SPHERE Meeting,
Sep. 9-11, 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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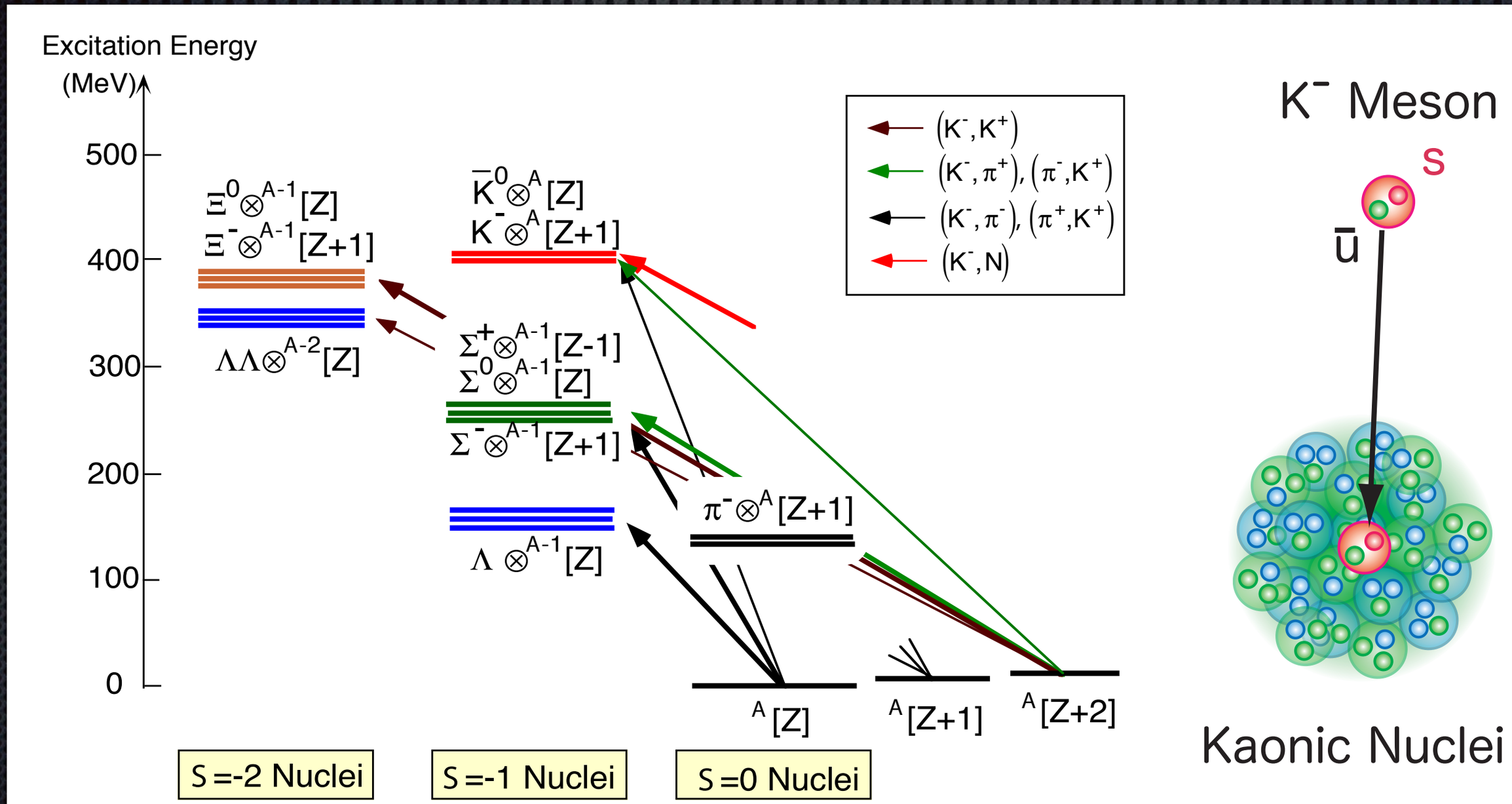
- Introduction of "K^-pp"
- E15 experiment : ^{3}He(K^-,n)"K^-pp" at 1 GeV/c
- E27 experiment : d(π^+,K^+)"K^-pp" at 1.69 GeV/c
- Summary

New type of Strange matter

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



K^-pp

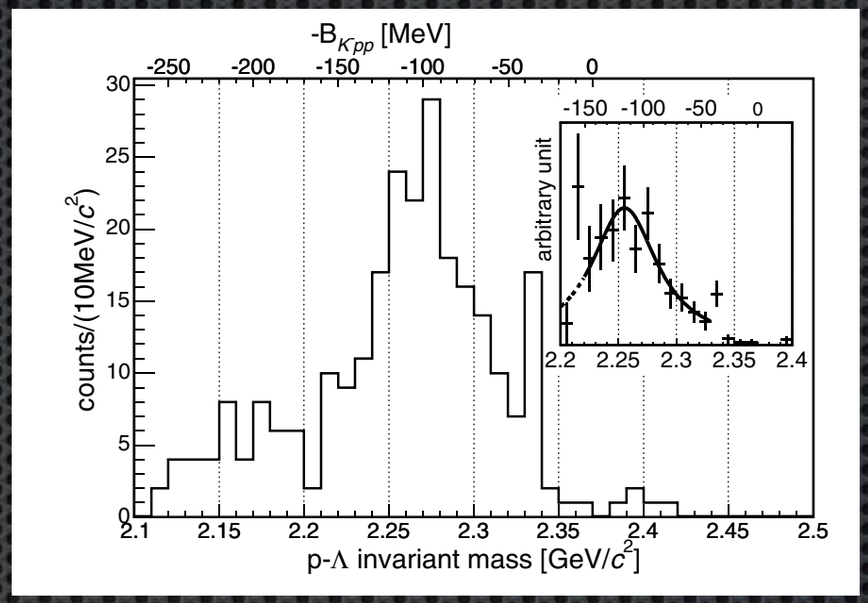
- $\overline{KN}$: attraction in Isospin=0
  - Kaonic hydrogen X-ray ; SIDDHARTA,
    M.Bazzi et al., NPA 881 (2012) 88-97.
  - Low-energy scattering measurements
  - $\Lambda(1405)$ below the K^-p threshold
- K^-pp : Y=1, I=1/2, $J^\pi=0^-$

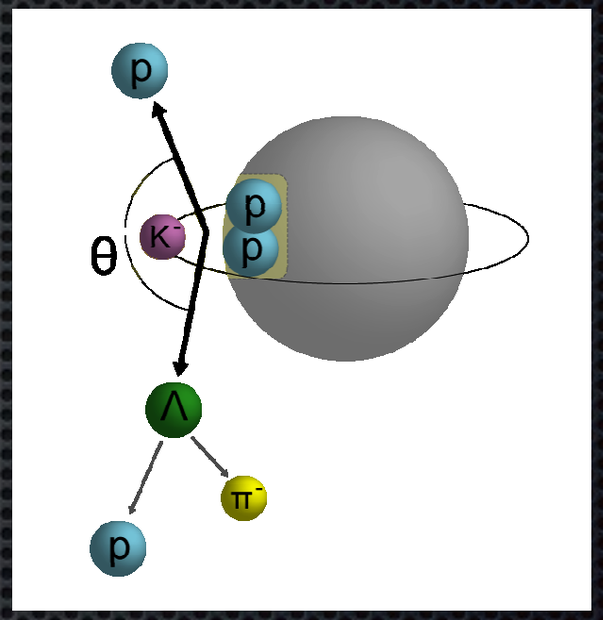
Experiments on K^-pp

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

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

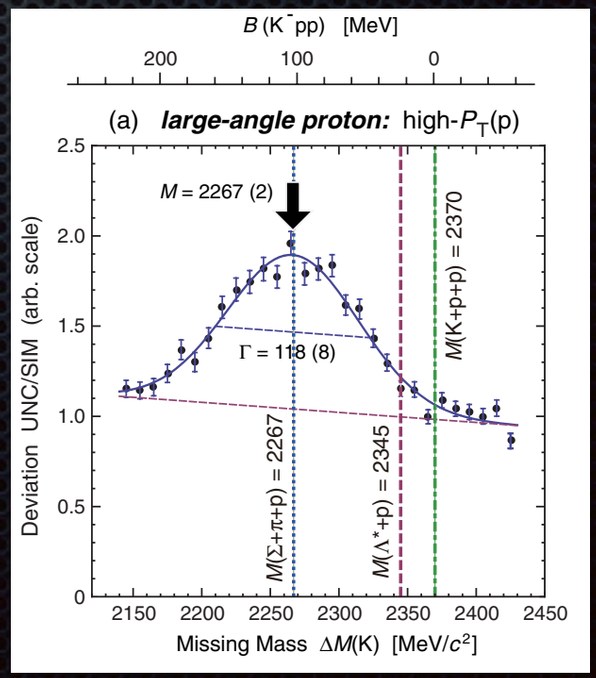
B=115+6/-5+3/-4 MeV
Γ= 67+14/-11+2/-3 MeV





- 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

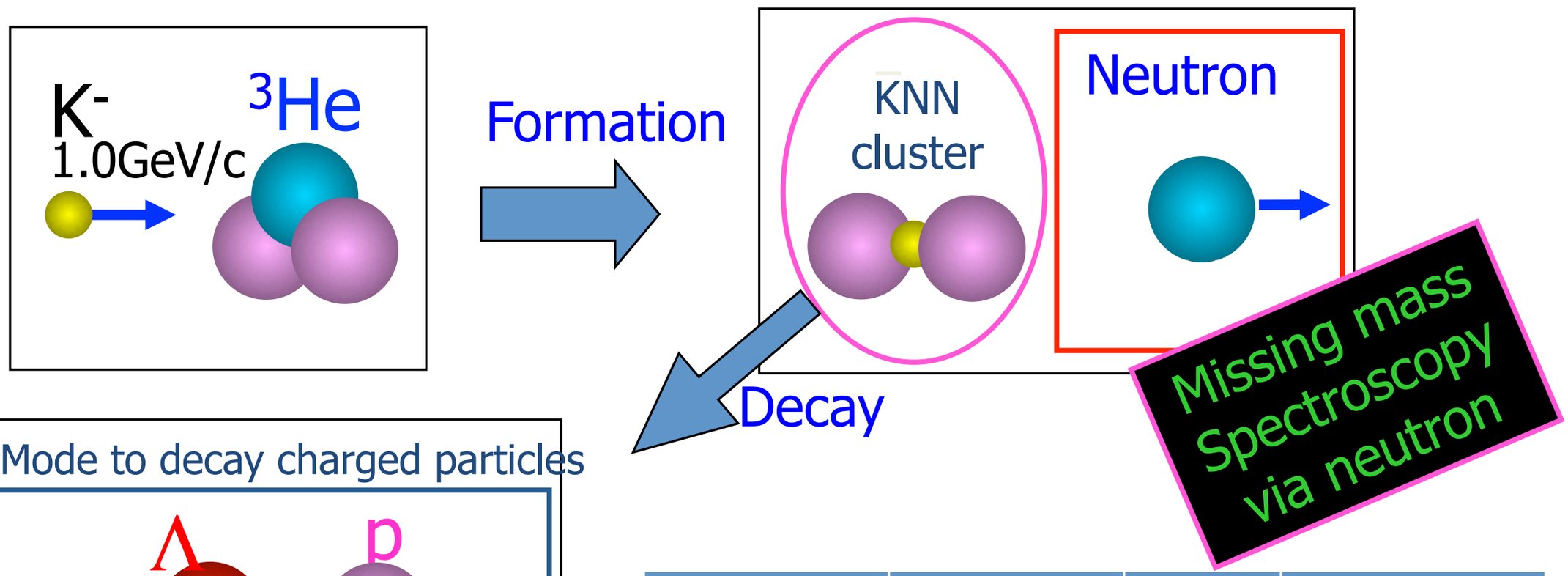
- FSI effects ? ; V.K. Magas et al., PRC 74 (2006) 025206.
- Λ^*N bound state ? ; T. Uchino et al., NPA 868-869 (2011) 53.

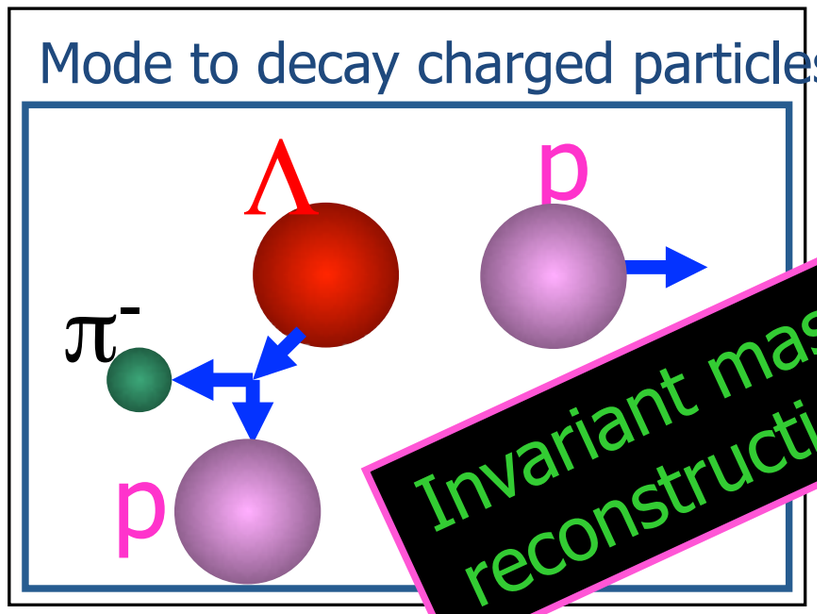
K^-pp Searches at J-PARC

- 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

- In-flight ^{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





	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 10^9
May, 2013 (Run#49c)	24 kW (30 Tppp, 6s)	88 h	5.1 x 10^9

J-PARC K1.8BR spectrometer

beam dump

beam sweeping magnet

liquid ^{3}He-target system

CDS

K-

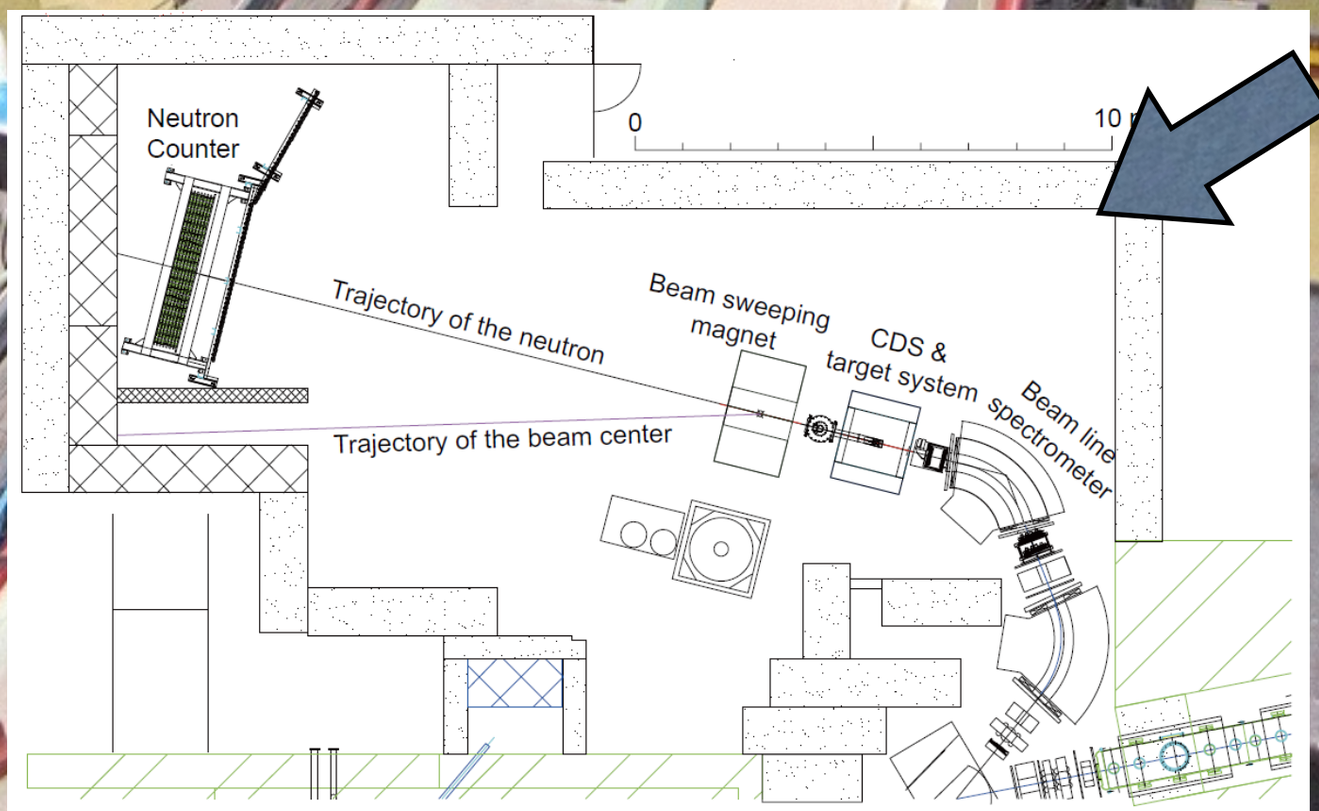
beam line spectrometer

γ, n

p

15m

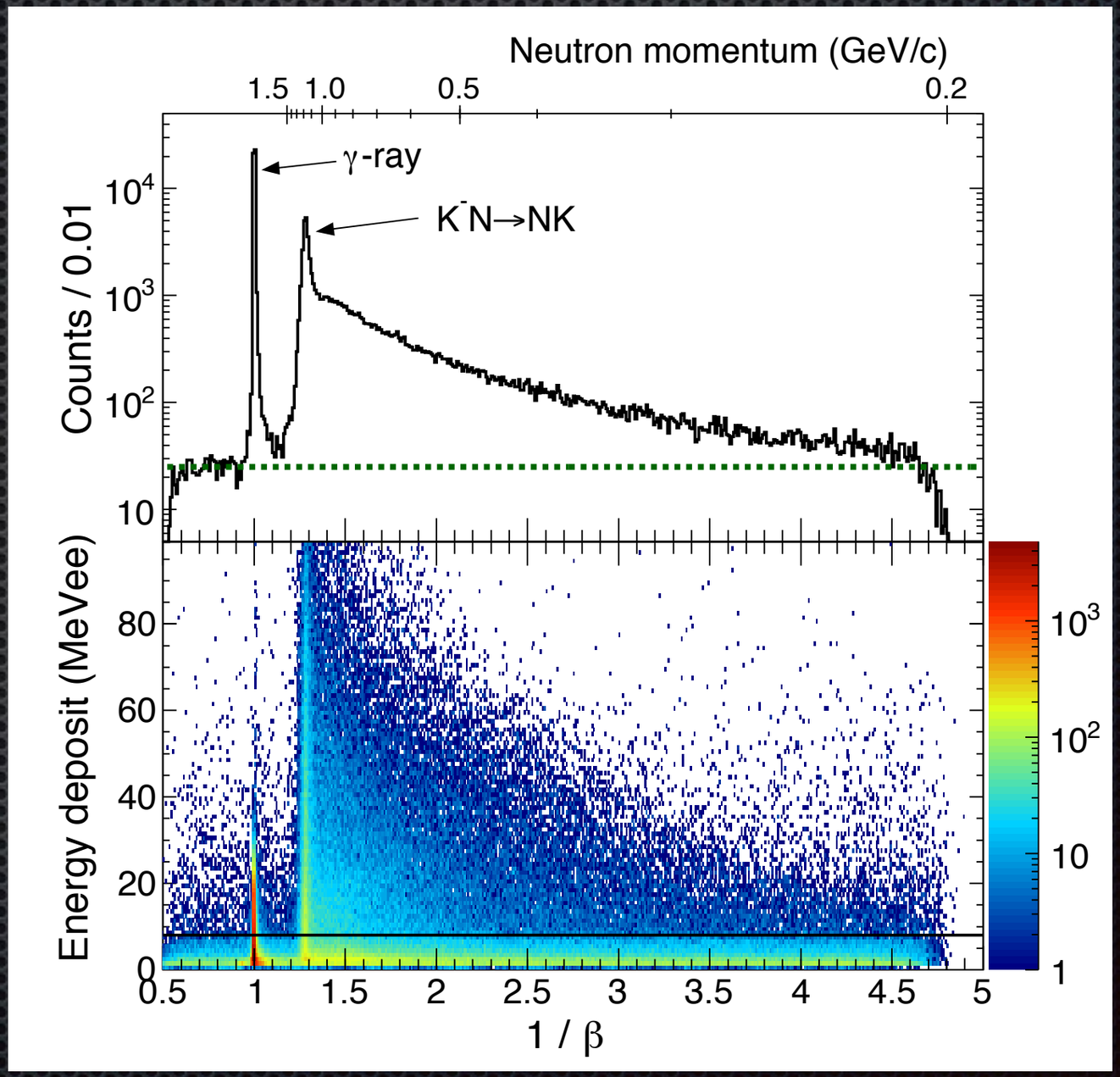
neutron counter
charge veto counter
proton counter



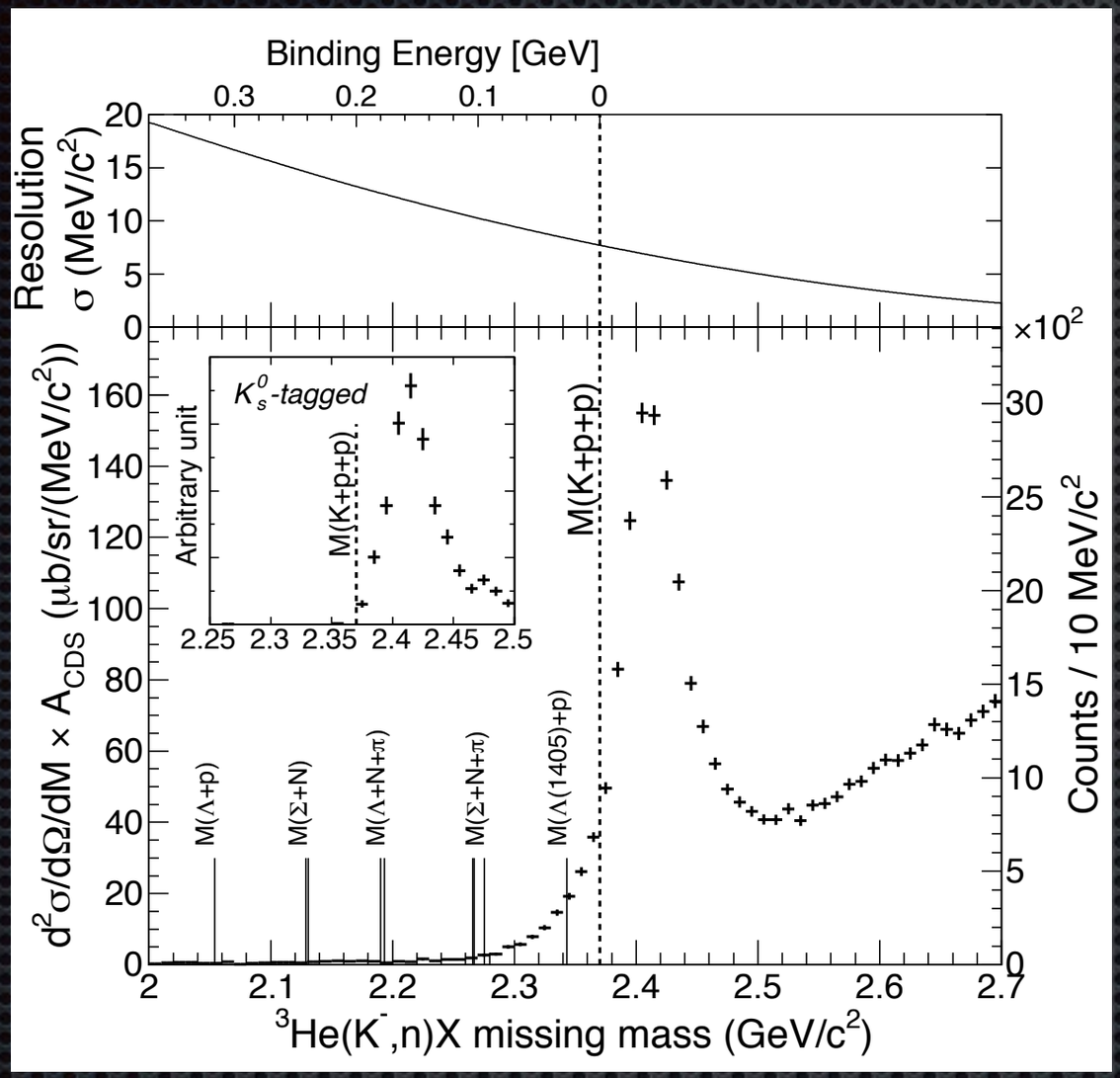
K. Agari et. al., PTEP 2012, 02B011

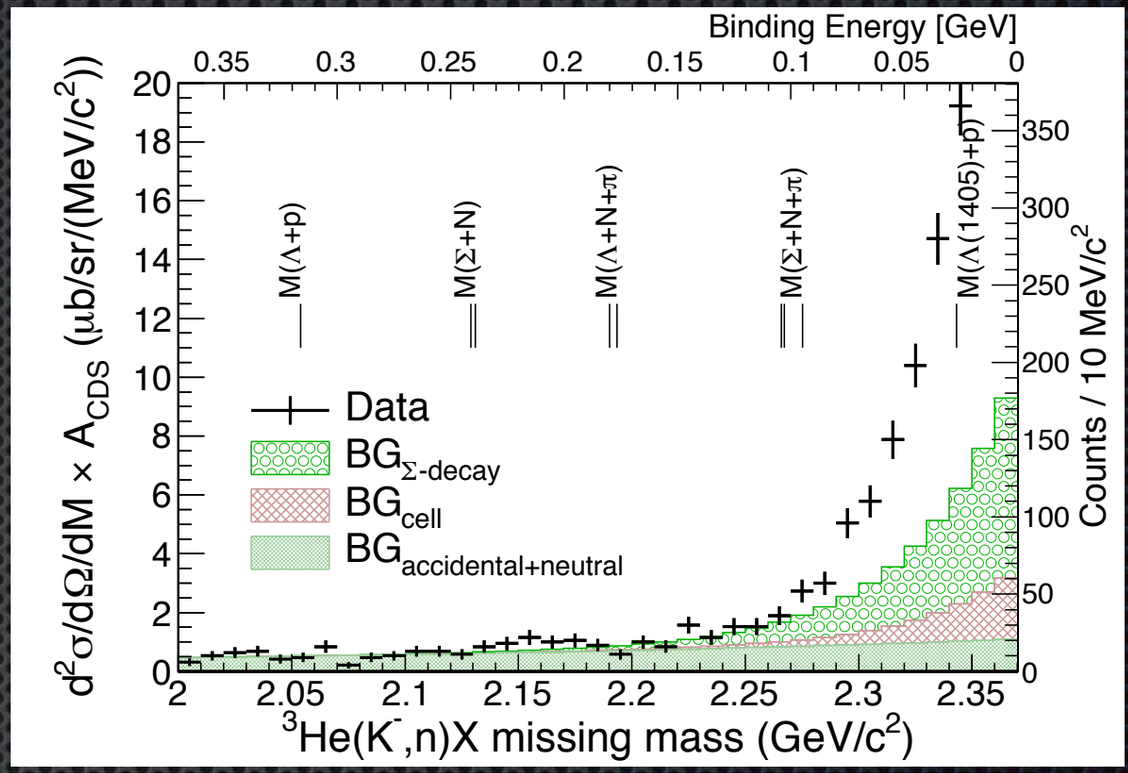
Neutron TOF

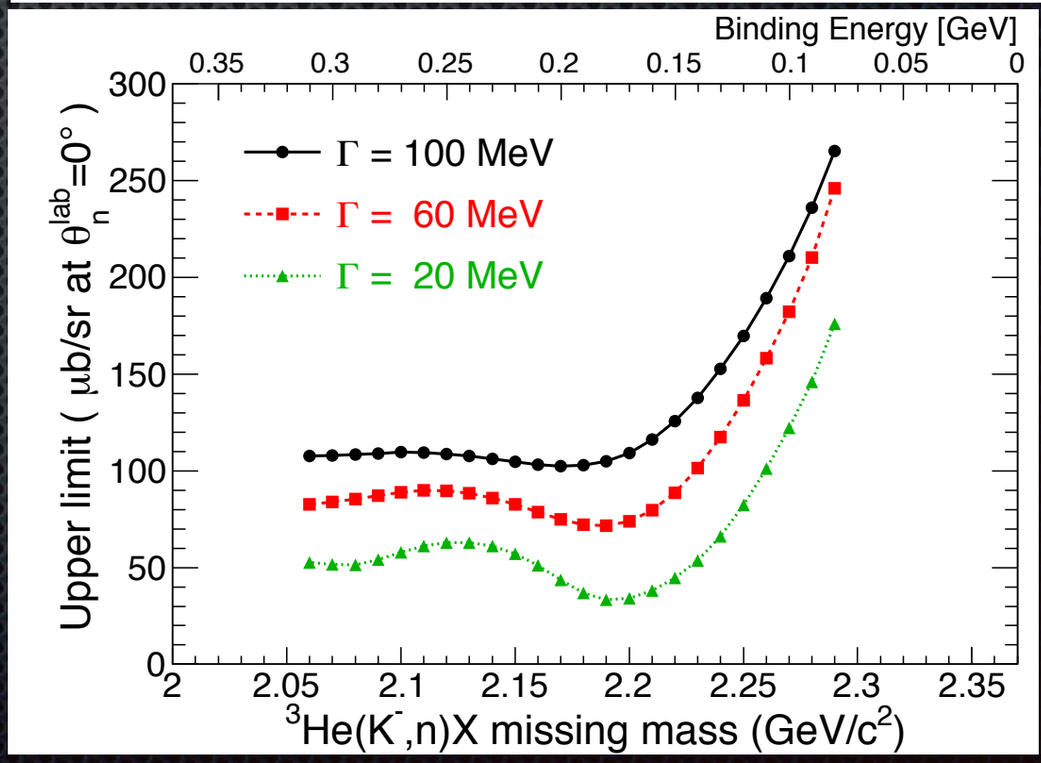
- 15-m TOF, 22 msr
- σ_t~150 ps
- 8 MeV_{ee} THR.
- Detection efficiency 0.23±0.4 @1.1GeV/c



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

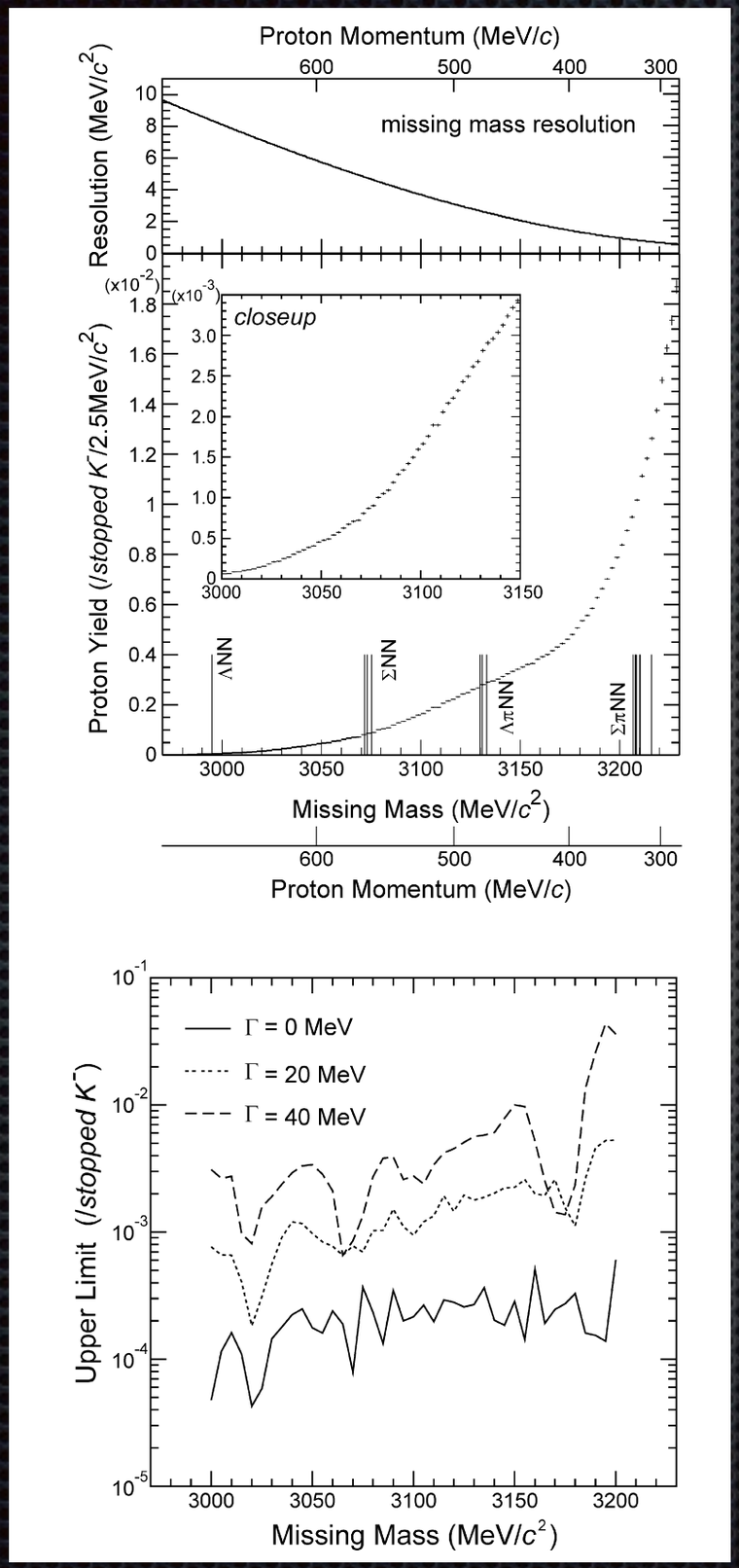


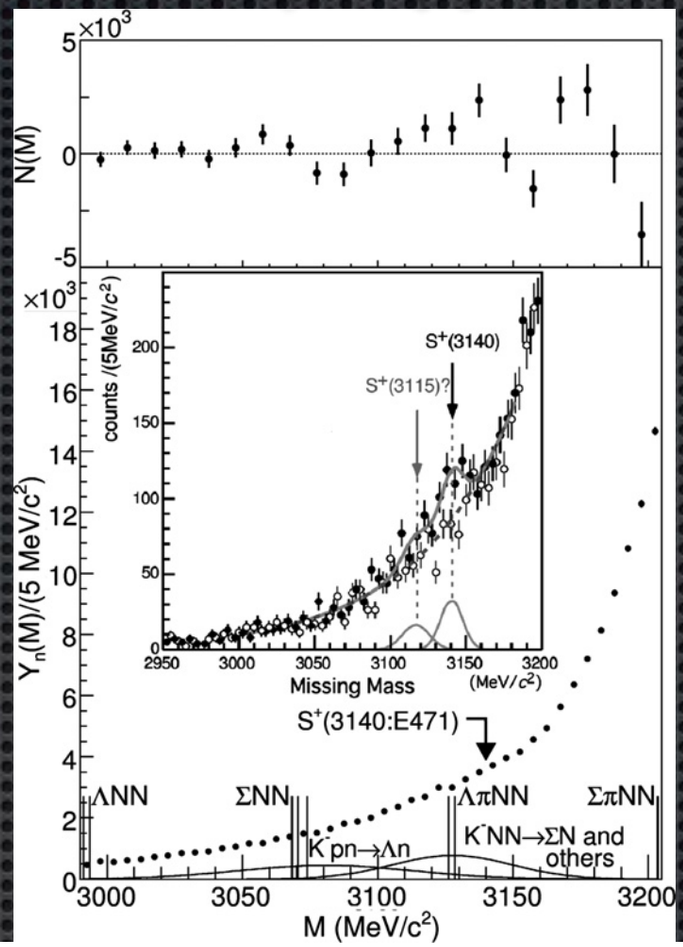




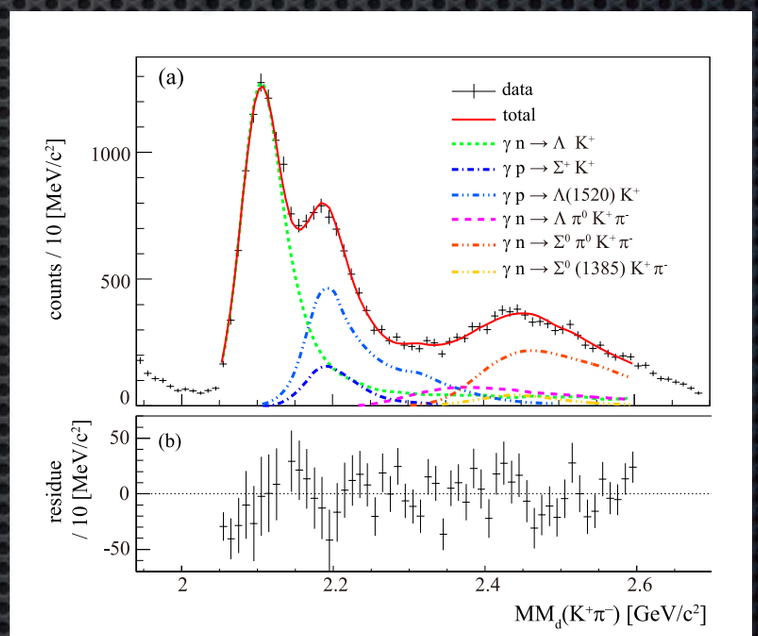
Inclusive Spectra with no evidence

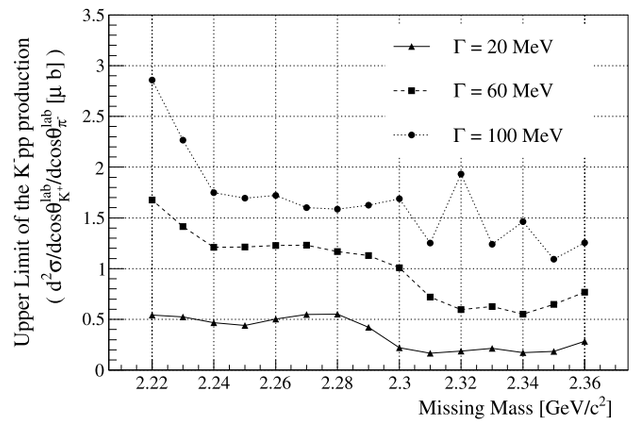
$^4He(K^-_{stop},n/p)$

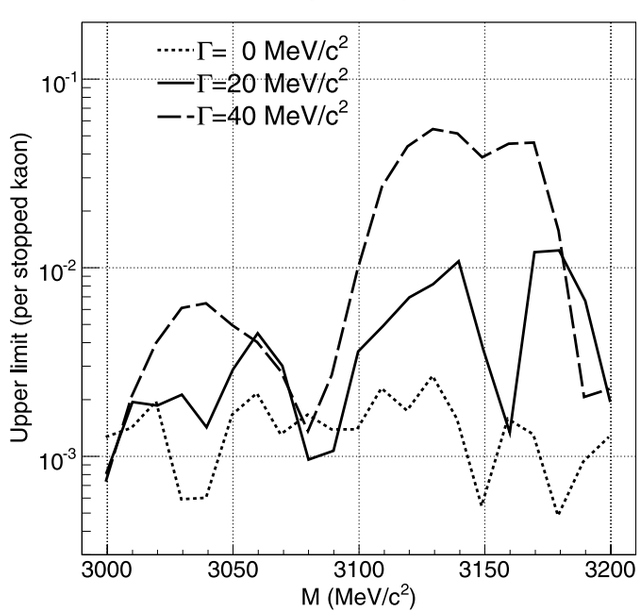




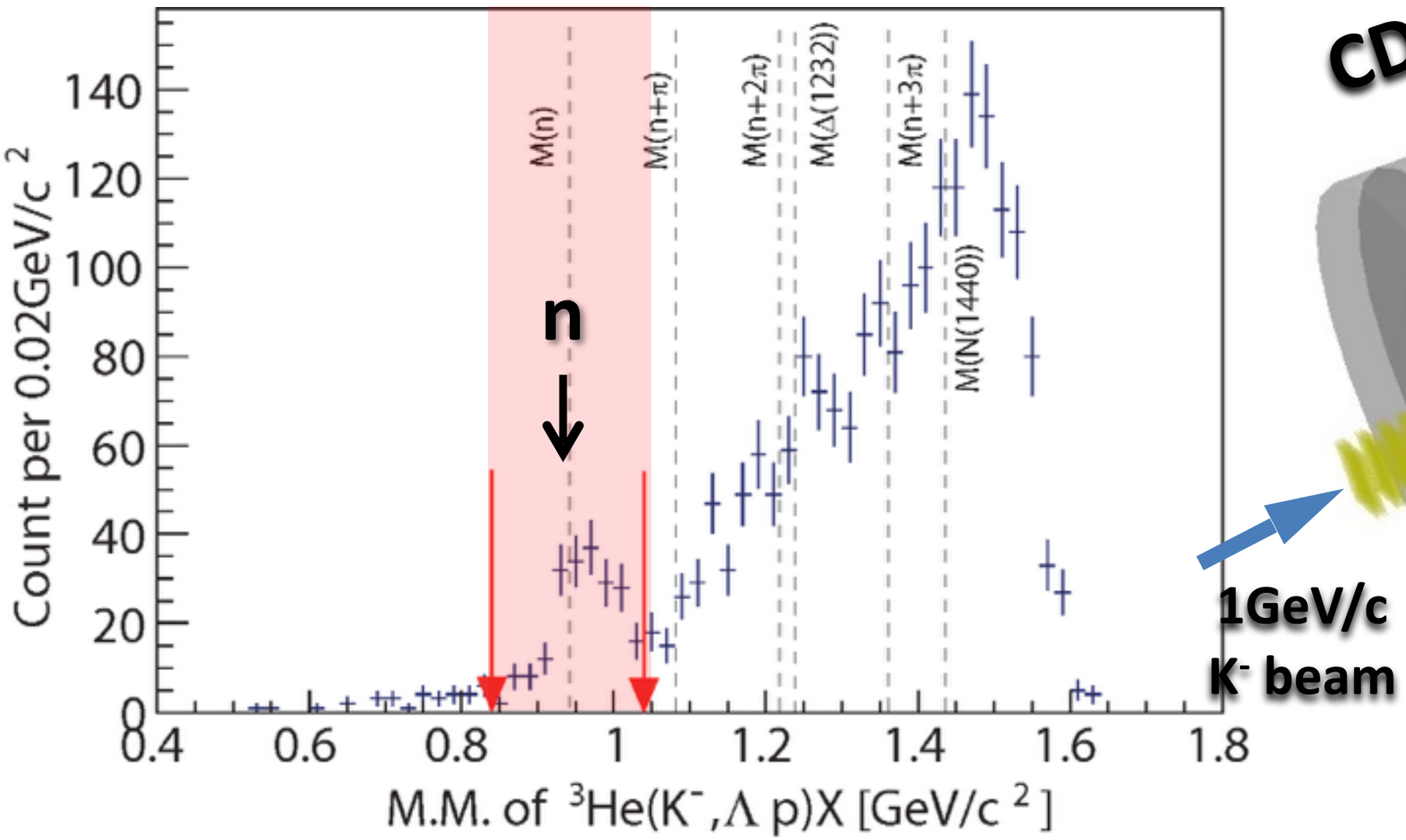
$\gamma d \rightarrow K^+\pi^-X$

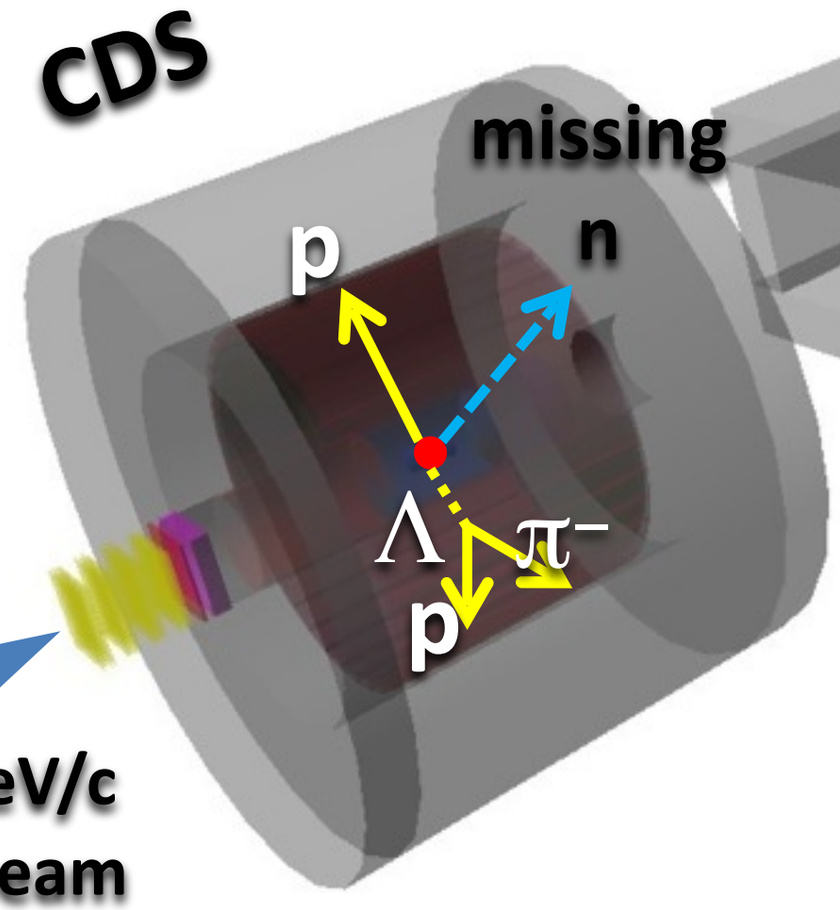






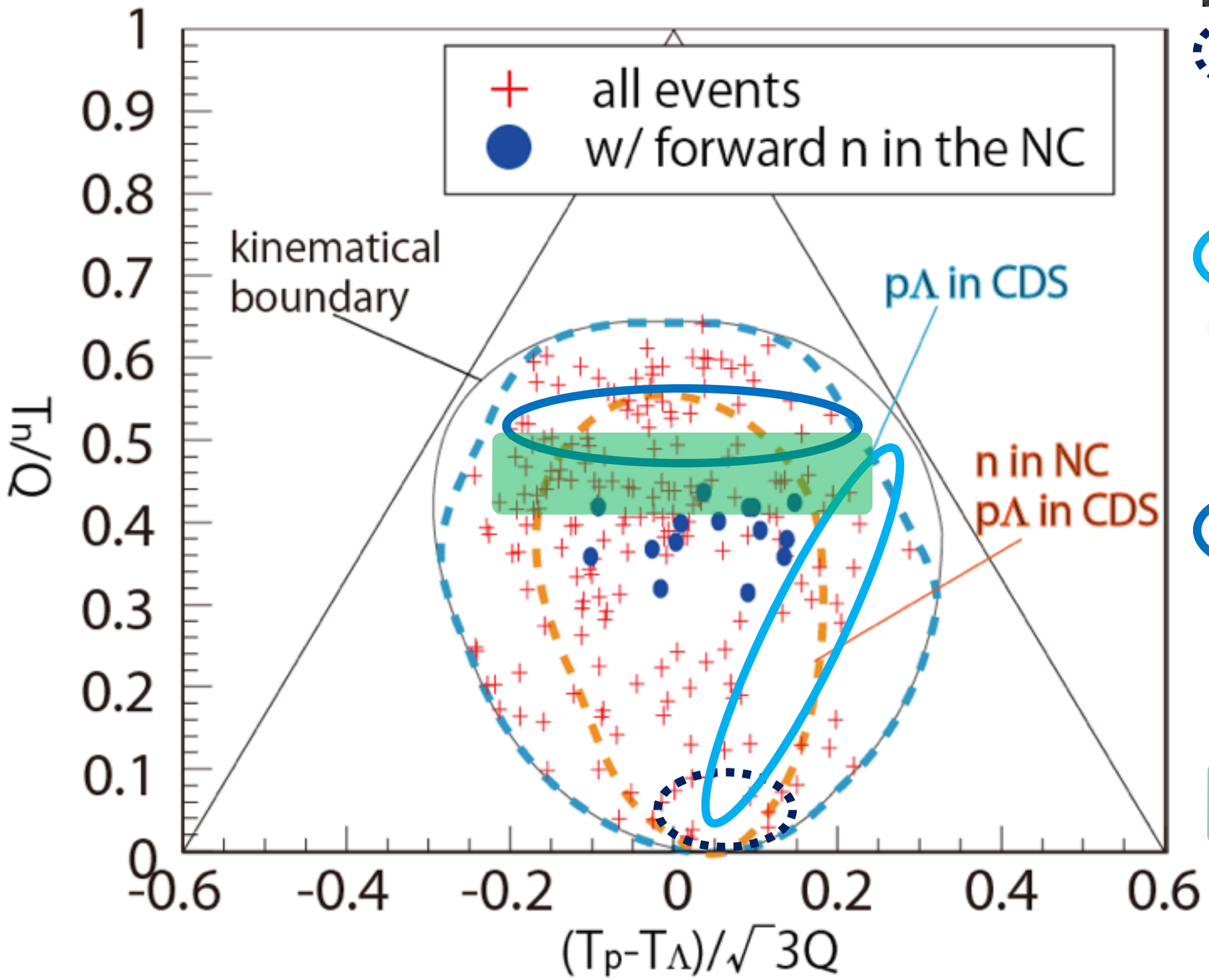
Exclusive ^{3}He(K^{-},Λp)n events





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

^{3}He(K^-,Λp)n ; Dalitz plot



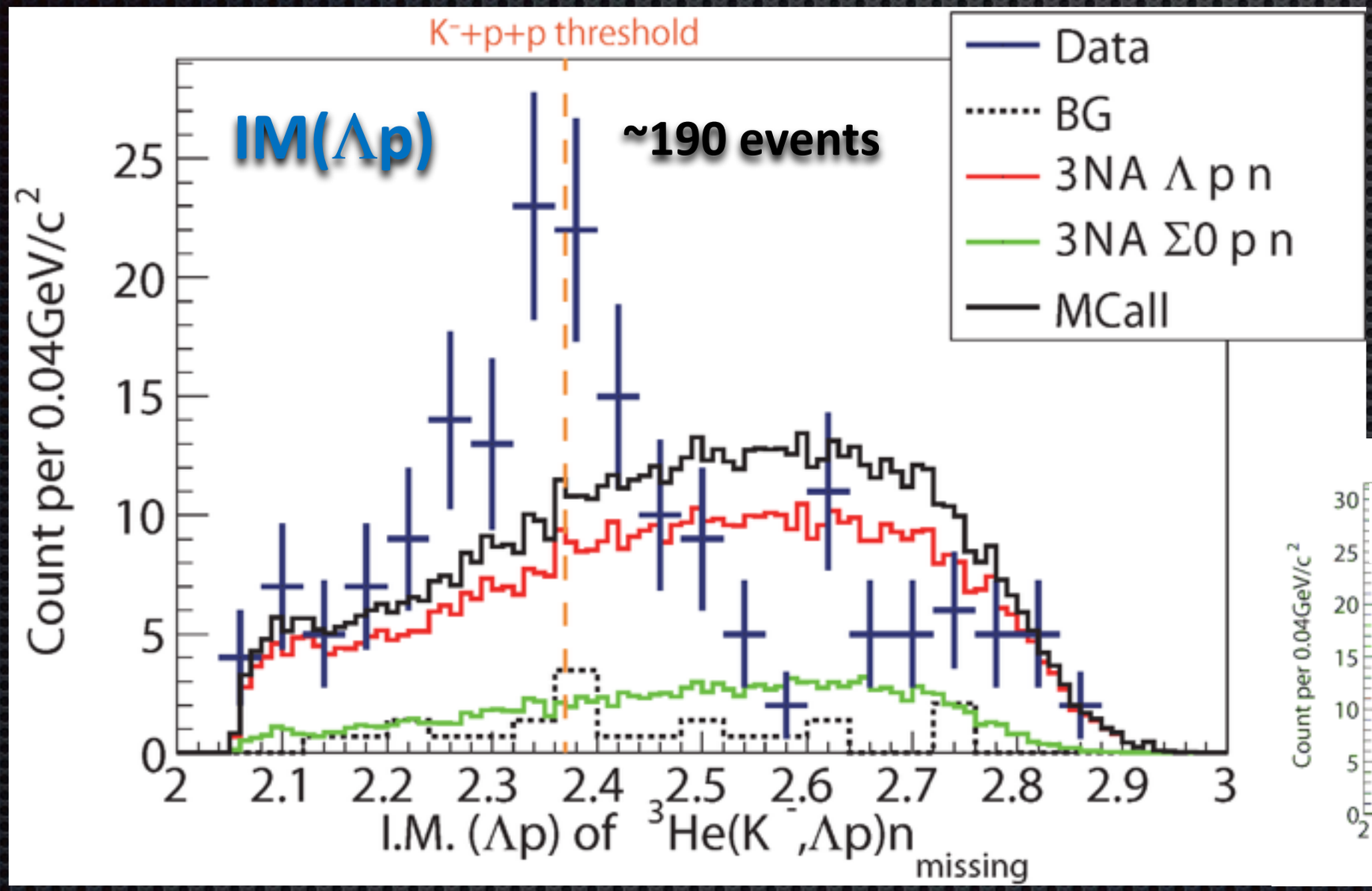
2NA:
e.g. $K^{-3}He \rightarrow \Lambda p n_s$

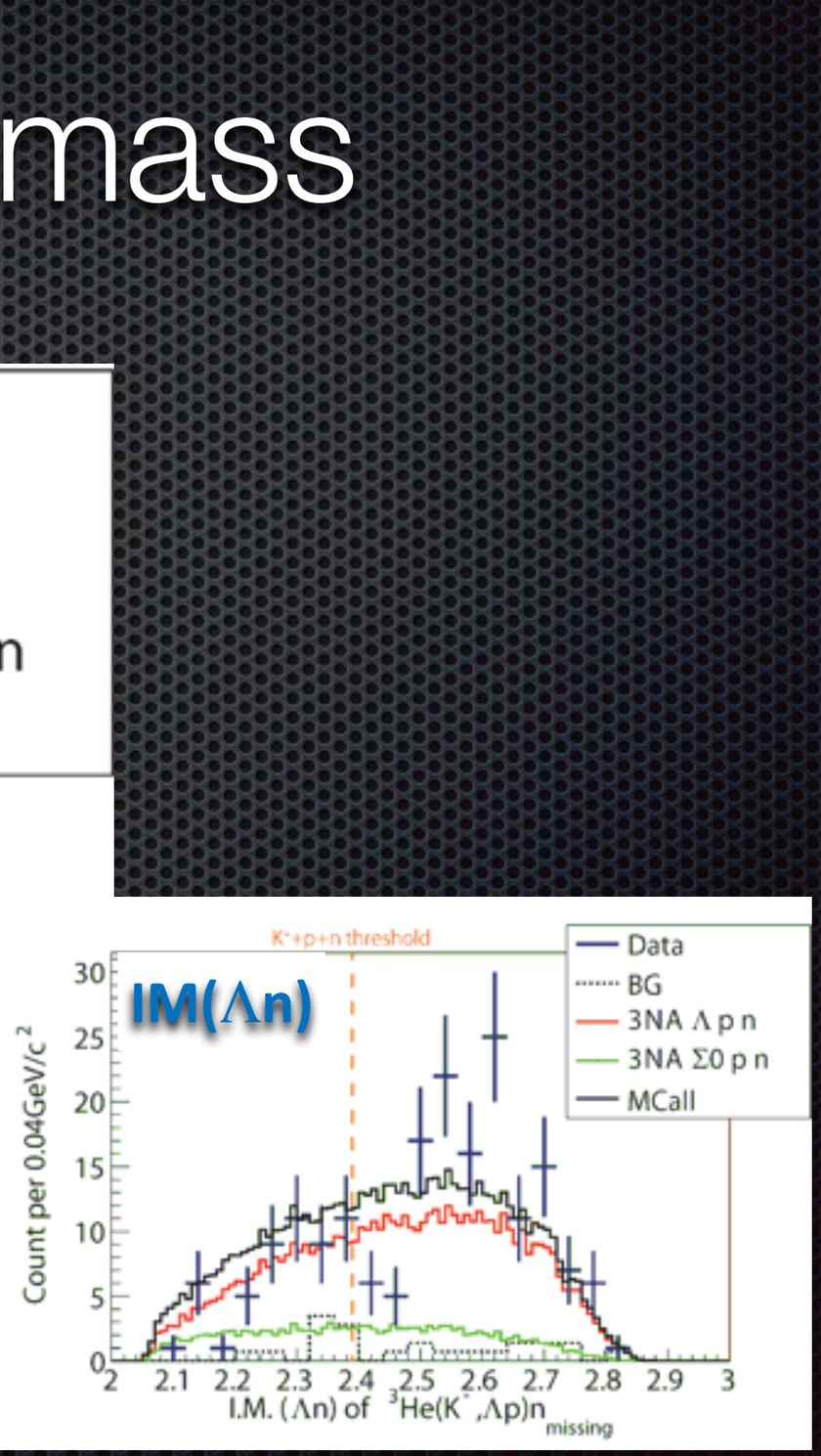
2NA+2step:
e.g. $K^{-3}He \rightarrow \Sigma^0 p n_s$,
$\Sigma^0 n_s \rightarrow \Lambda n$

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

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

^{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

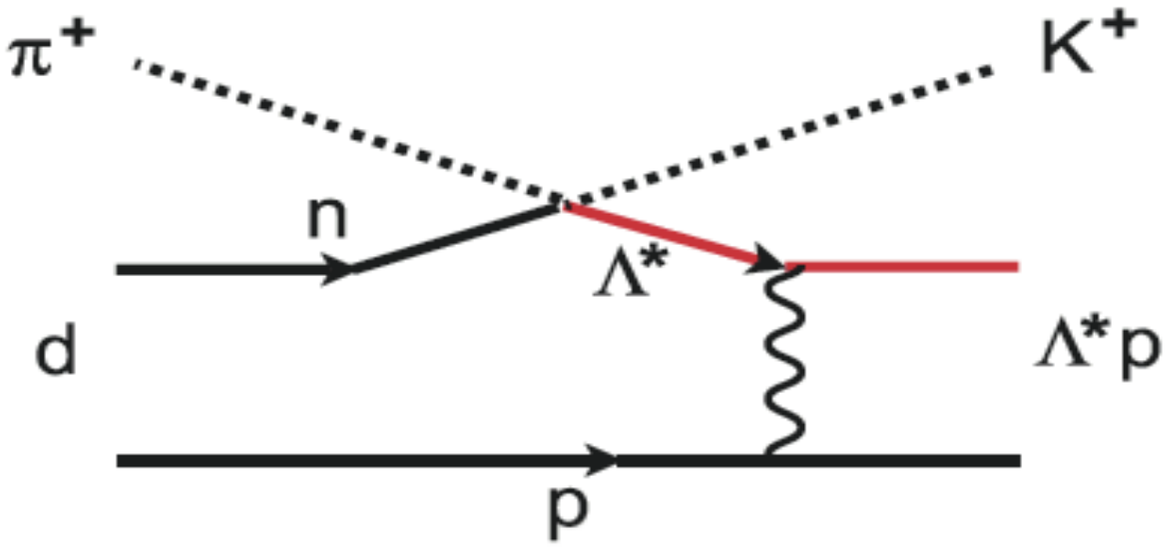
- $K^{-}{}^{3}He$ reaction at 1 GeV/c : 4-days data taking was successful.
  - Excess below the $K^{-}pp$ threshold in (K^{-},n) spectrum.
    - $^{3}He(K^{-},\Lambda p)n$ exclusive process (3-nucleon abs.?) was observed.
- Next physics data taking in 2015 : 10 times more data !

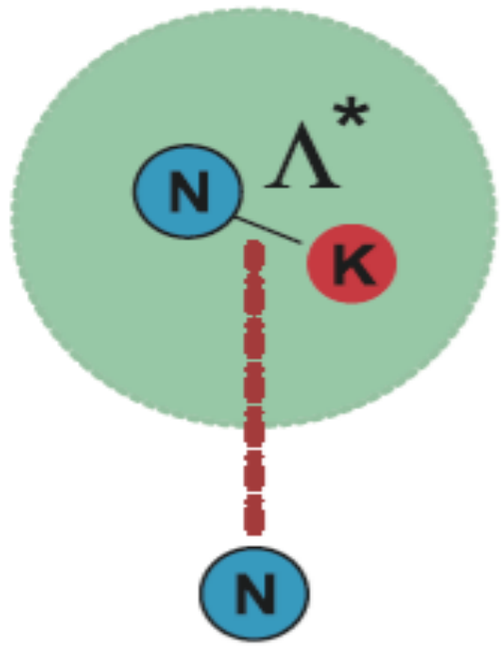
E27: *d*(π^+,K^+) reaction

π^+ + "n" --> "Λ^*" + K^+

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

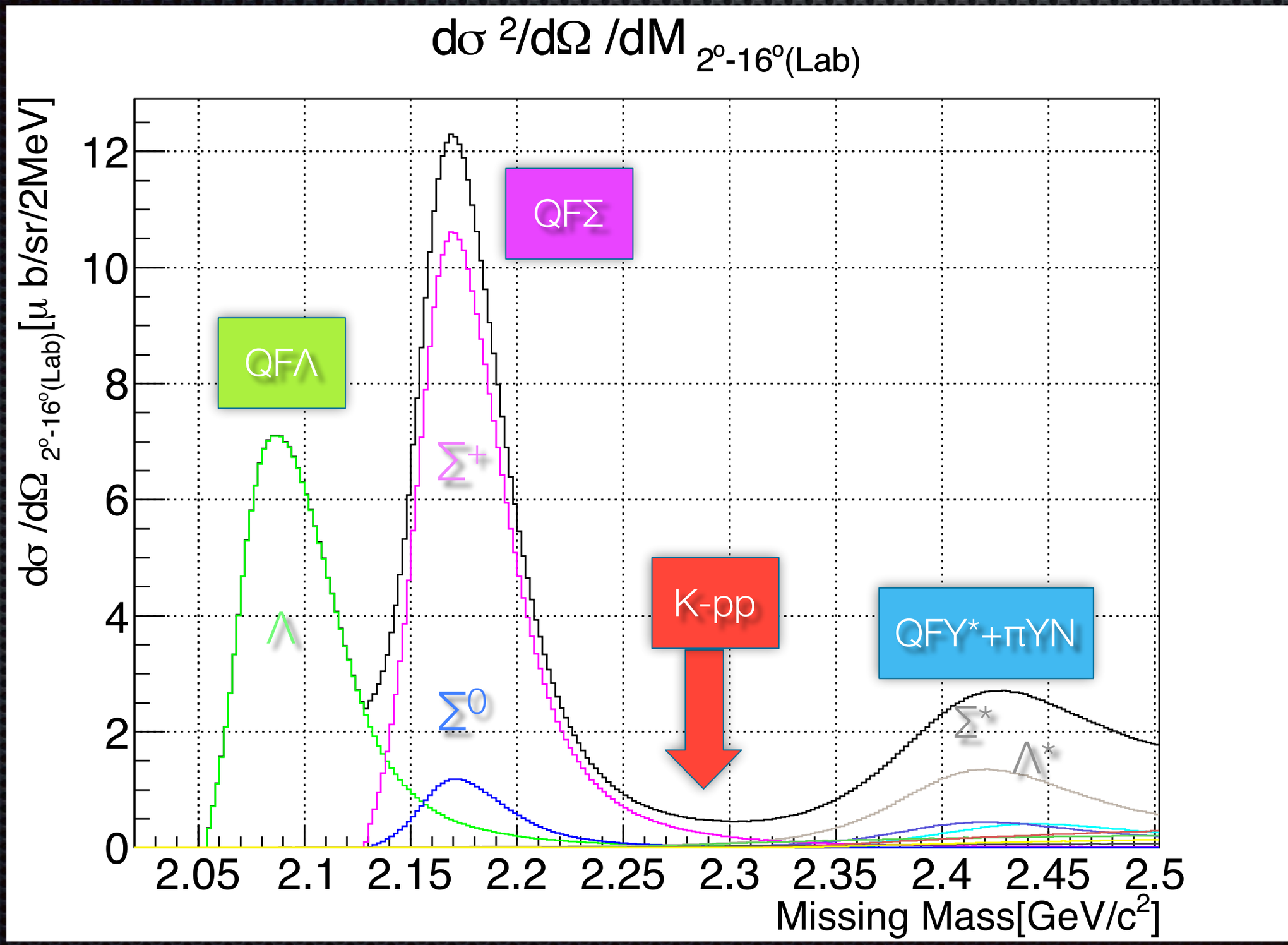
--> quasi-free Λ^* ***dominant***





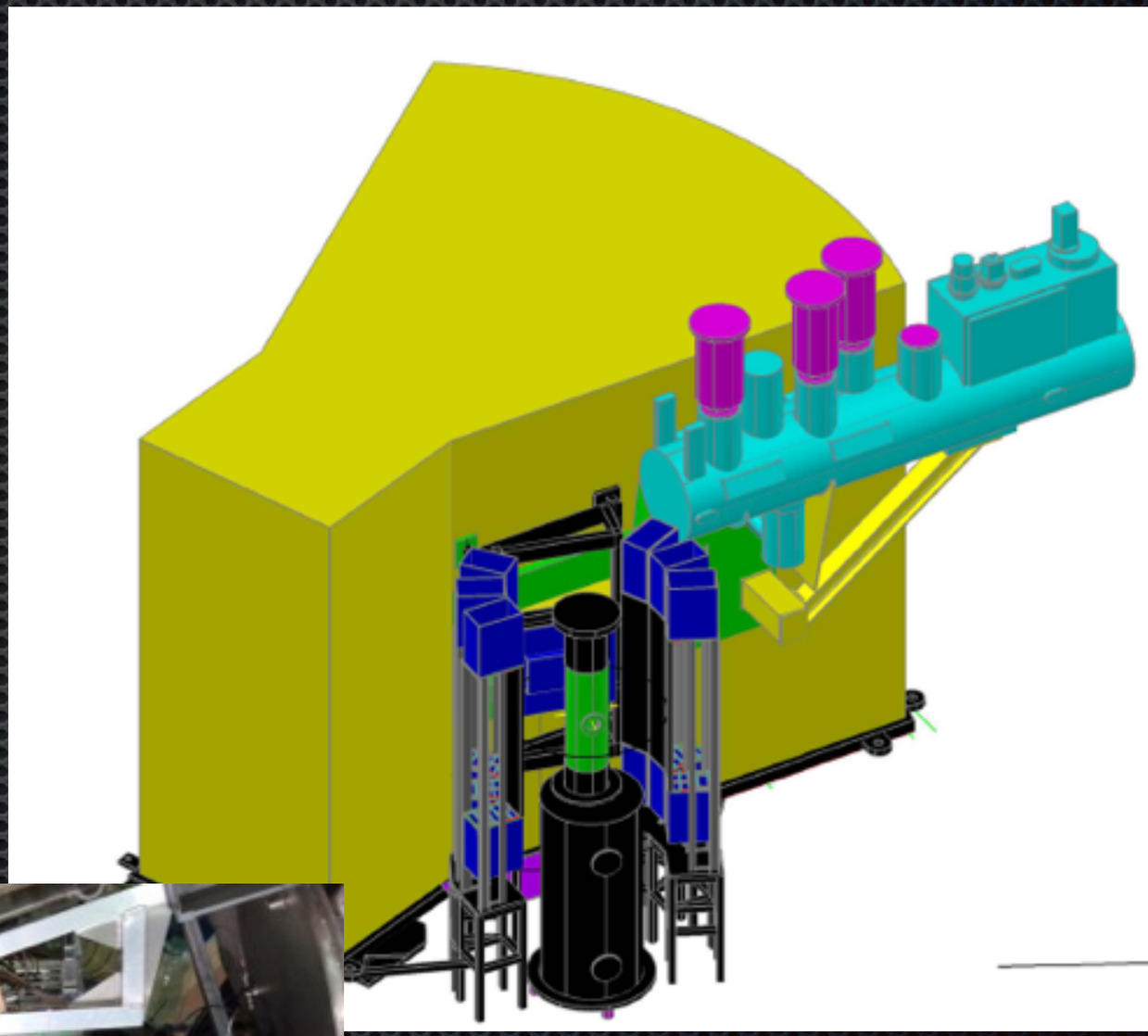
Yamazaki & Akaishi, Phys. Rev. C76 (2007) 045201.

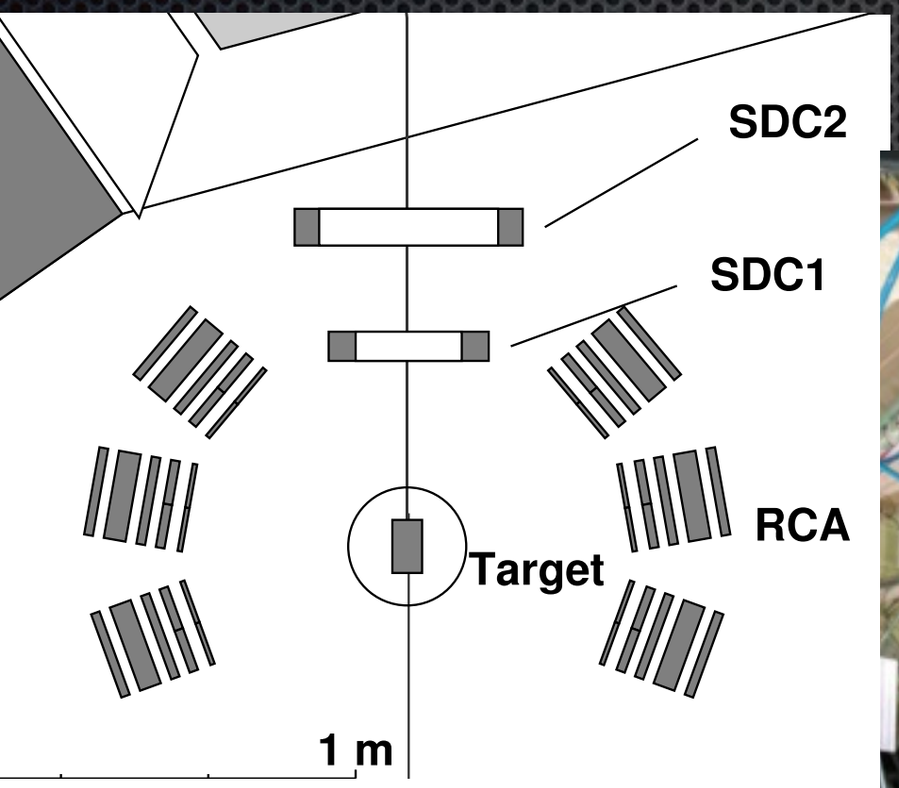
d(π⁺,K⁺) inclusive spectrum; in simulation

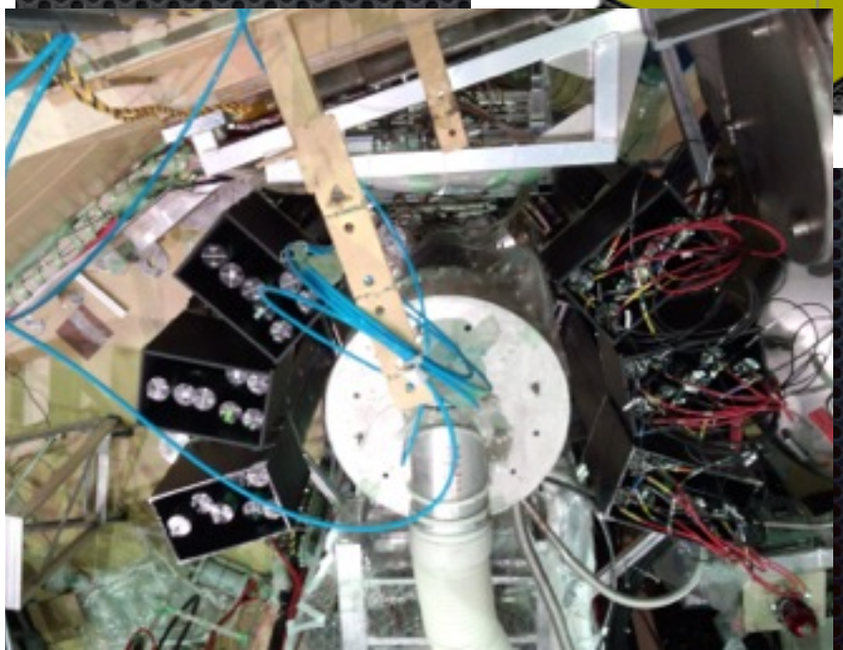


Range Counter System for E27

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

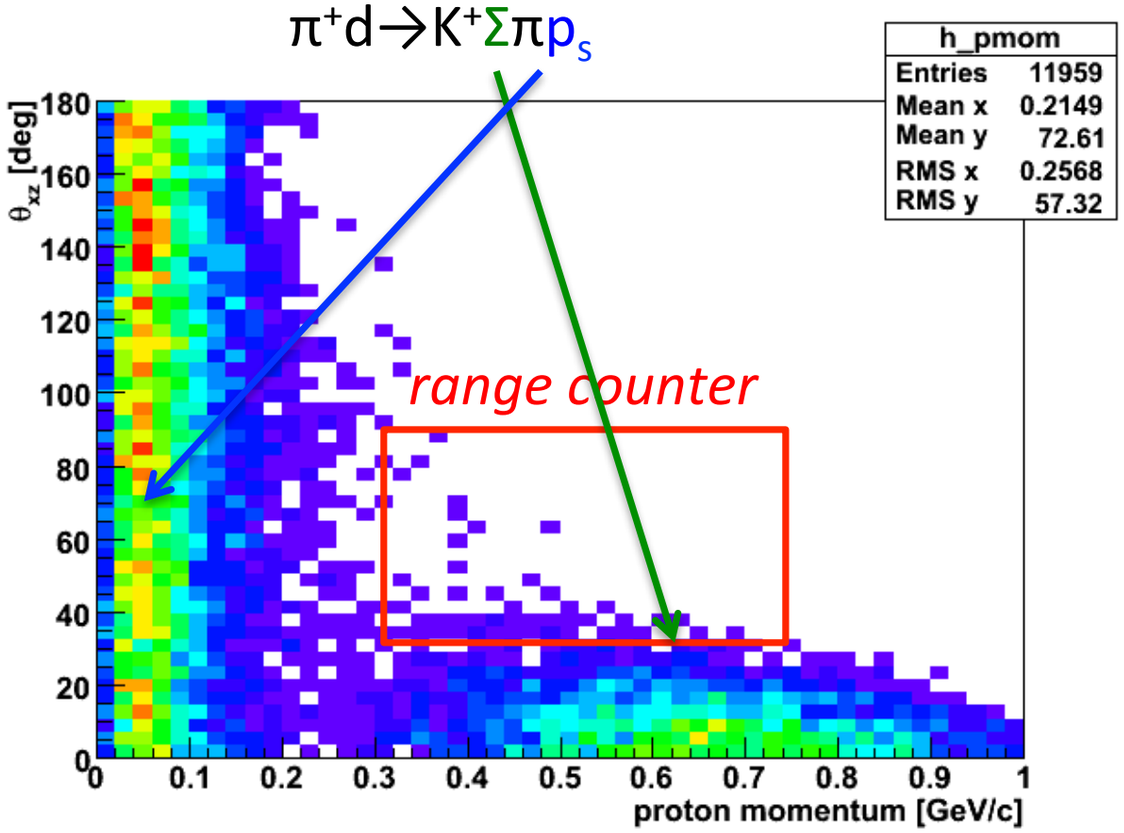




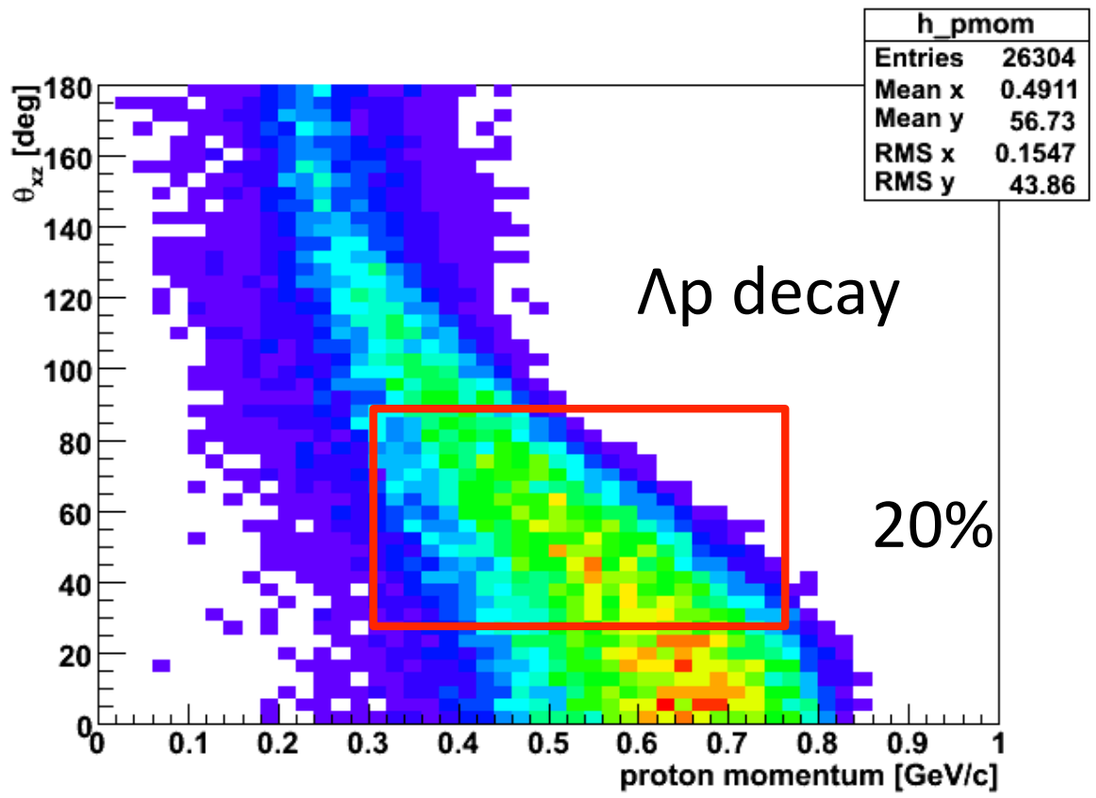


One-proton tagging

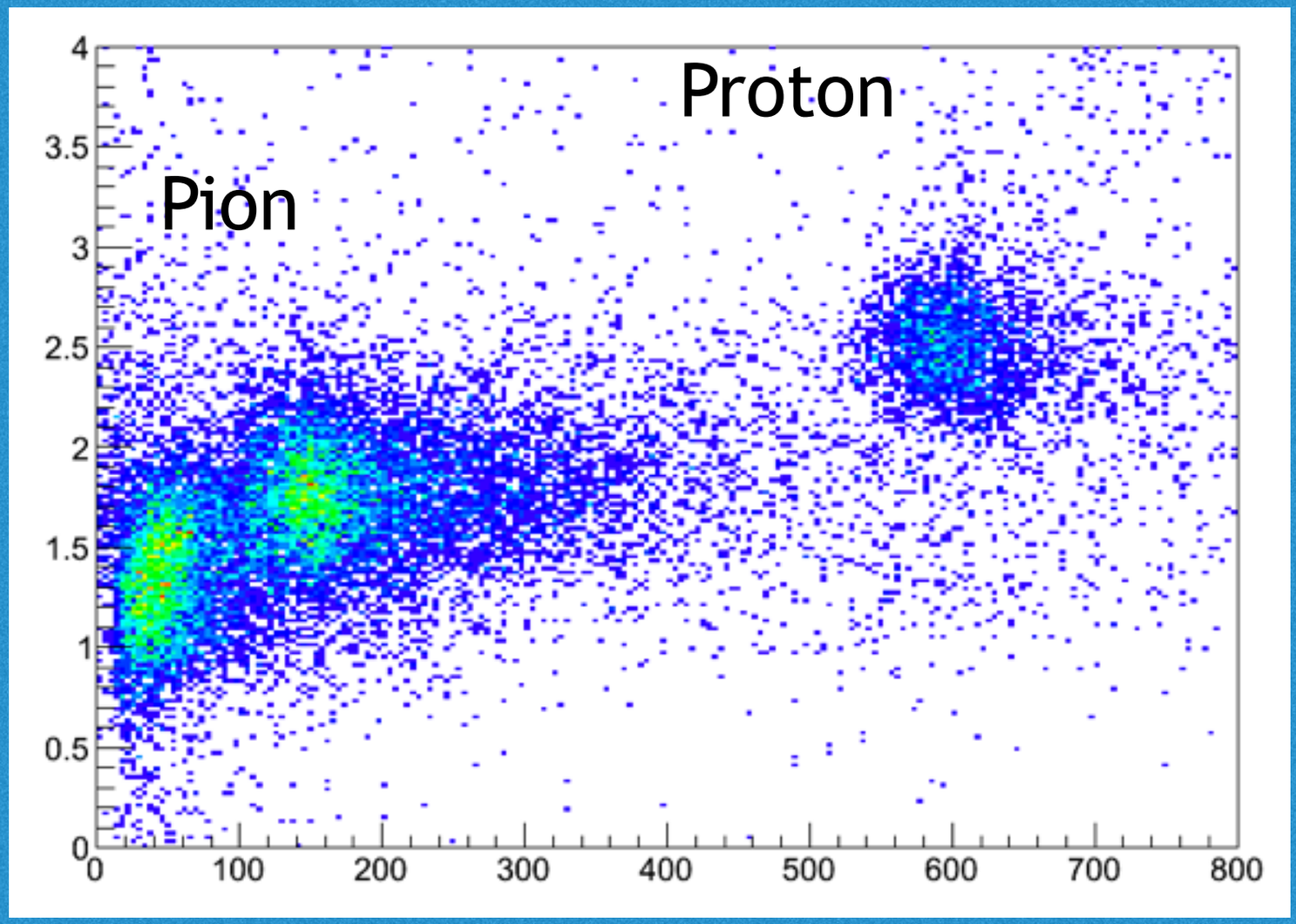
Quasifree Y productions



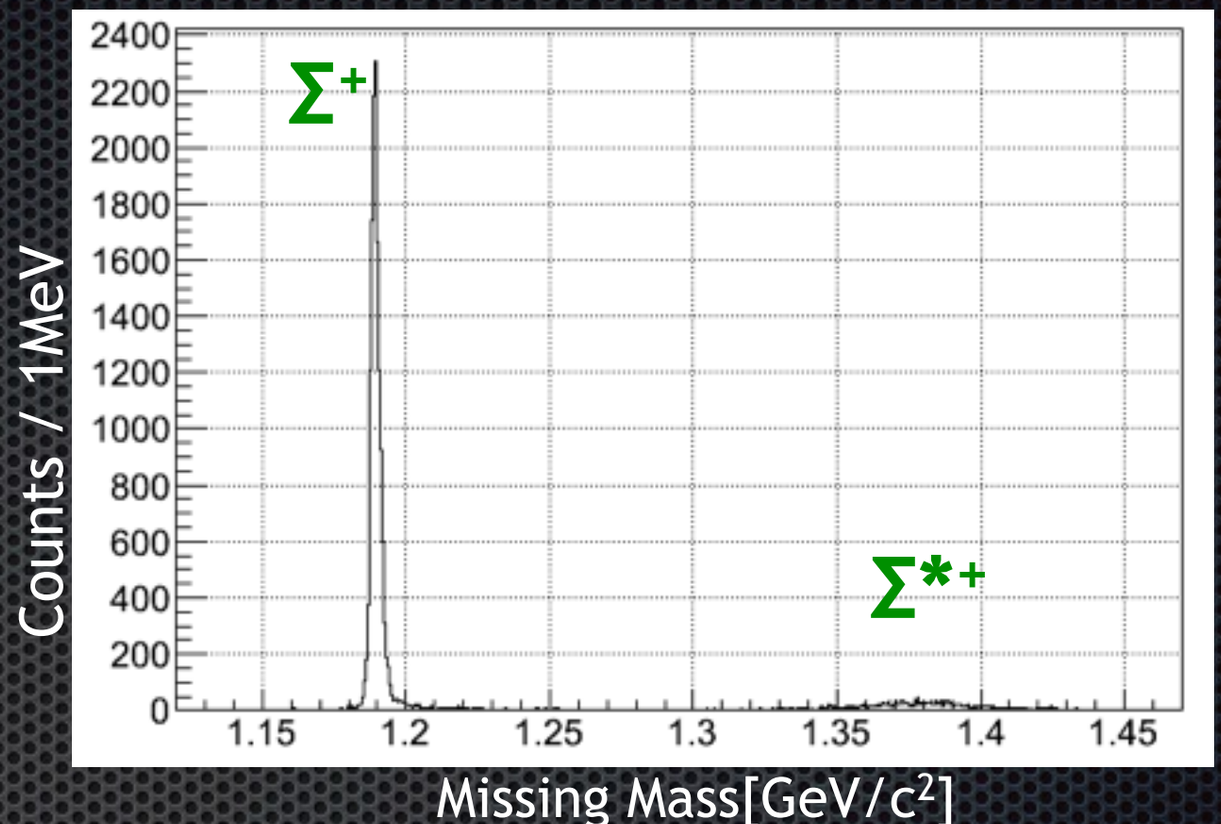
Non-mesonic decay from K-pp



Particle Identification in Range Counter

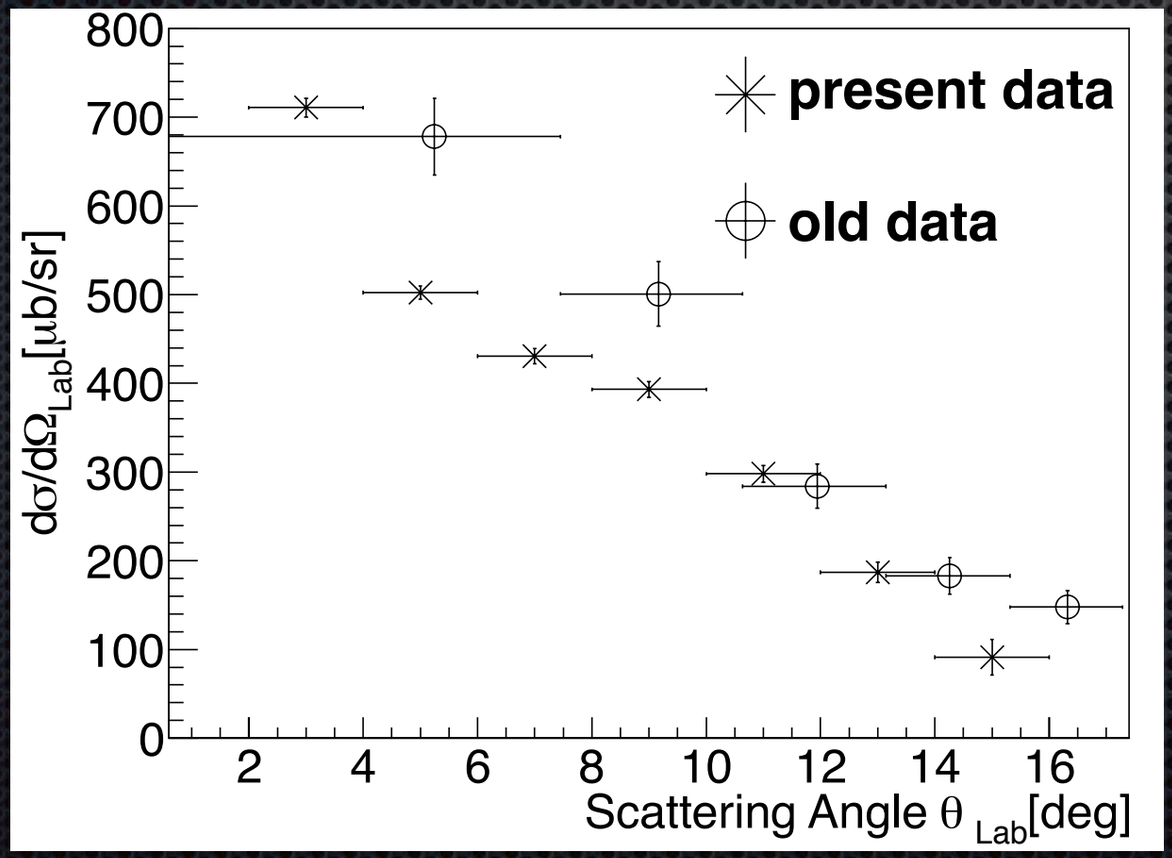


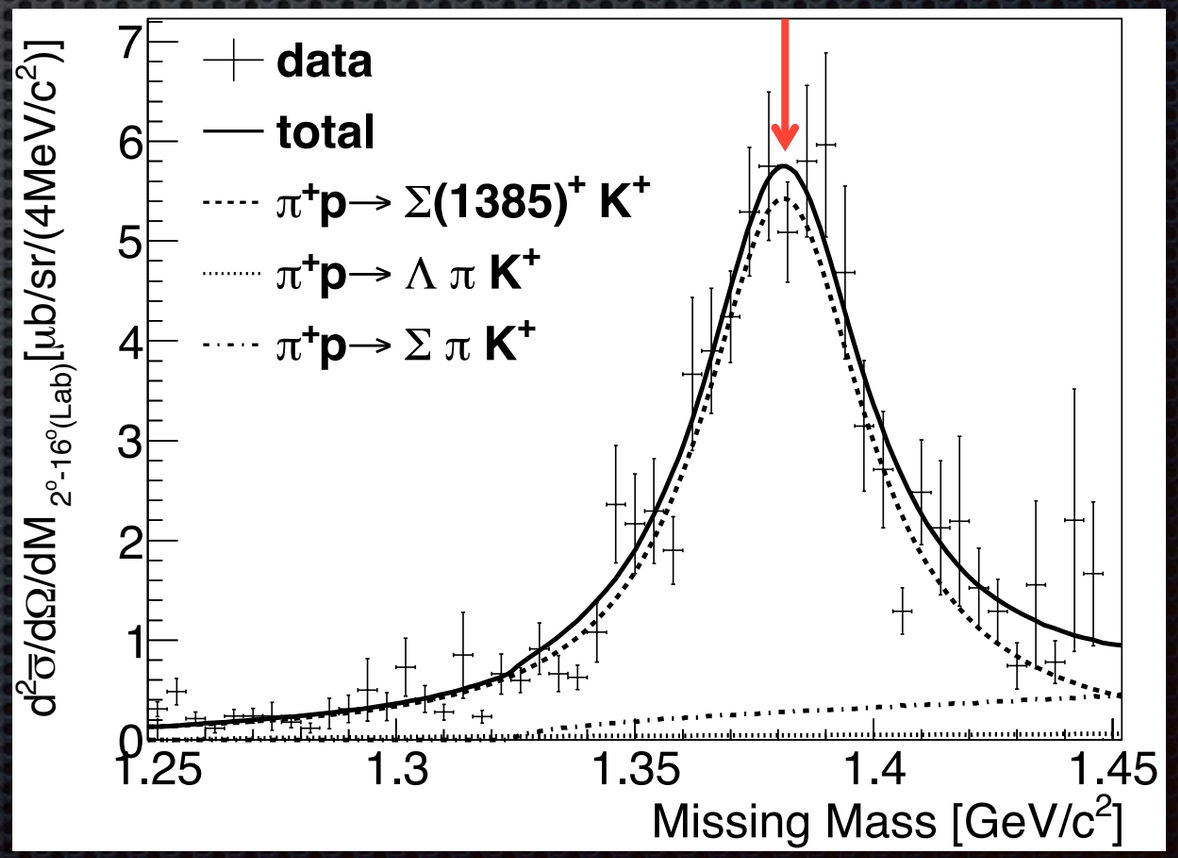
$p(\pi^+,K^+)1.69$ GeV/c



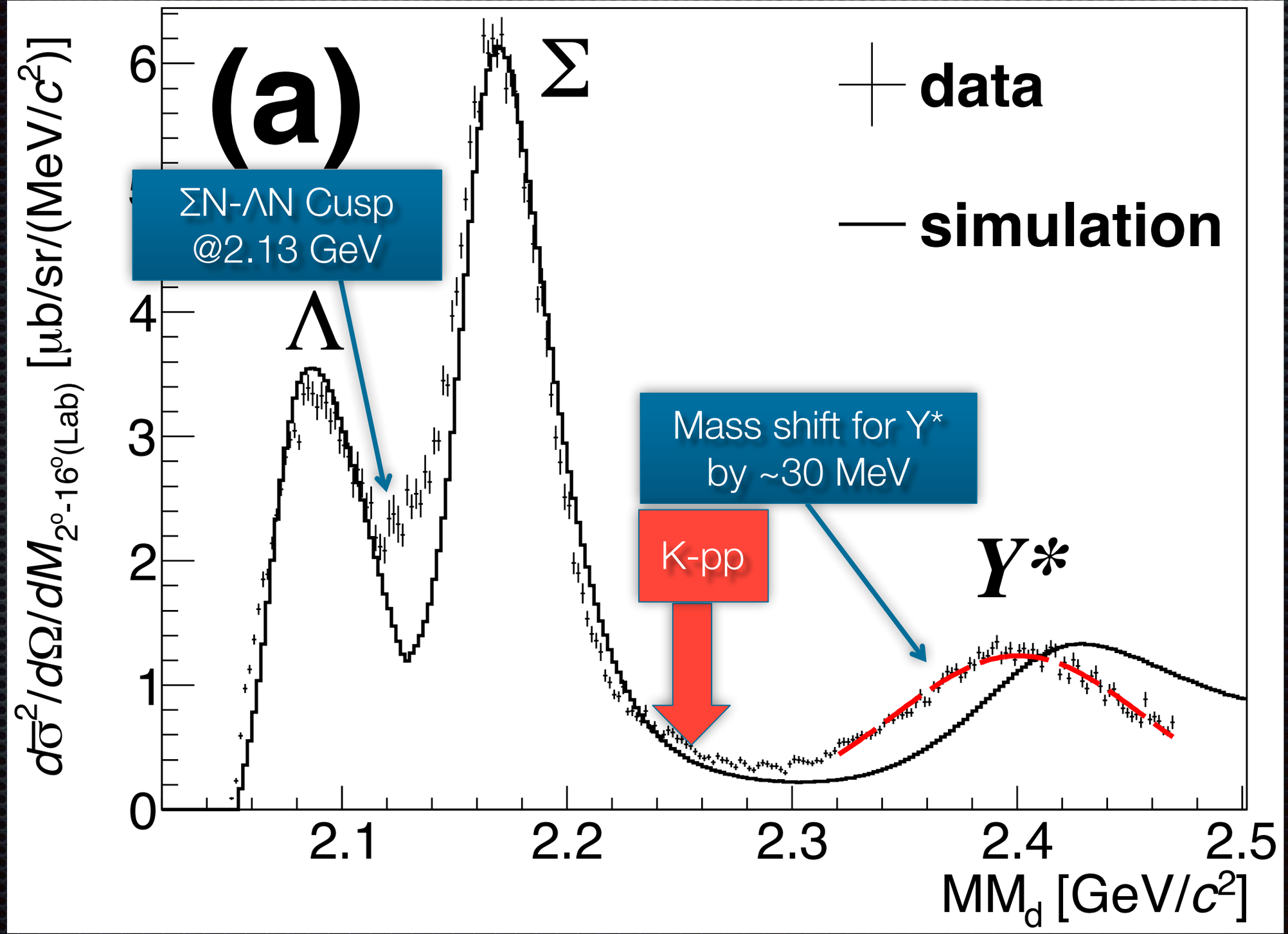
$p(\pi^+,K^+)\Sigma^+$ @1.69 GeV/c

- Σ^+ production



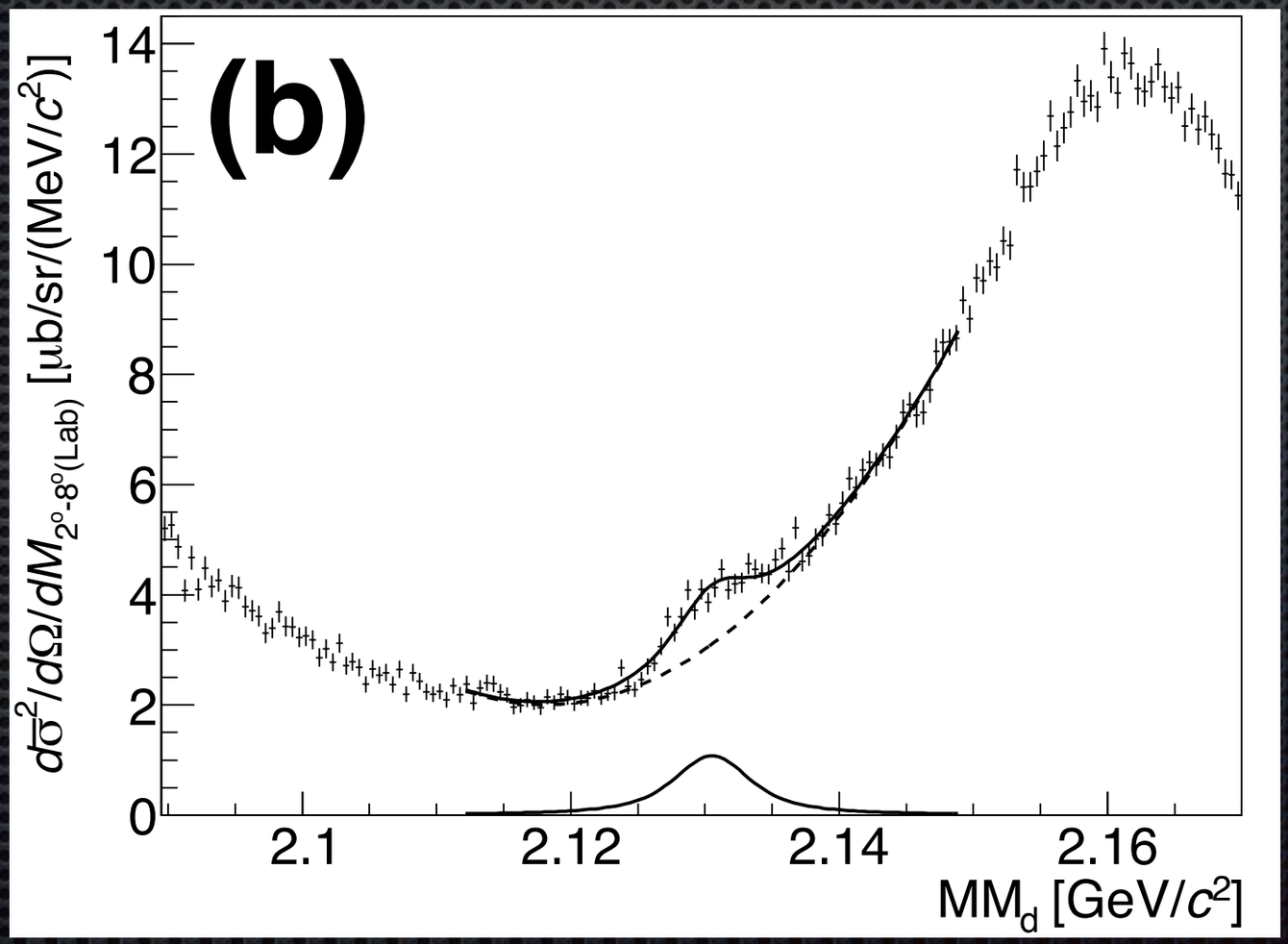


d(π⁺, K⁺) @1.69 GeV/c

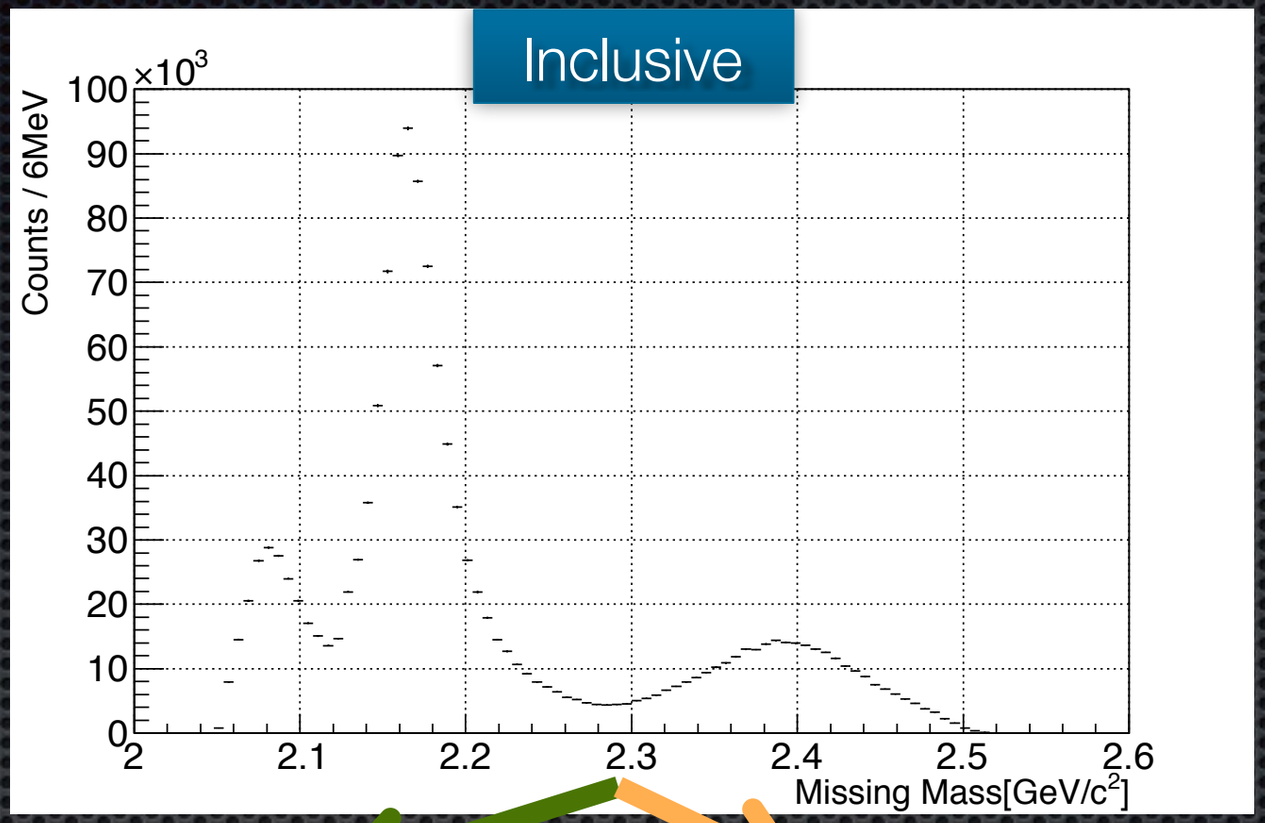

(a)
Σ
Λ
ΣN-ΛN Cusp
@2.13 GeV
Mass shift for Y*
by ~30 MeV
K-pp
Y*
data
simulation
$d\sigma^2/d\Omega/dM_{2°\text{-}16°(\text{Lab})}$ [μb/sr/(MeV/c^2)]
MM_d [GeV/c^2]
0
1
2
3
4
6
2.1
2.2
2.3
2.4
2.5

ΣN→ΛN cusp

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

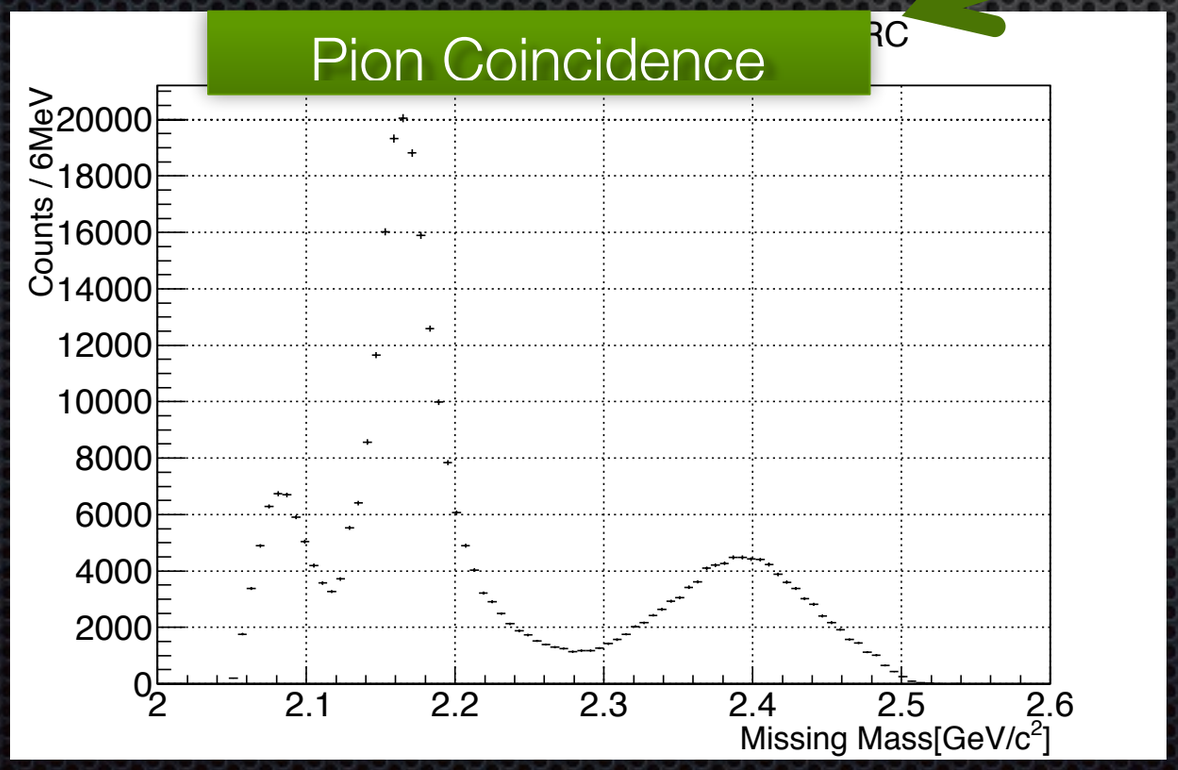


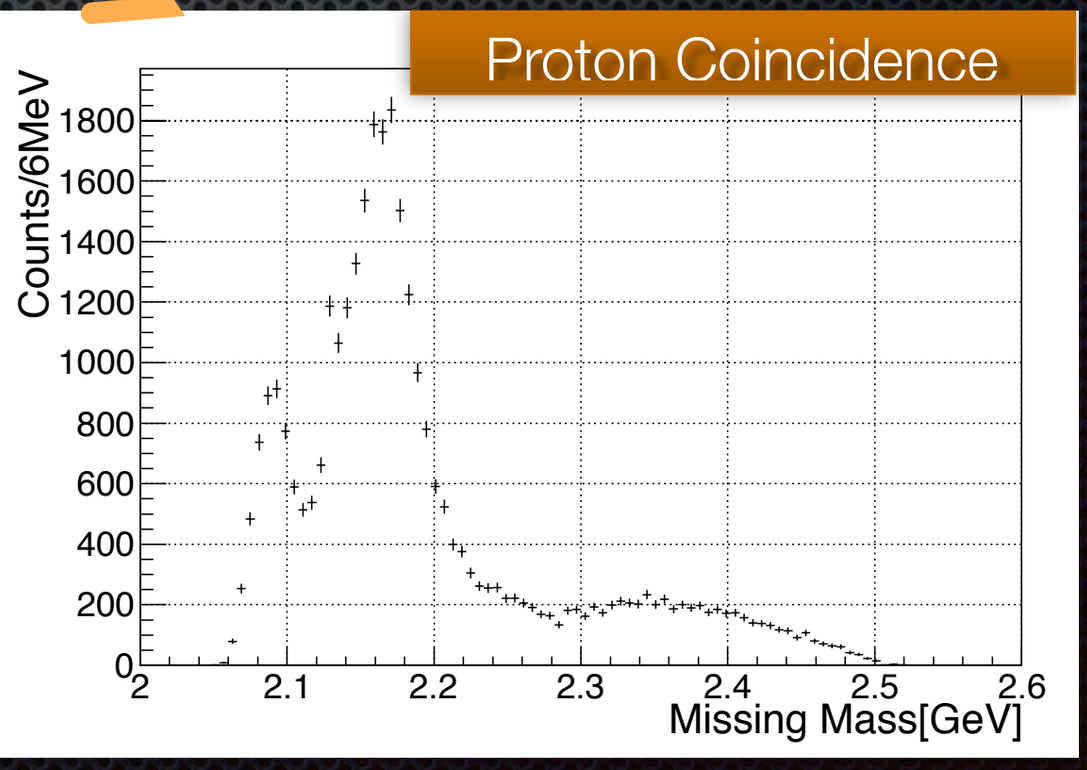
Coincidence study



"pion"=π or slow p

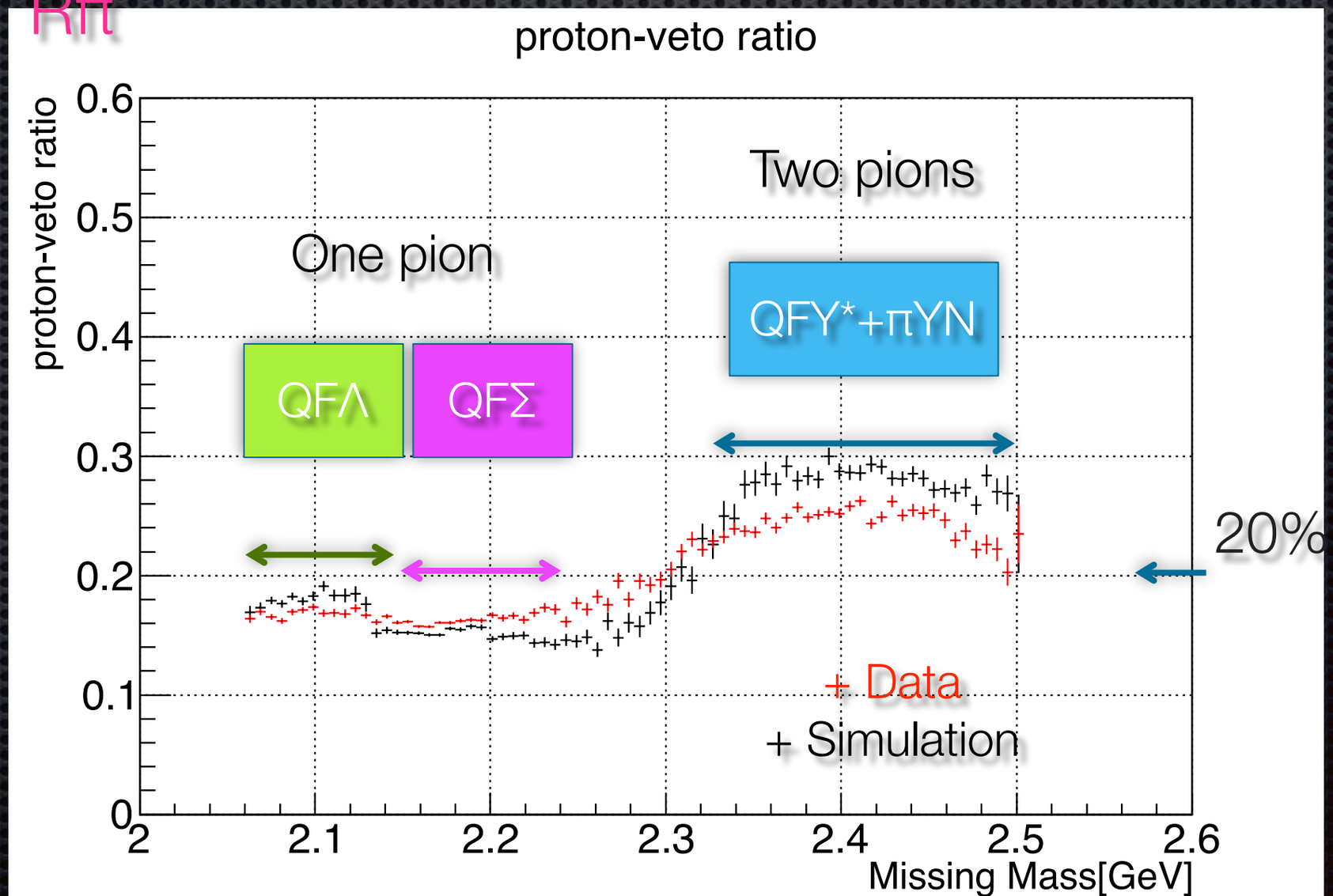
"proton"=p>280 MeV/c





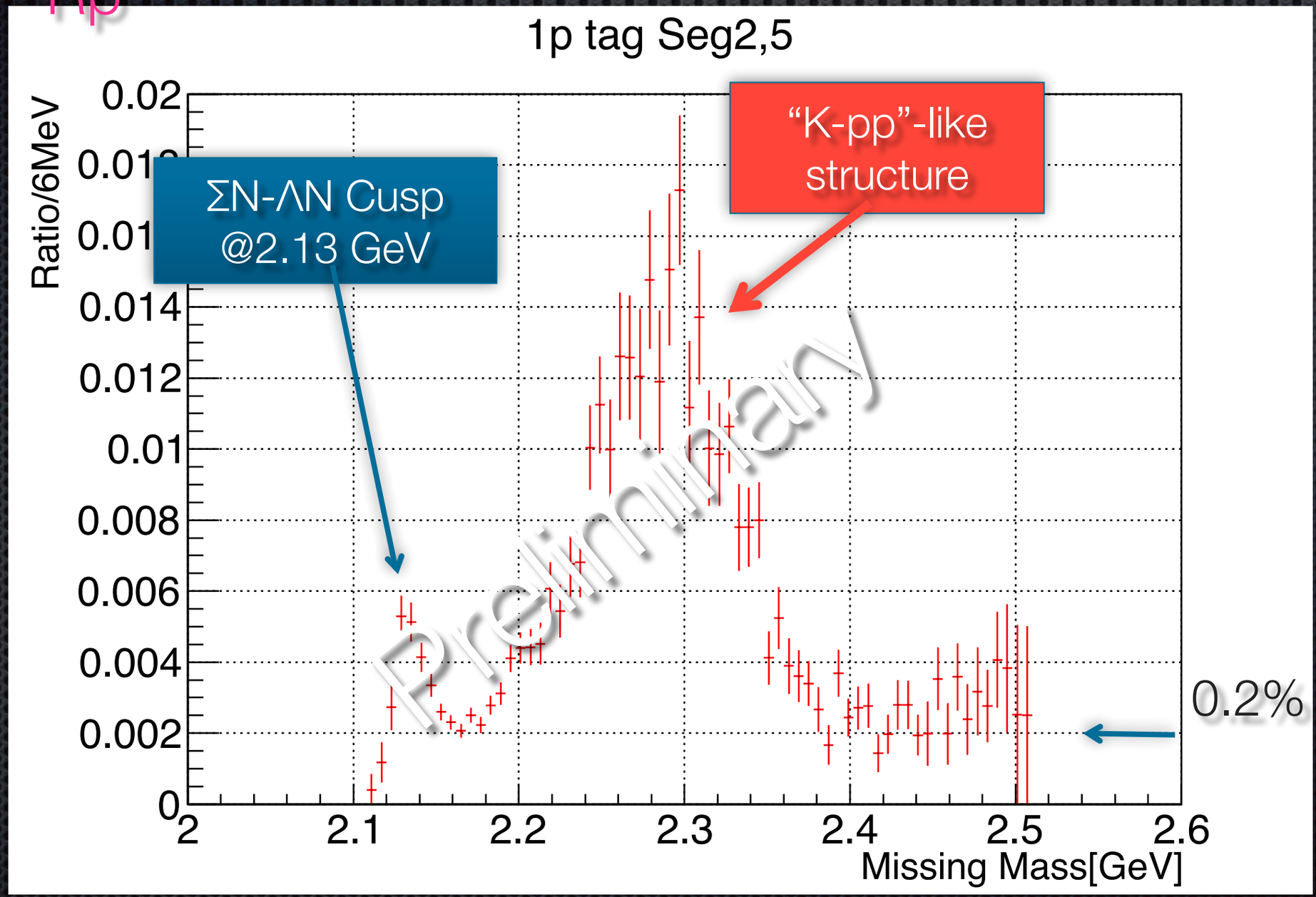
Pion Coincidence Rate

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



Proton Coincidence Rate

Rp

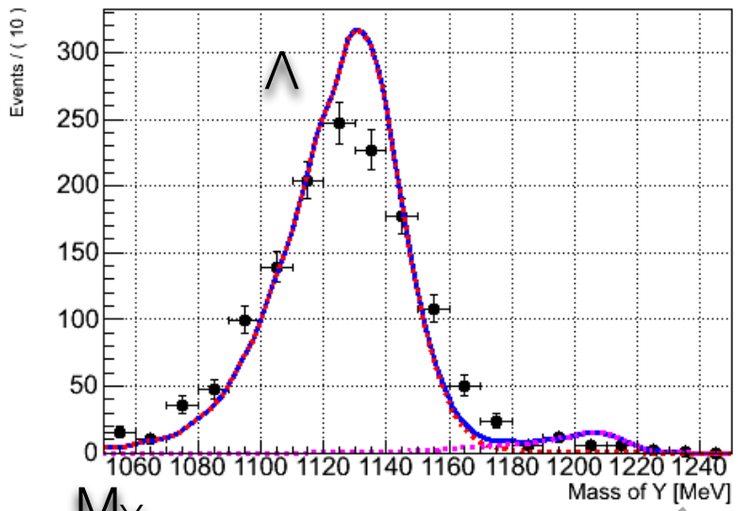


Hyperon mass with two protons

- $d(\pi^+,K^+)K^-pp$; $K^-pp \rightarrow Y+p$, $Y \rightarrow \pi+p(+\gamma+\pi)$
  - $M_Y^2 = (E_\pi+M_d-E_{K^-}-E_p)^2-(p_\pi-p_{K^-}-p_p)^2$

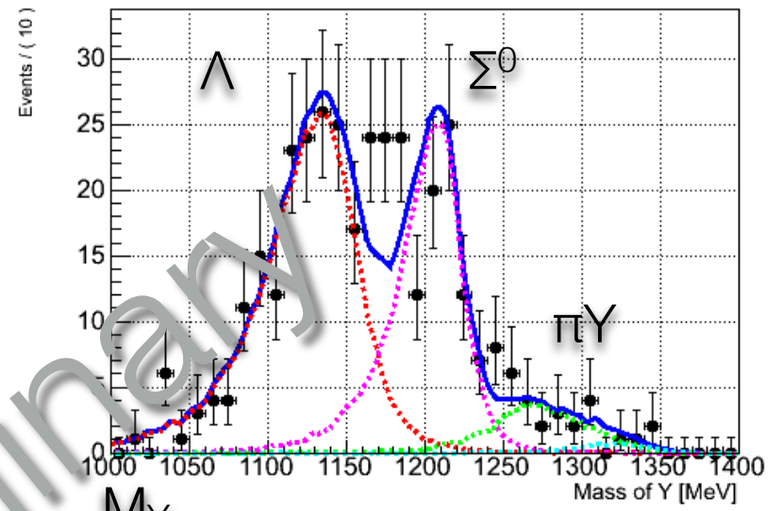
Black: Data , Red: Λp, Pink: Σ^0p, Green: Λπ^0p, Sky: $\Sigma^+\pi^-$p, Blue: All component

2.1<MM<2.22[GeV/c^2]



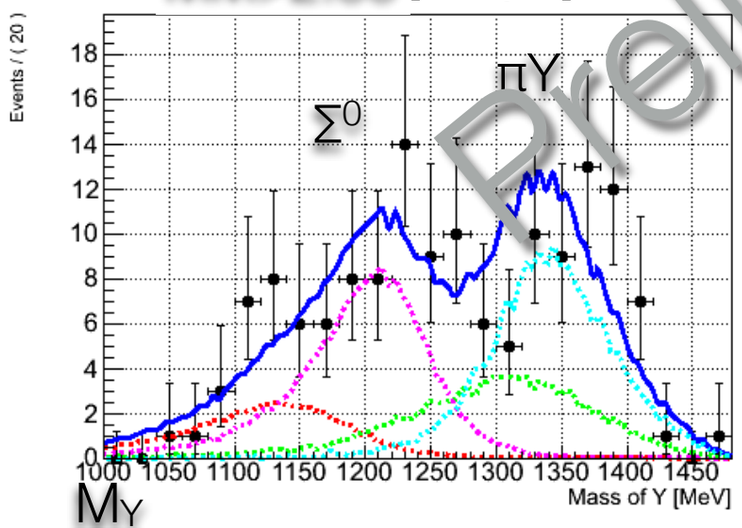
M_Y

2.22<MM<2.35[GeV/c^2]

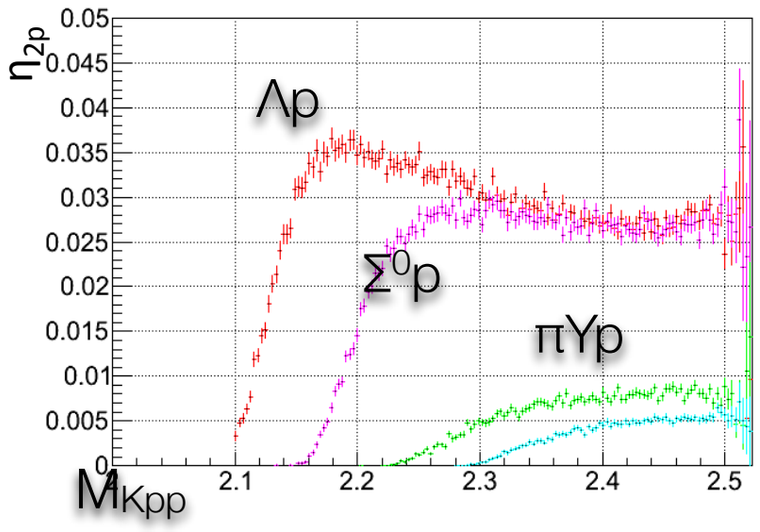


M_Y

MM>2.35 **[GeV/c^2]**



M_Y



Summary

- E15 : 4-days data taking
  - ^{3}He(K^{-},n) missing mass spectrum
    - Excess below the K+p+p threshold
  - ^{3}He(K^{-}, Λp)n exclusive measurement
    - 3-nucleon absorption ?
    - 10 times more data in 2015
- E27 : A pilot run of ~10 days
  - d(π^{+},K^{+}) missing mass spectrum at 1.69 GeV/c
    - threshold cusp at 2.13 GeV/c^{2}
    - mass shift of ~30 MeV in Y* region
  - proton coincidence
    - an enhancement of "*$K^{-}pp$*"-like structure
    - BR : Λp, Σ^{0}p, πYN ~ 1 : 1 : < 0.5