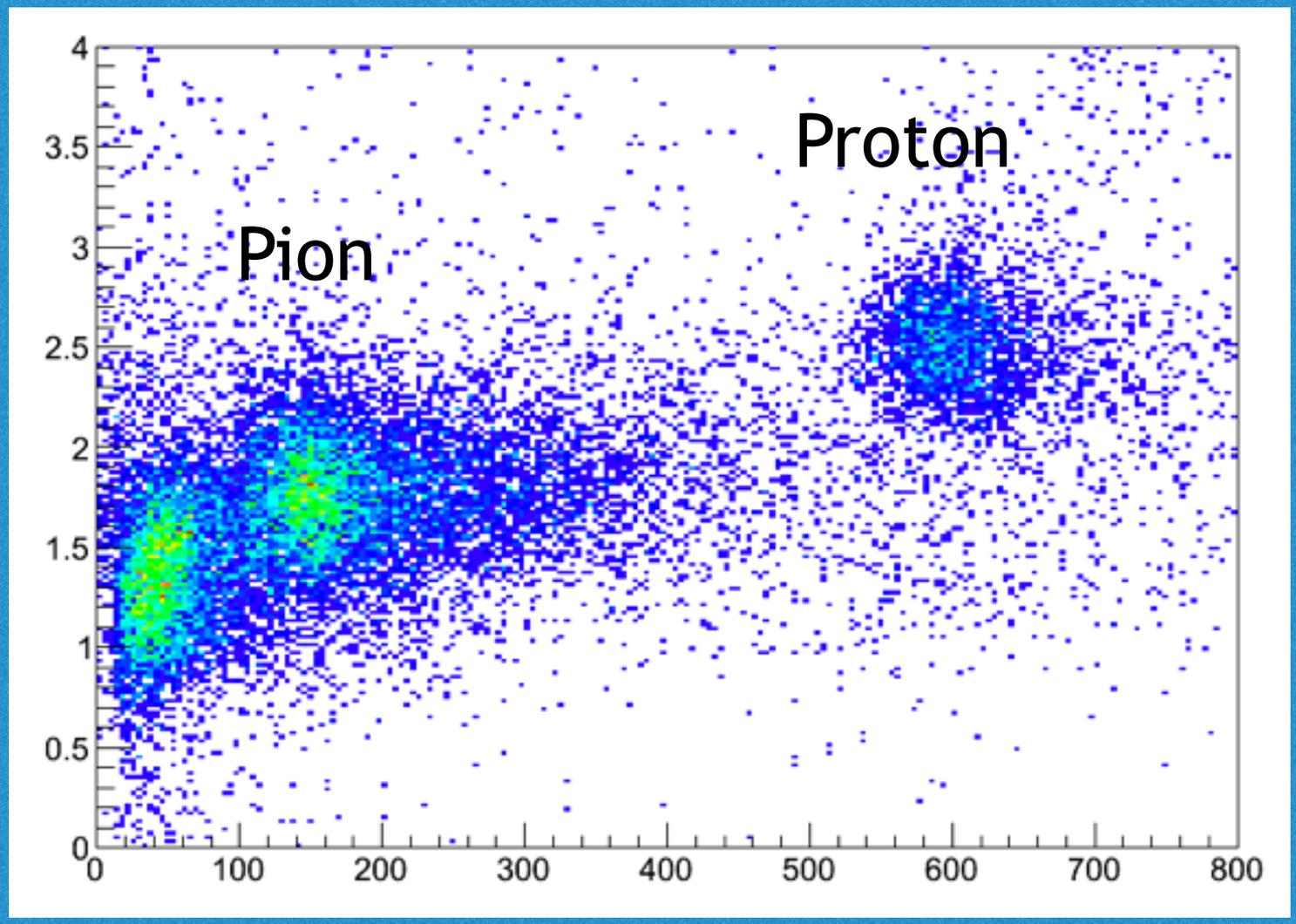
Quasifree Y productions



Non-mesonic decay from K-pp

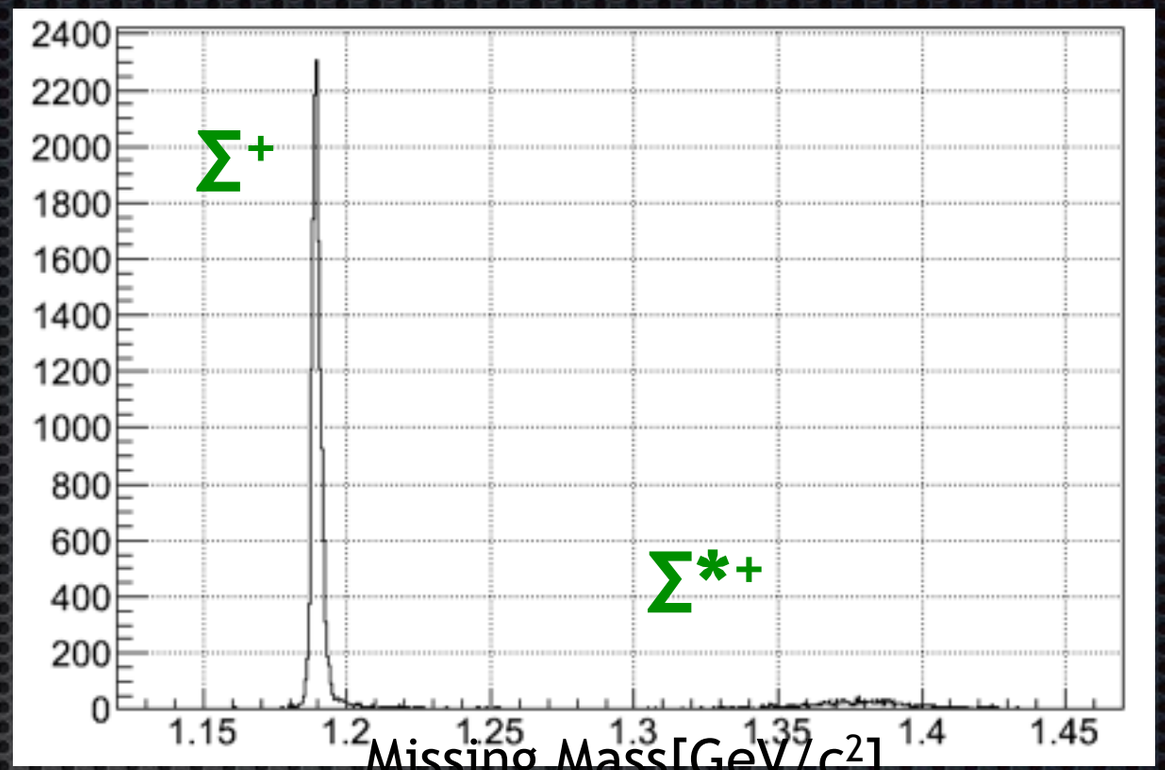


Particle Identification in Range Counter

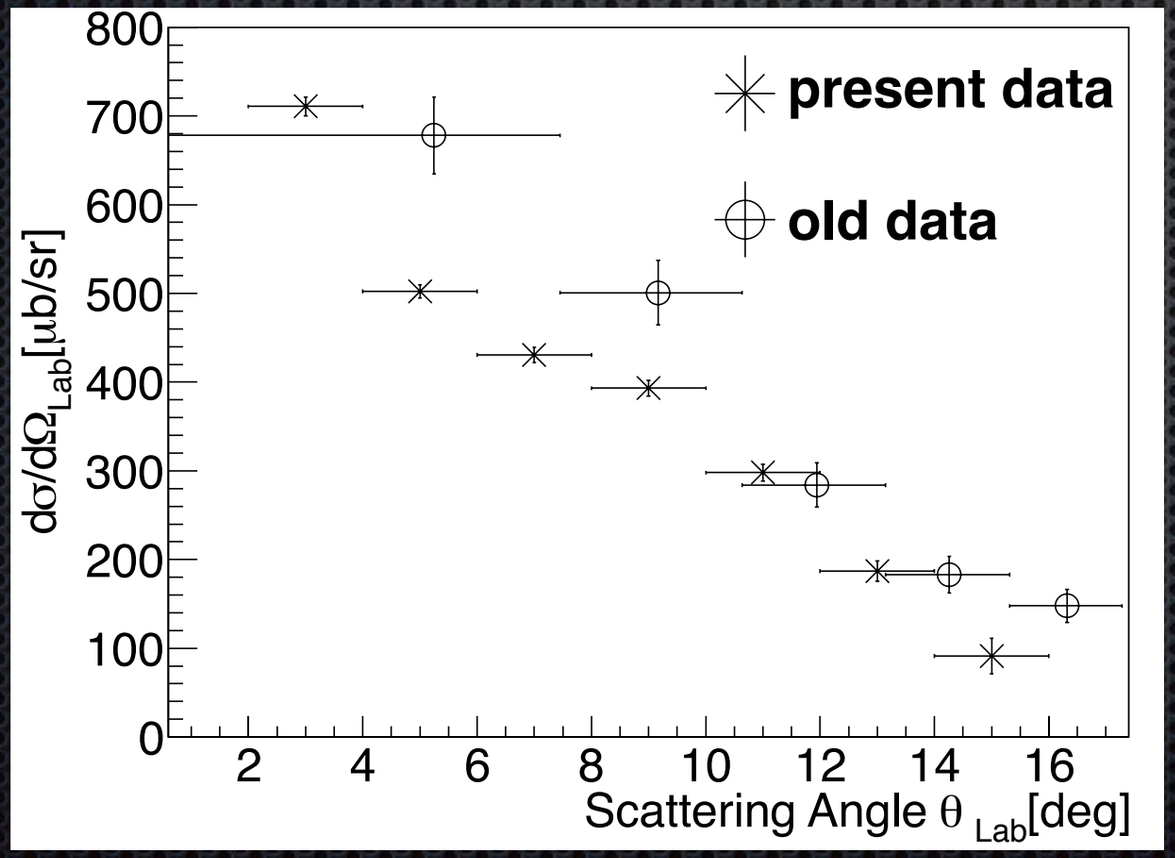


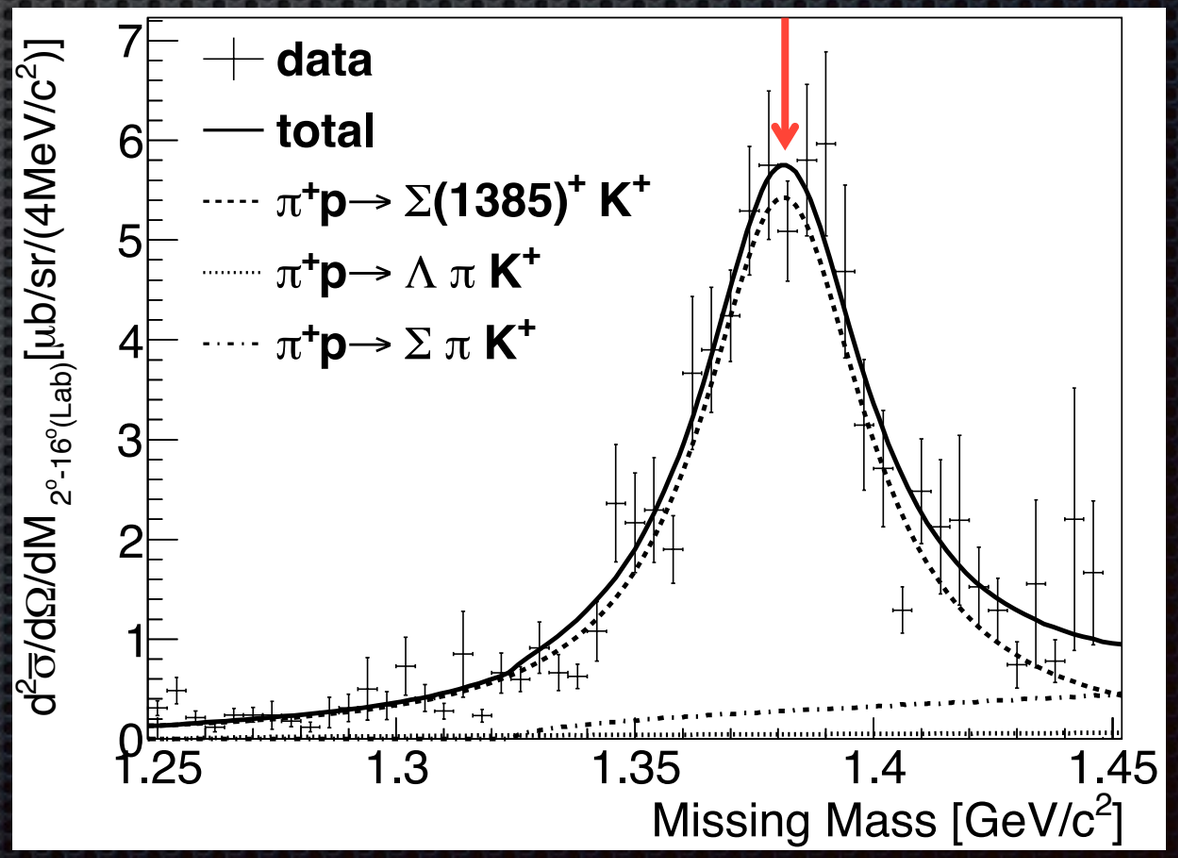
$p(\pi^+,K^+)$1.69 GeV/c

- Σ^+ production
  - ΔM = 3.2MeV(FWHM)
  - Mass = 1188.92MeV
- $\Sigma^+(1385)$ production
- $Y\pi$ production



$p(\pi^+,K^+)\Sigma^+$ @1.69 GeV/c





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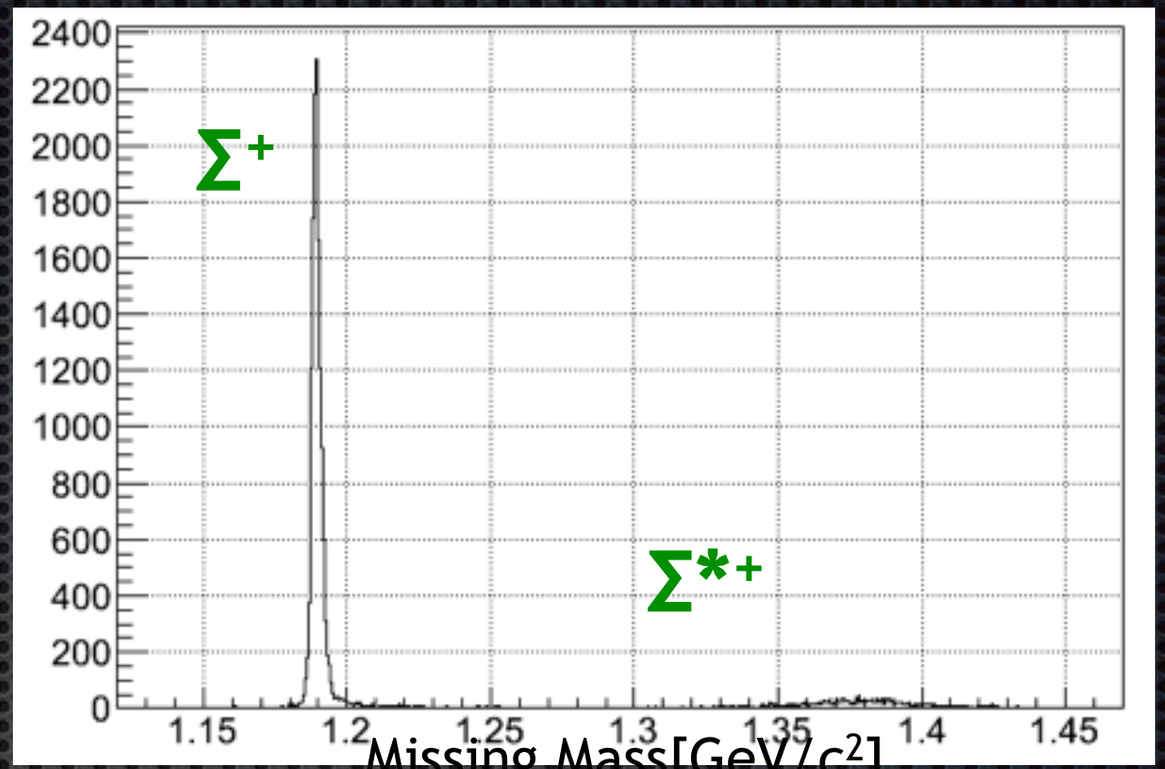
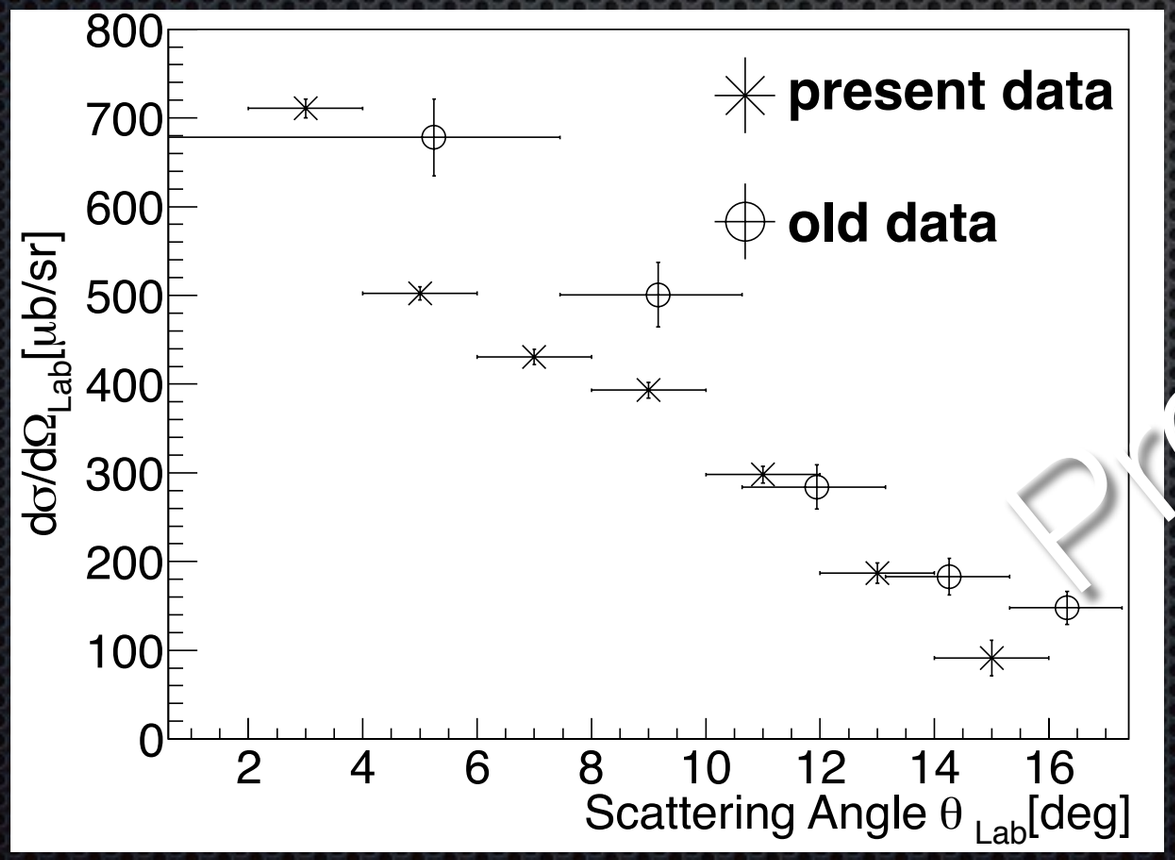
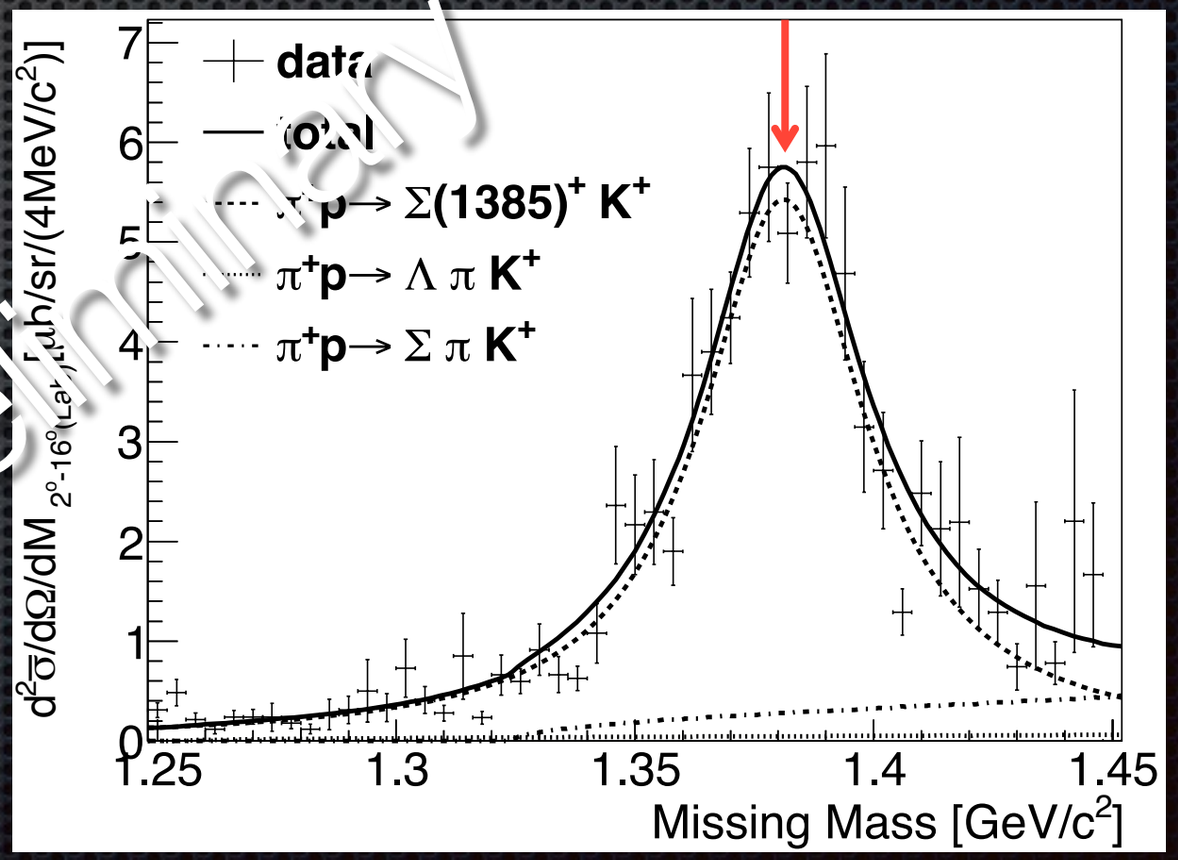


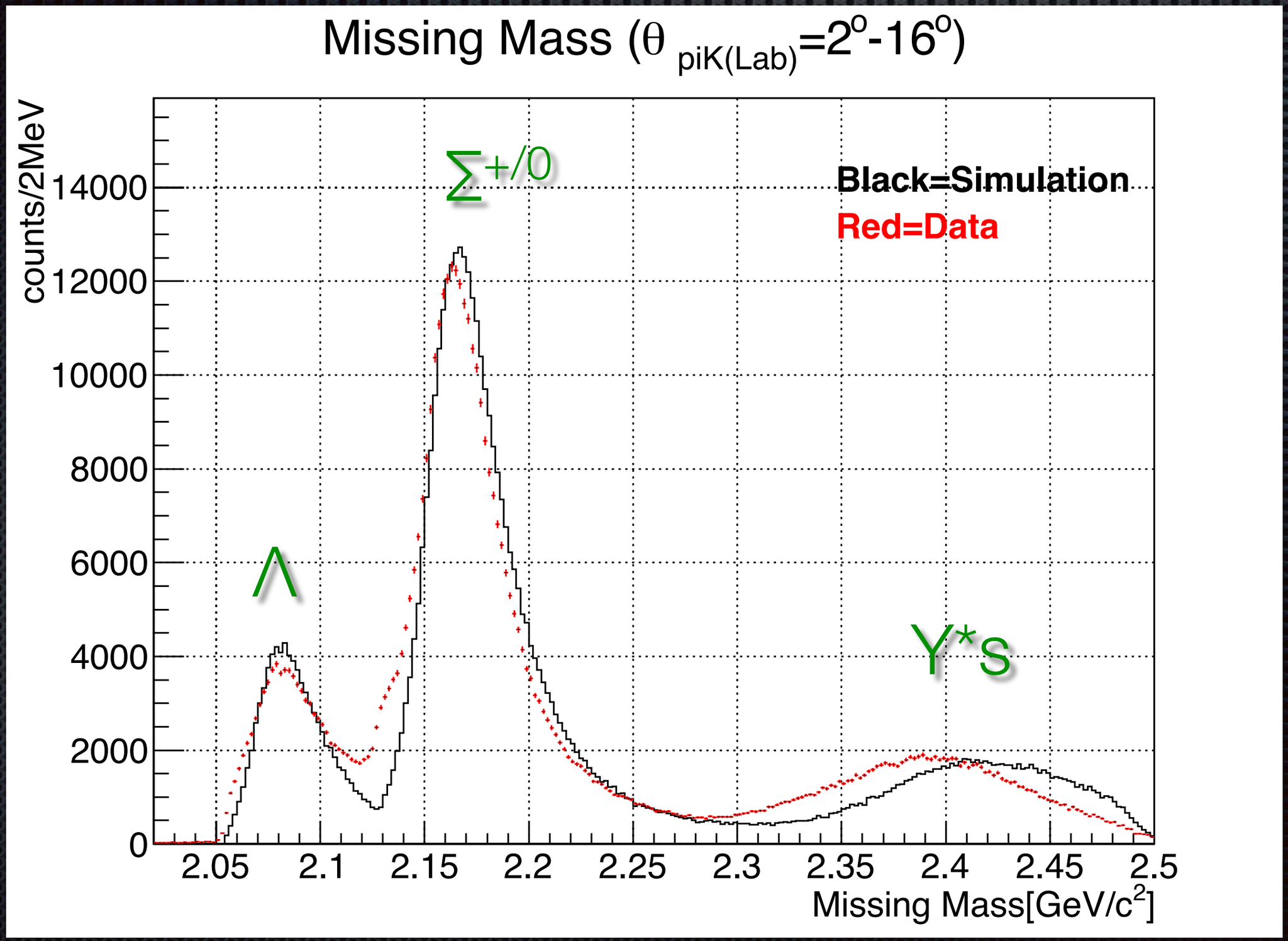
$p(\pi^+,K^+)\Sigma^+$ @1.69 GeV/c



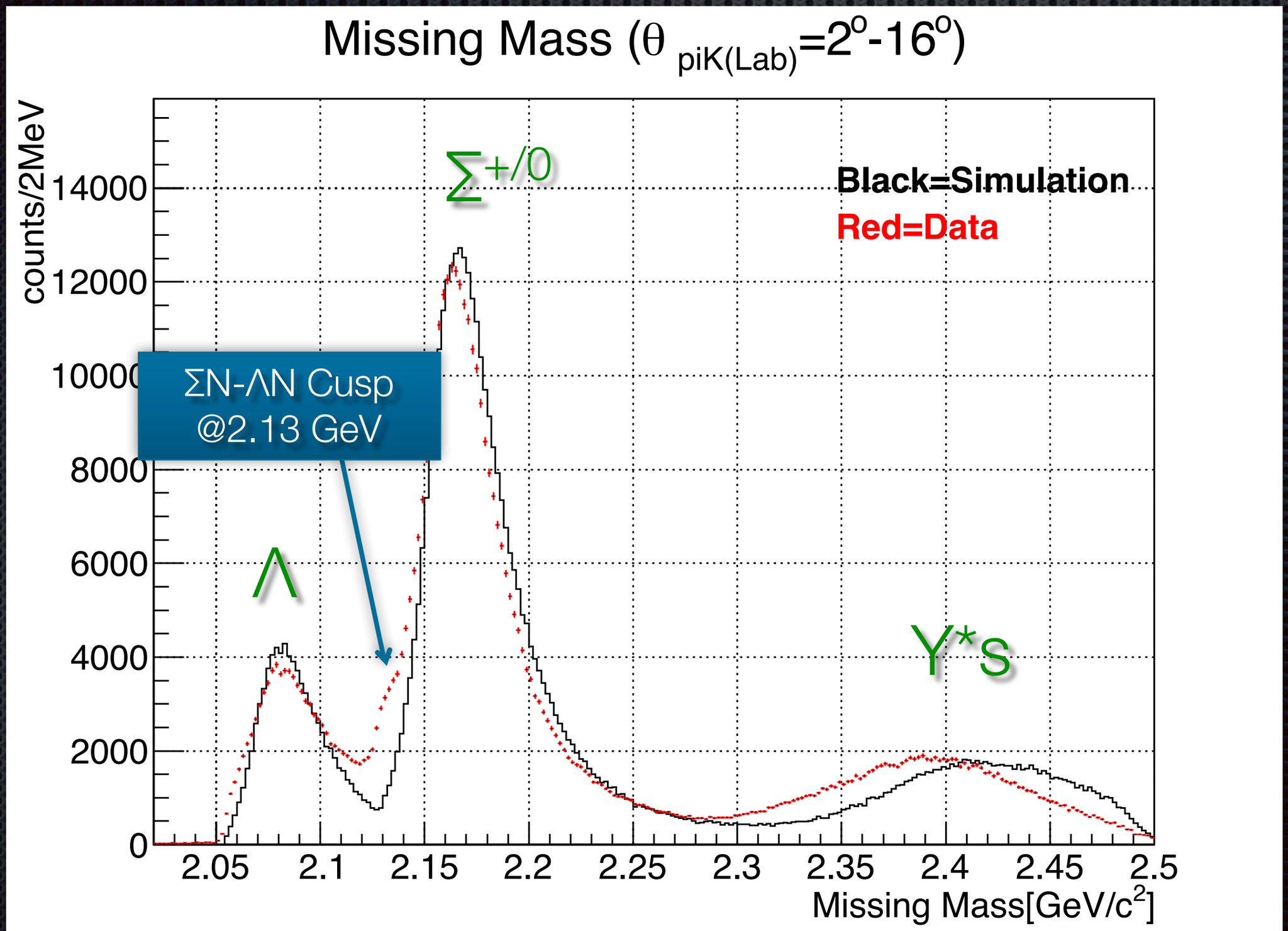


Preliminary

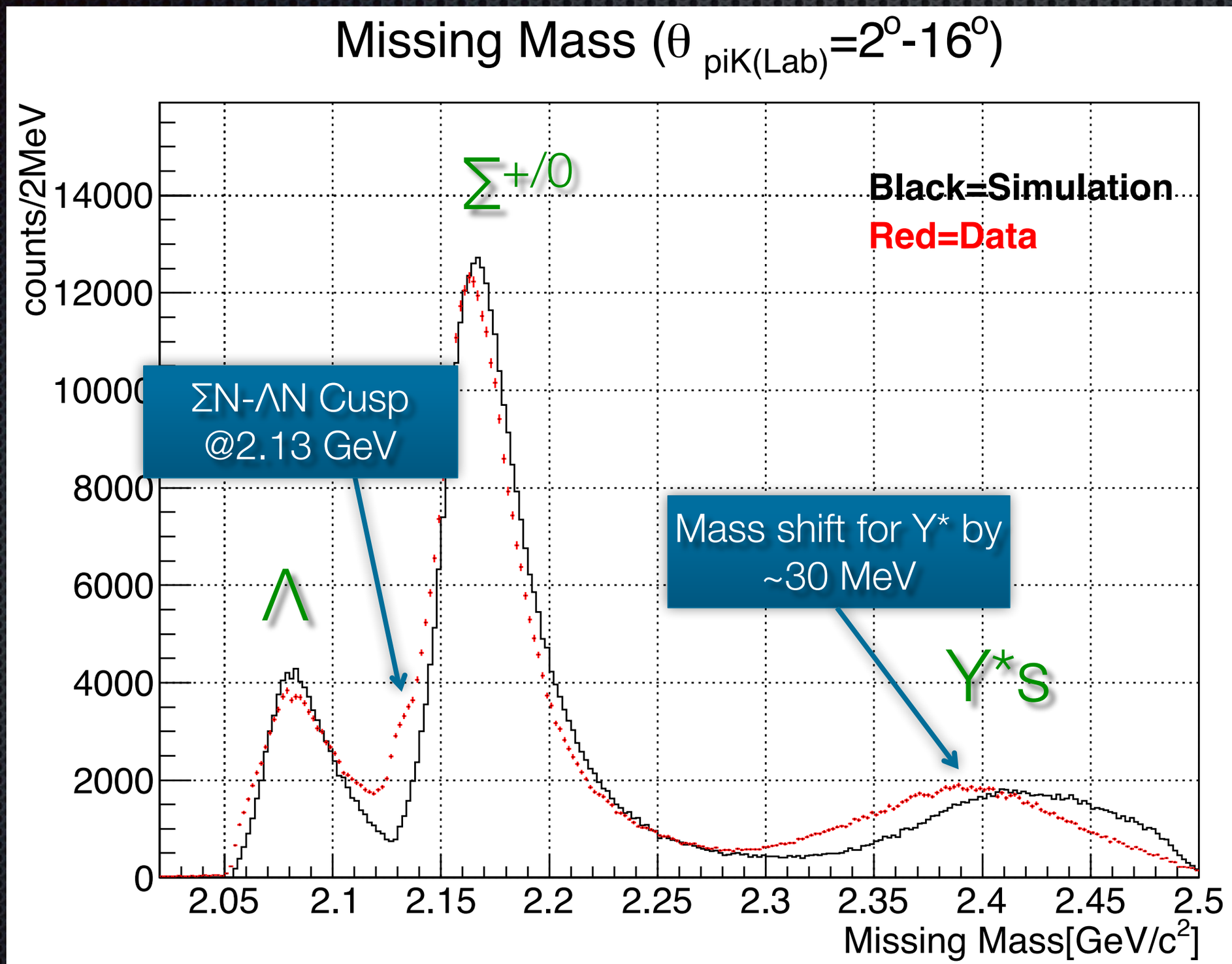
d(π^+, K^+) @1.69 GeV/c



d(π⁺, K⁺) @1.69 GeV/c


Missing Mass (θ piK(Lab)=2°-16°)
counts/2MeV
14000
12000
10000
8000
6000
4000
2000
0
2.05
2.1
2.15
2.2
2.25
2.3
2.35
2.4
2.45
2.5
Missing Mass[GeV/c²]
Σ+/0
Λ
ΣN-ΛN Cusp
@2.13 GeV
Y*S
Black=Simulation
Red=Data

d(π⁺, K⁺) @1.69 GeV/c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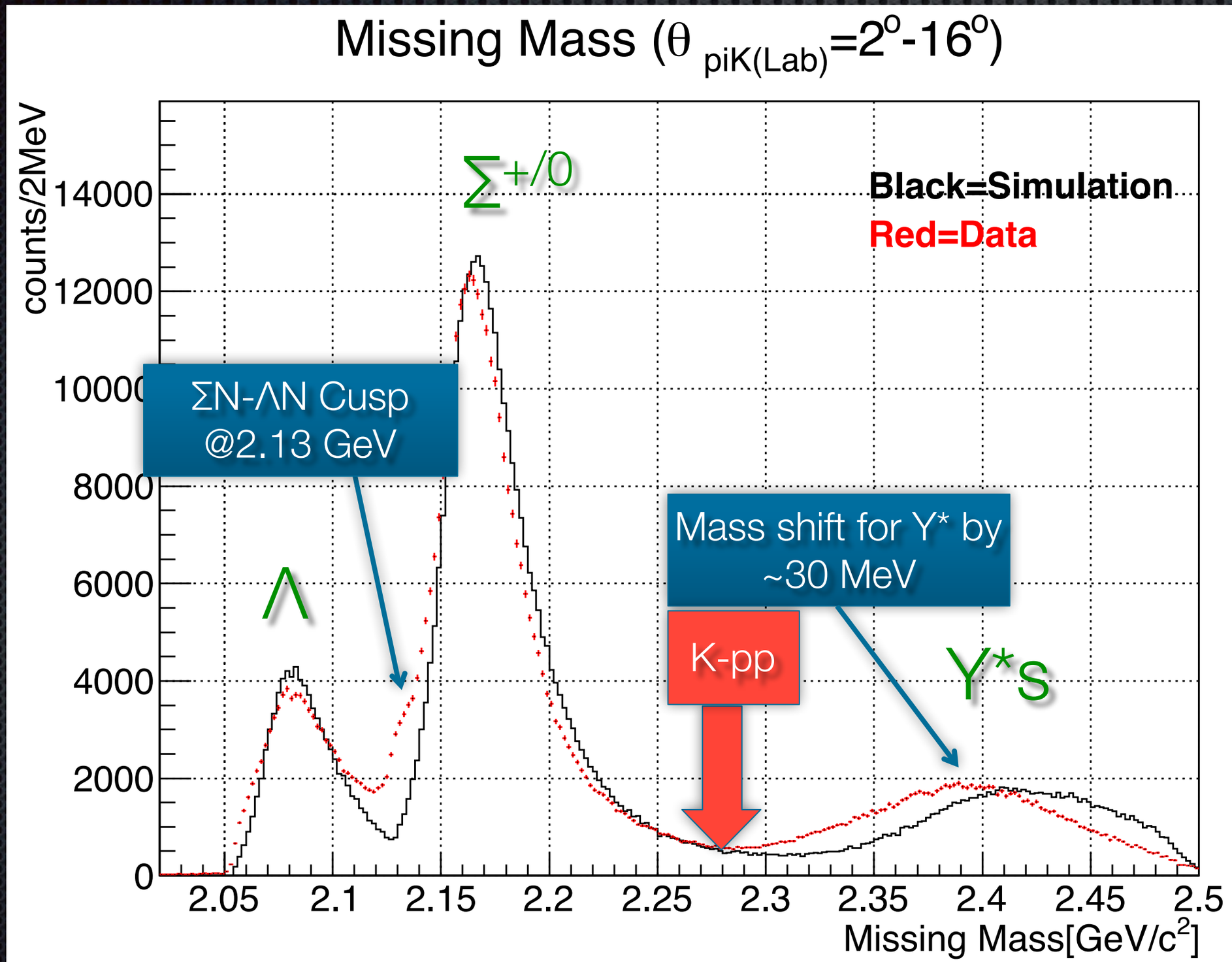
Mass shift for Y* by
~30 MeV

d(π⁺, K⁺) @1.69 GeV/c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counts/2MeV
14000
12000
10000
8000
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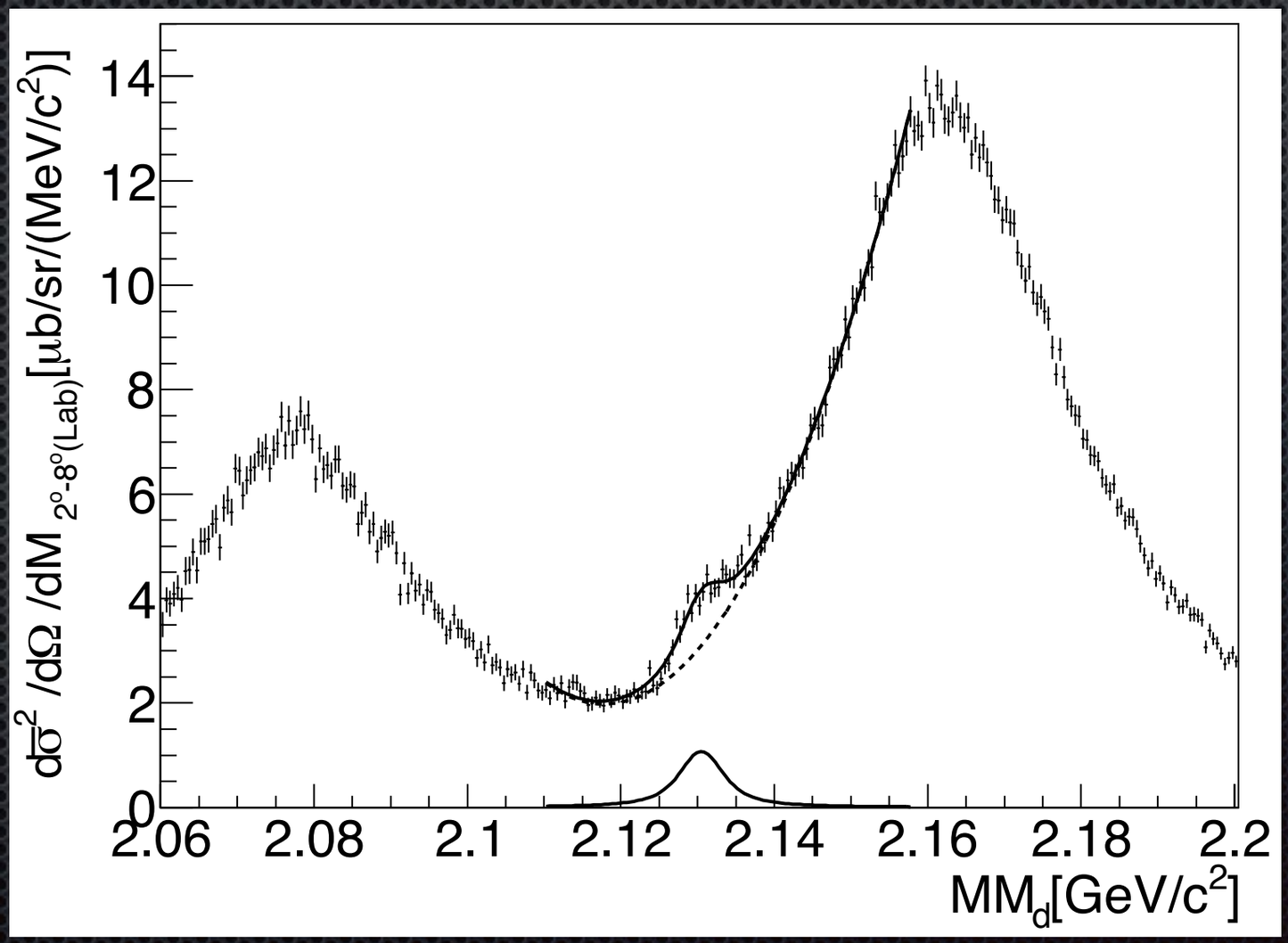
ΣN→ΛN cusp

- Peak at 2130.5±0.4±0.8 MeV
- Width = 5.4±0.8+0.3/-0.7 MeV



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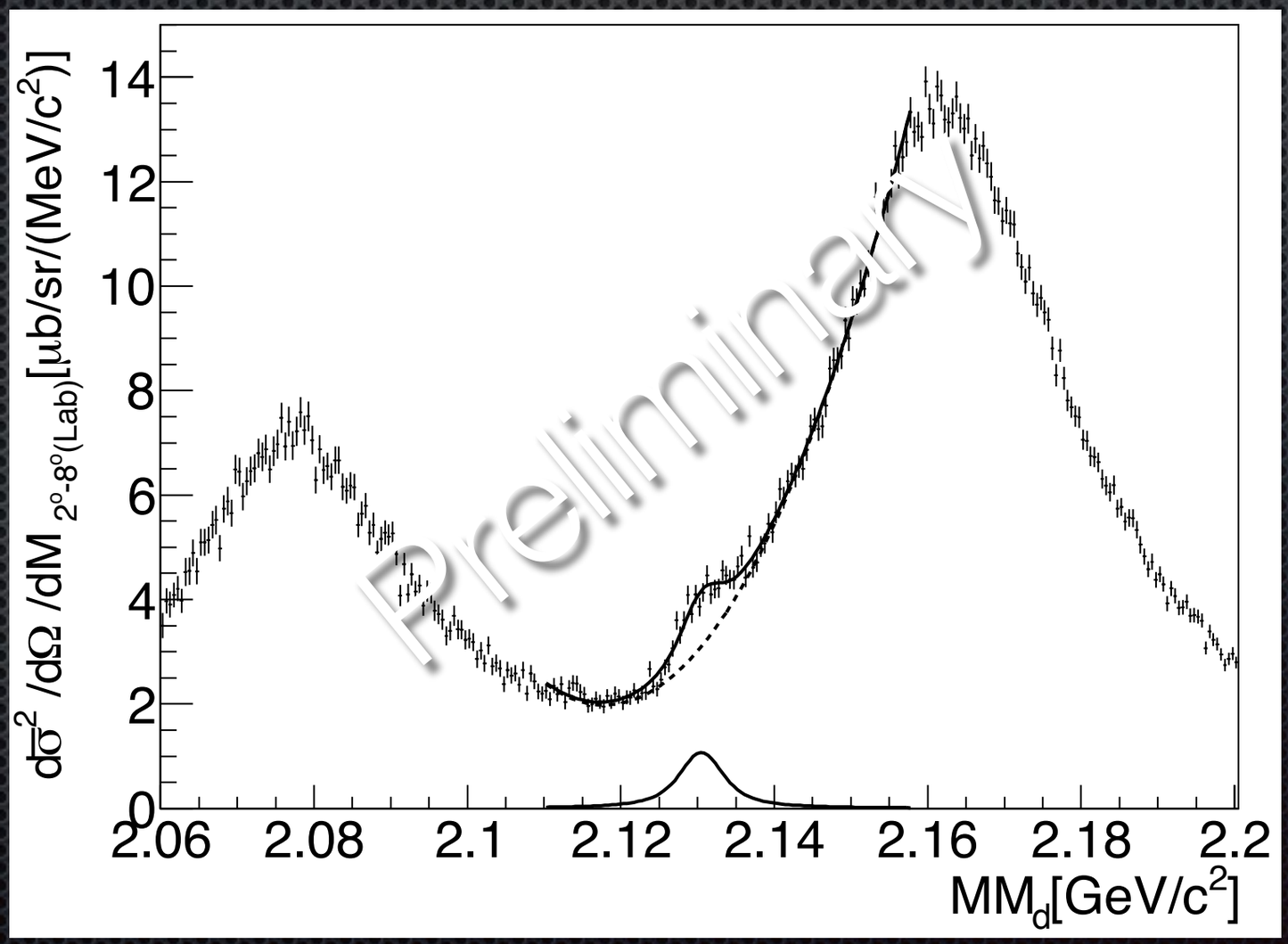
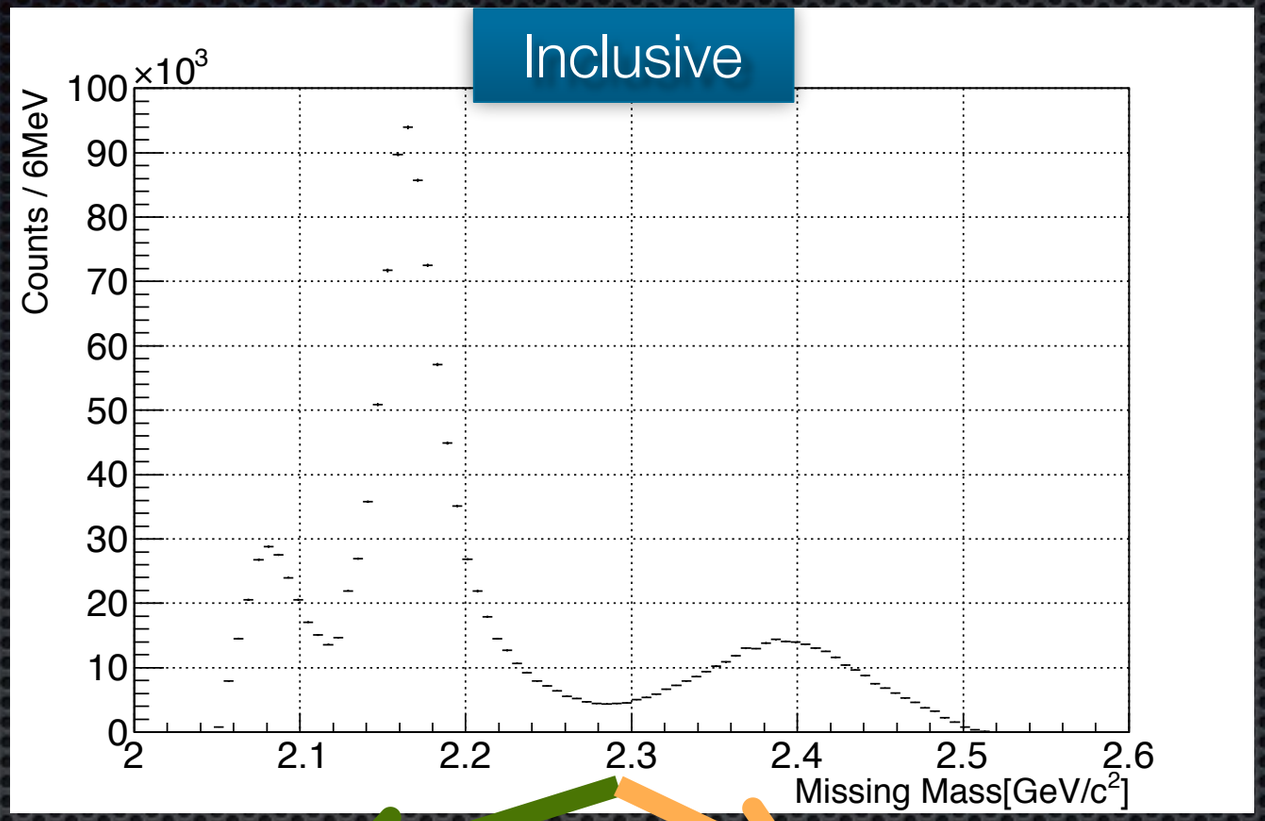
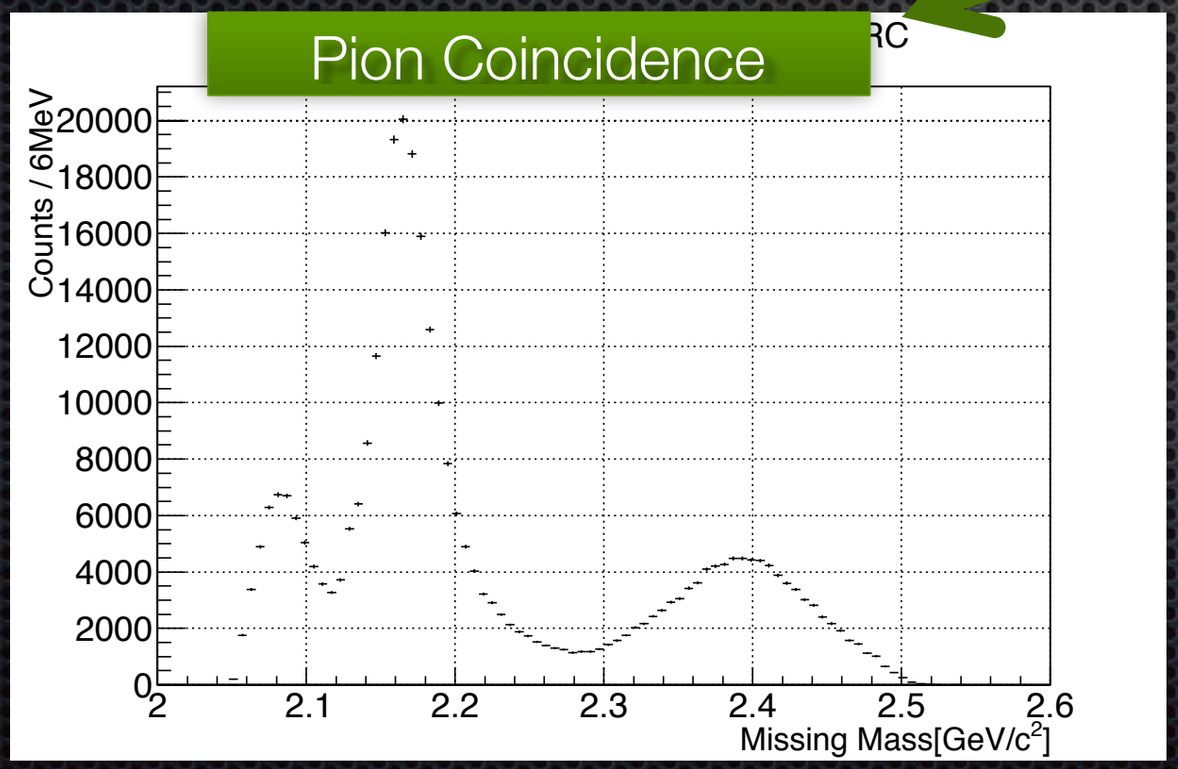


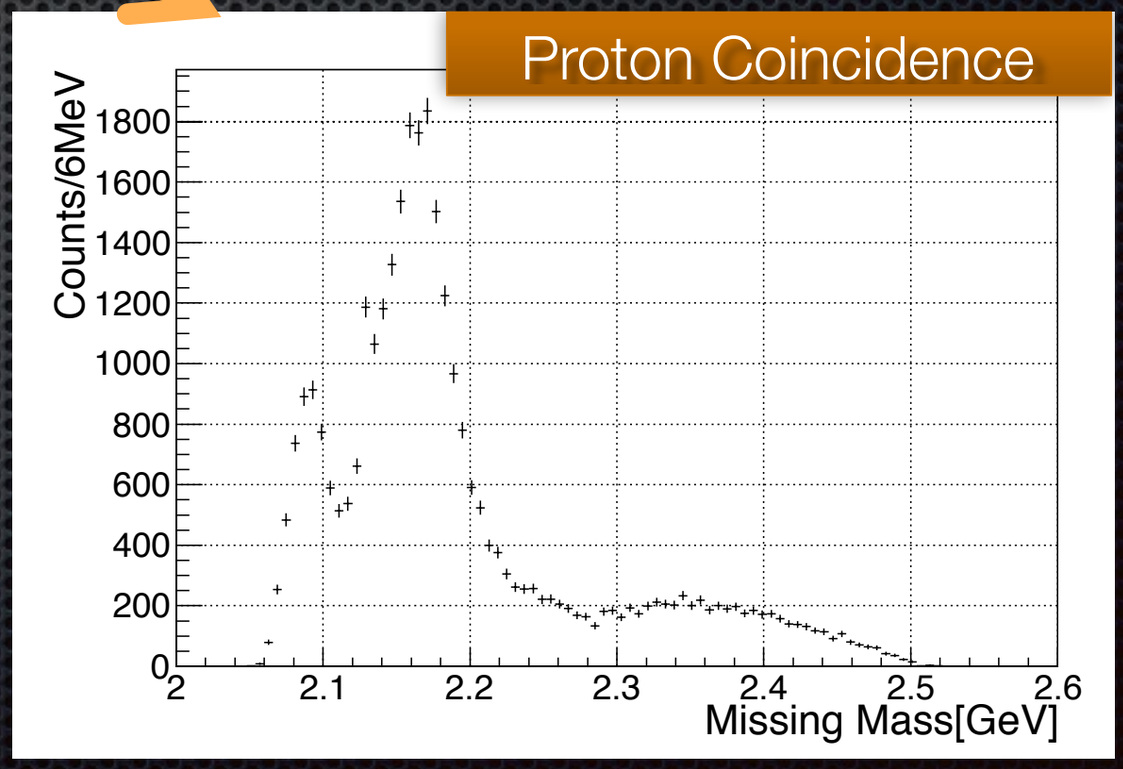
Coincidence study



"pion"=π or slow p

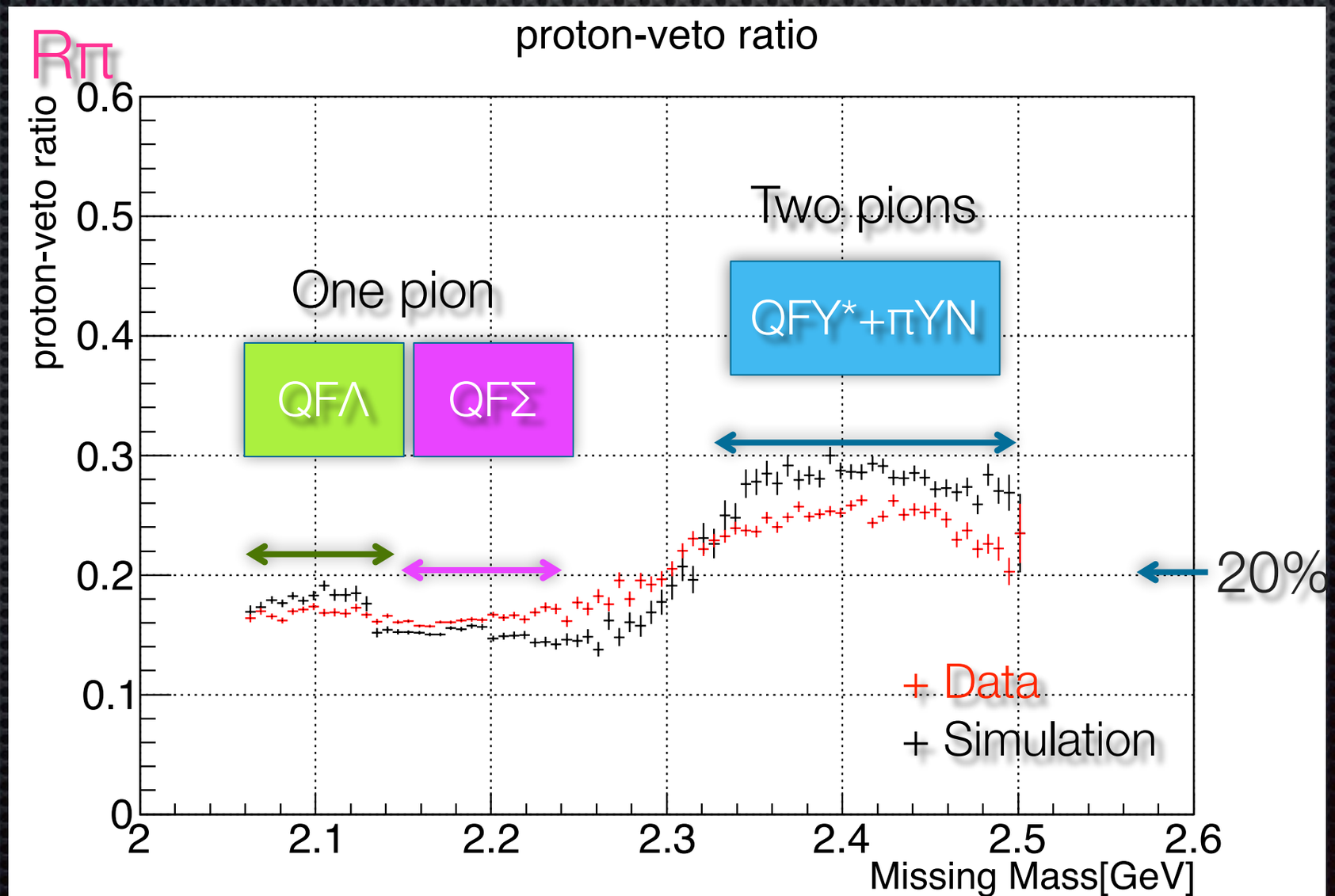
"proton"=p>280 MeV/c



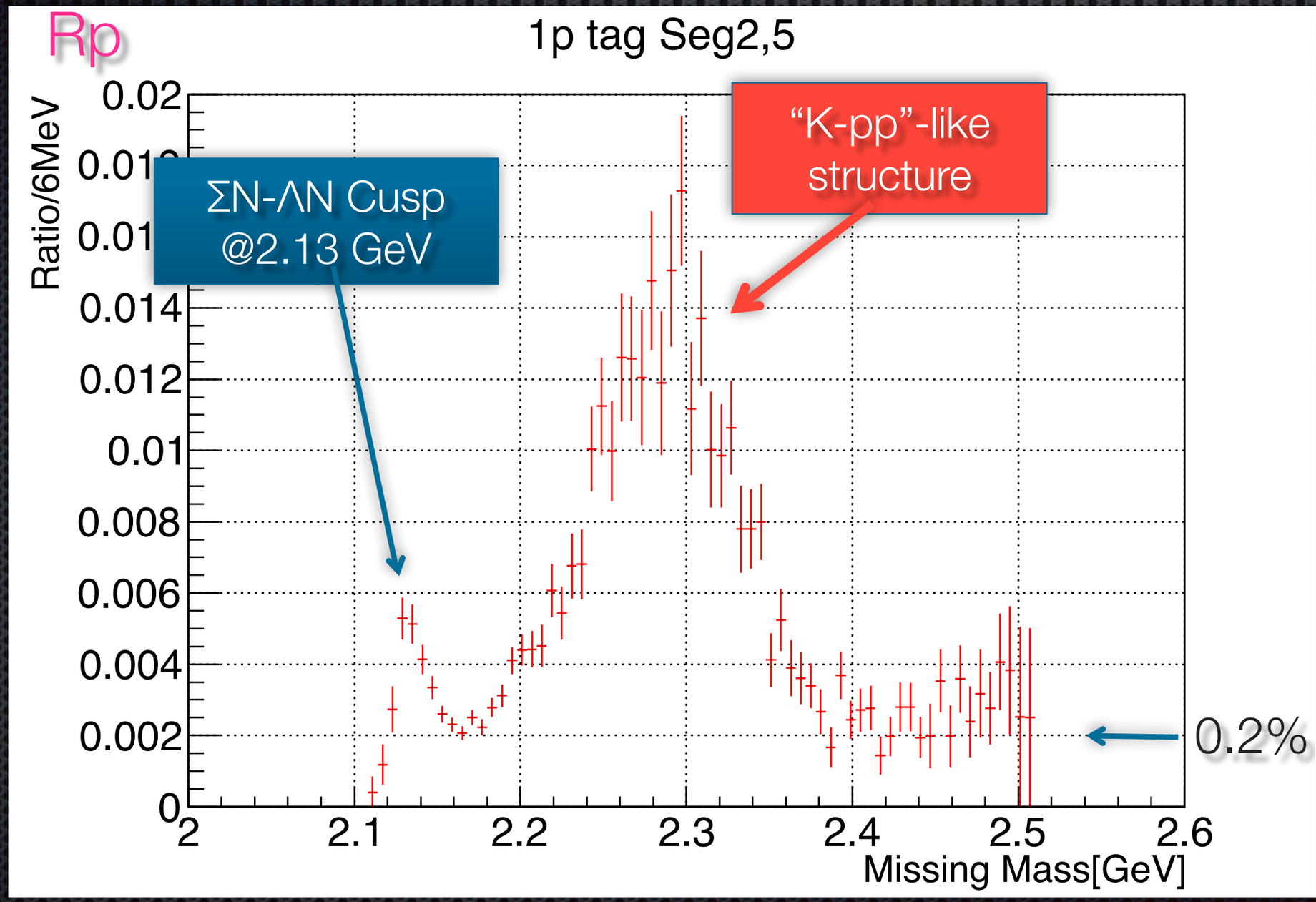


Pion Coincidence Rate

- R_π = (Pion coincidence spectrum)/(Inclusive spectrum)
- $R_\pi \propto$ (π emission BR)x(π detection efficiency)



Proton Coincidence Rate



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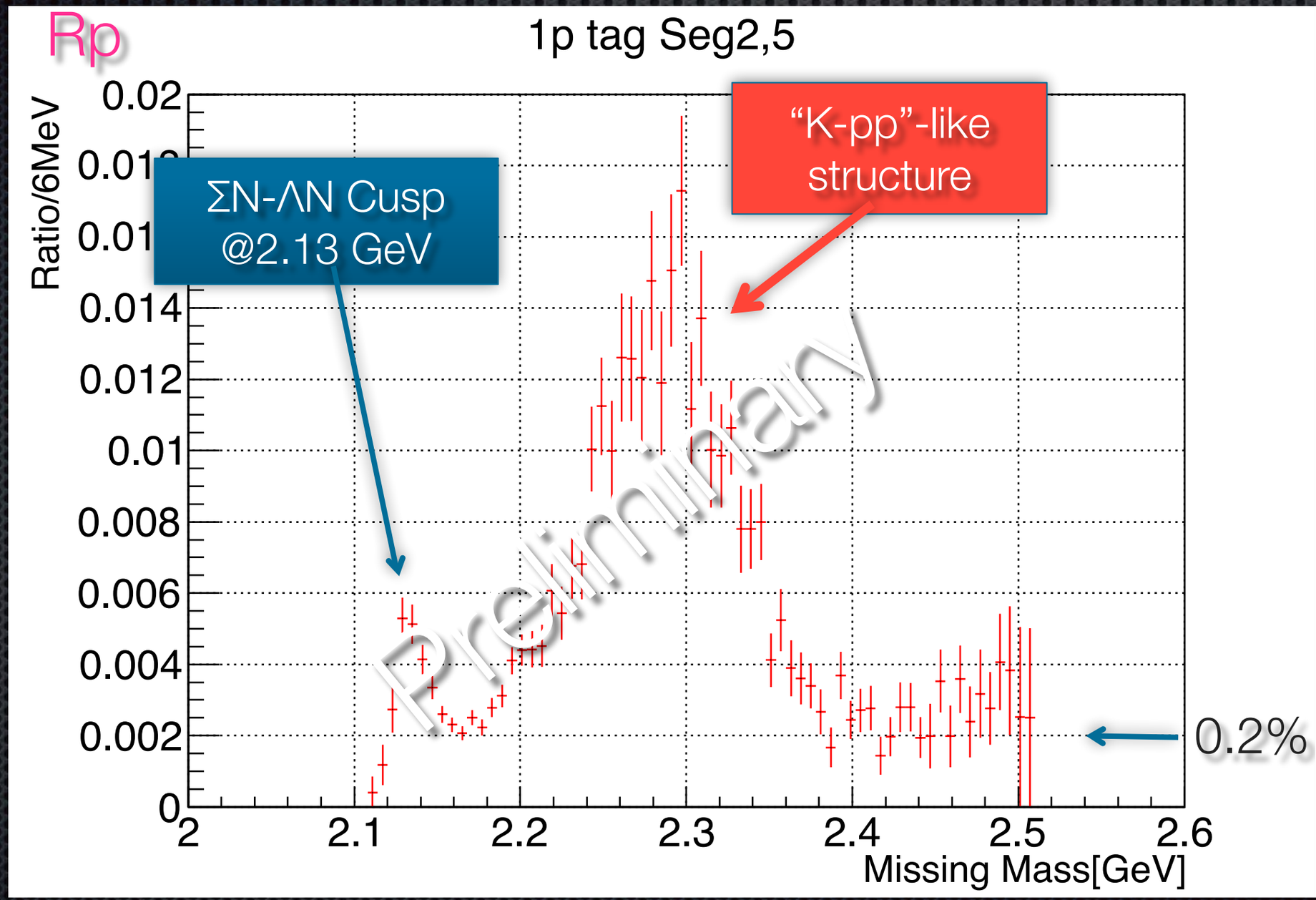

Hyperon mass with two protons

- $d(\pi^+,K^+)K^-pp$; $K^-pp \rightarrow Y+p$, $Y \rightarrow \pi+p(+\gamma+\pi)$
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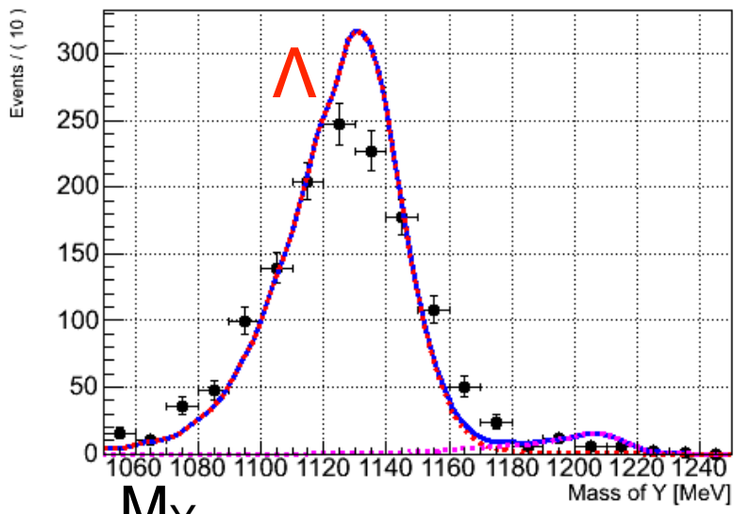
Black: Data , Red: Λp, Pink: Σ^0p, Green: Λπ^0p, Sky: $\Sigma^+\pi^-$p, Blue: All component

2.1<MM<2.22[GeV/c²]



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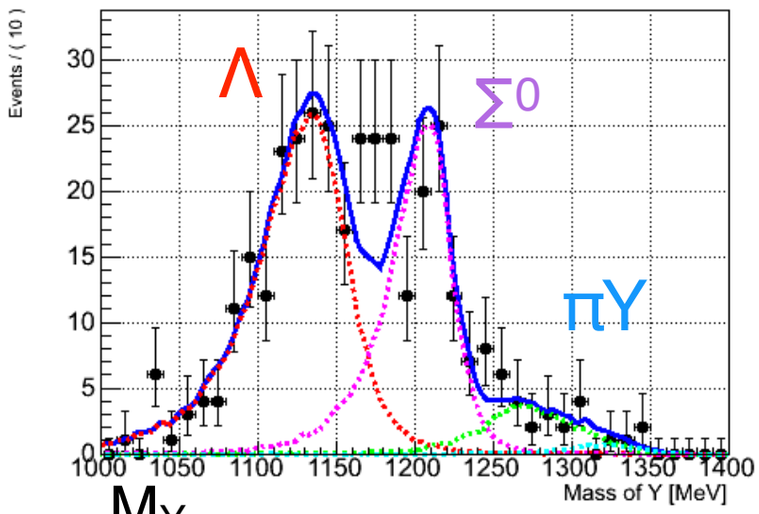

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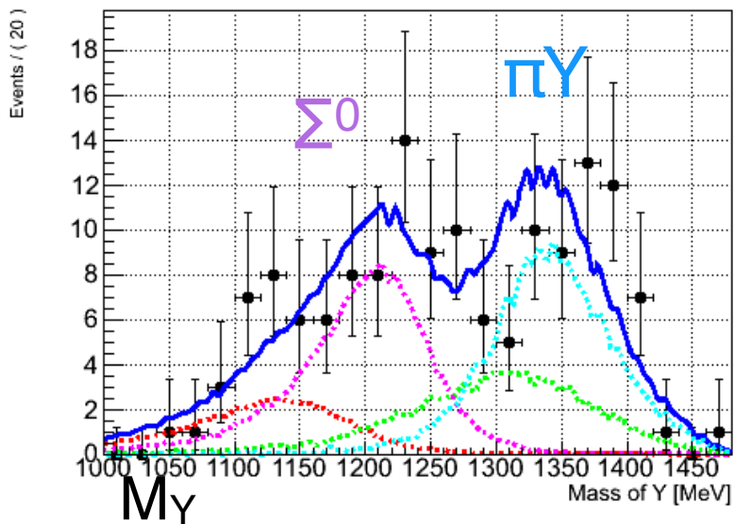

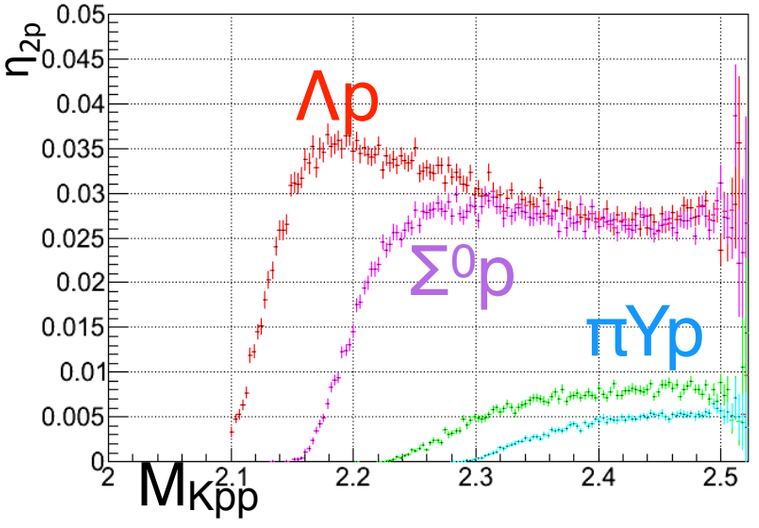

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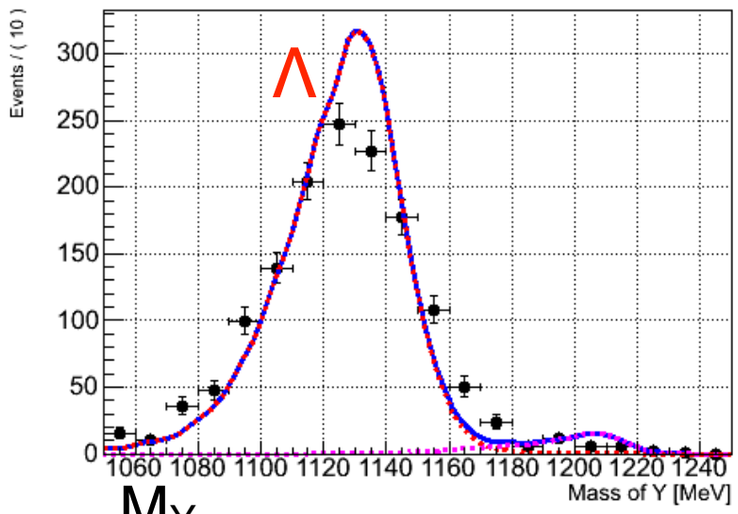

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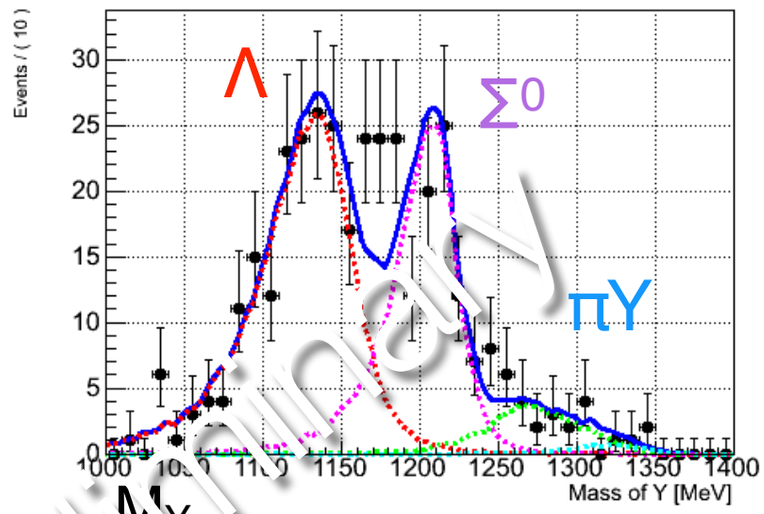

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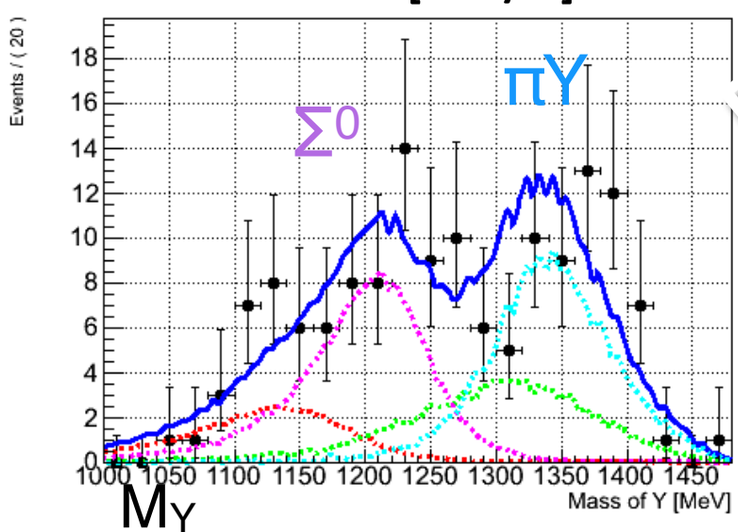

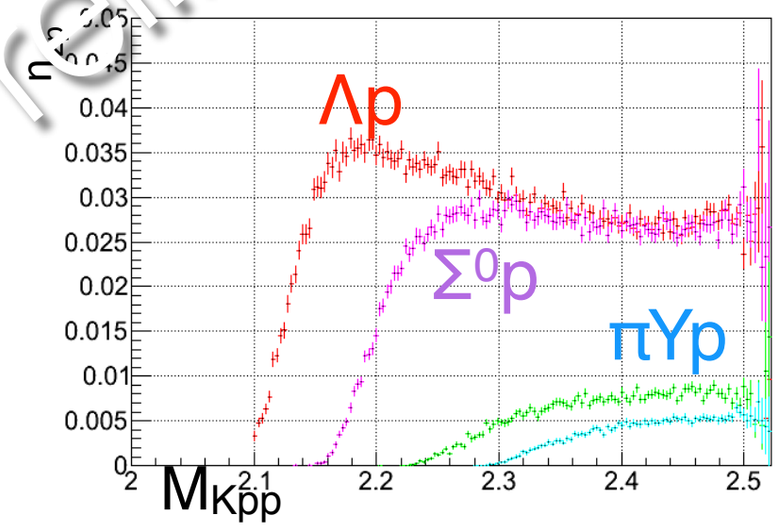

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    - BR : Λp, Σ^0p, πYN ~ 1 : 1 : 0.1