E10 status

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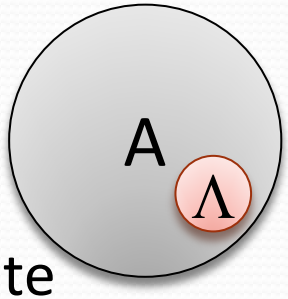
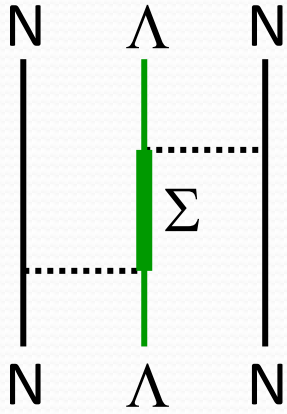
for the E10 Collaboration

Study of Λ hypernuclei and ΛN interaction



- Λ hypernucleus
  - System made of a Λ hyperon and a nucleus(A)
    - ΛN interaction strong enough to form a bound state
  - Binding energies and structures of Λ hypernuclei give us the information of the ΛN interaction
- How far can we extend the hypernucler chart?
  - Importance of "glue-like role" of Λ hyperon
  - ΛN interaction also stabilize host nucleus
- How about ΛNN 3-body force?
  - Prediction of a strong ΛNN 3-body force
  - Force comes from ΛN-ΣN mixing process



Aims of E10 experiment

- E10 is proposing study of neutron-rich Λ hypernuclei
- **Aim 1**: Λ hypernuclei close to the neutron drip-line
  - Highly neutron-rich Λ hypernuclei
    - ${}^{6}_{\Lambda}$H (1p, 4n and 1Λ), ${}^{9}_{\Lambda}$He (2p, 6n and 1Λ)
  - "glue-like role" of Λ hyperon is critical in such loosely bound hypernuclei
- **Aim 2**: ΛN interaction at the extreme condition
  - Effect of ΛN-ΣN mixing or ΛNN 3-body force may be observed in structures of neutron-rich Λ hypernuclei
  - Neutron-rich Λ hypernuclei are good laboratories to study these effects

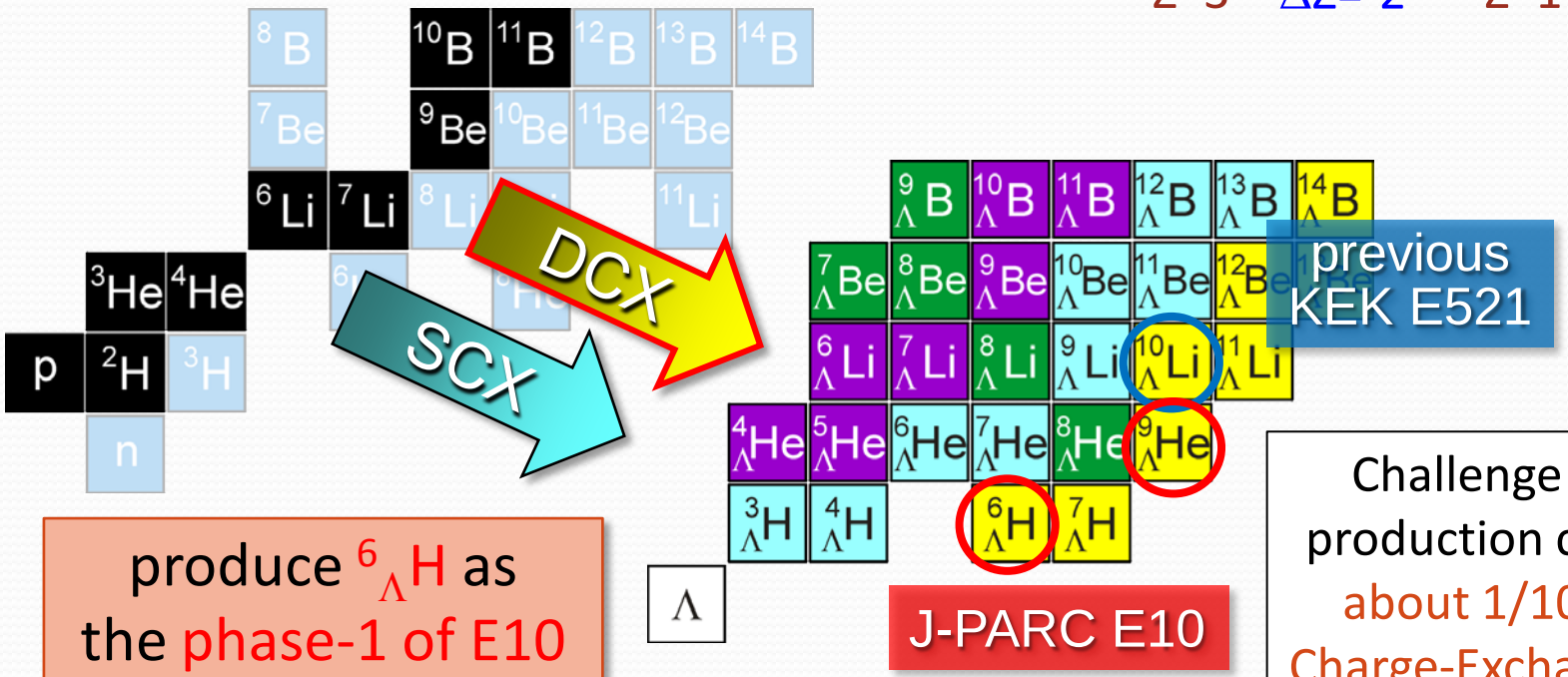
Production of neutron-rich Λ hypernuclei

- How to produce?
  - Double Charge-eXchange (DCX) reaction

$$\pi^- + p + p \rightarrow K^+ + \Lambda + n$$

$$^{6}Li\left(\pi^-, K^+\right)\,^{6}_{\Lambda}H$$

Z=3 ΔZ=-2 Z=1

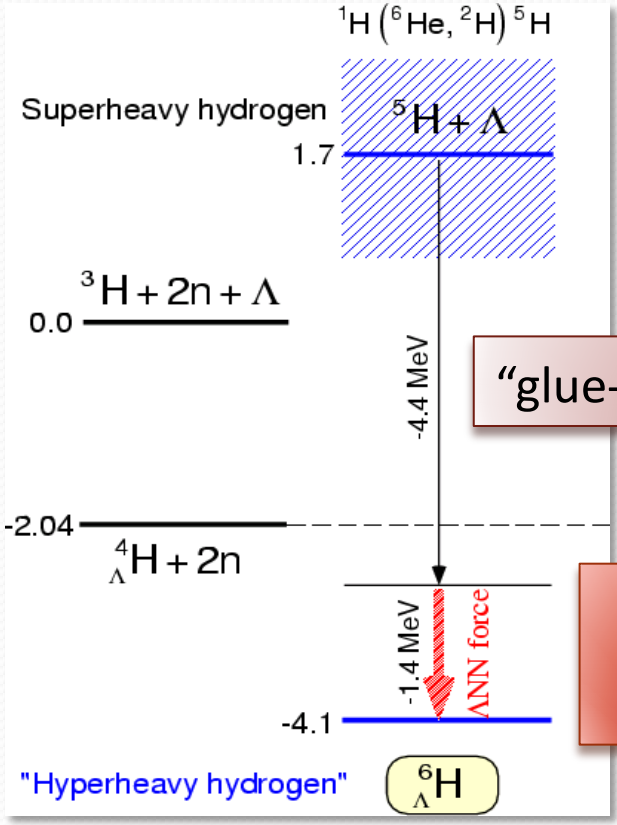


produce $^{6}_{\Lambda}H$ as the phase-1 of E10

Challenge is the tiny production cross section about 1/1000 of Non Charge-Exchange reaction

${}^{6}_{\Lambda}$H hypernucleus and ΛN interaction

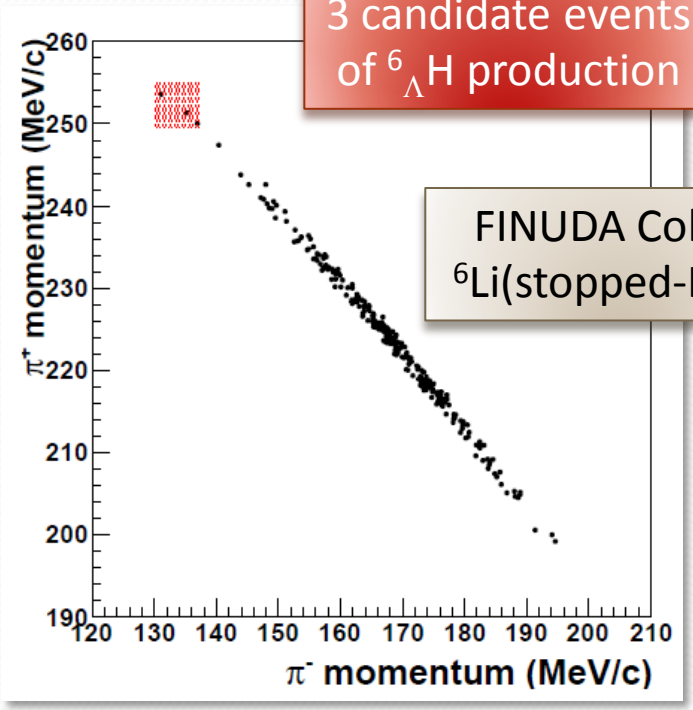
- Possible contribution due to strong ΛN-ΣN mixing
- FINUDA reported bound states of ${}^{6}_{\Lambda}$H



"glue-like role" of Λ

coherent ΛN-ΣN mixing

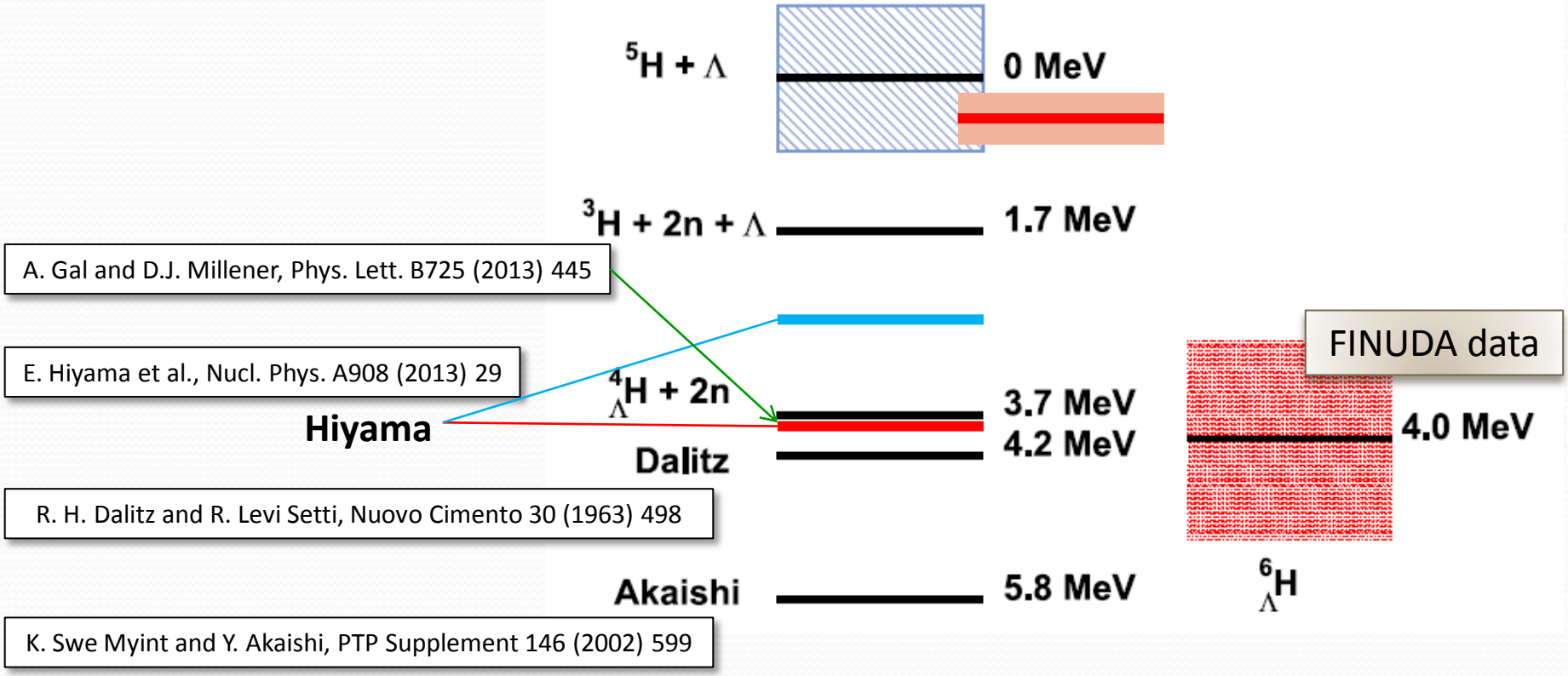
K. Swe Myint and Y. Akaishi, PTP Supplement 146 (2002) 599



M. Agnello et al., FINUDA Collaboration, PRL 108 (2012) 042501
M. Agnello et al., FINUDA Collaboration, NPA 881 (2012) 269

${}^{6}_{\Lambda}$H hypernucleus and ΛN interaction (2)

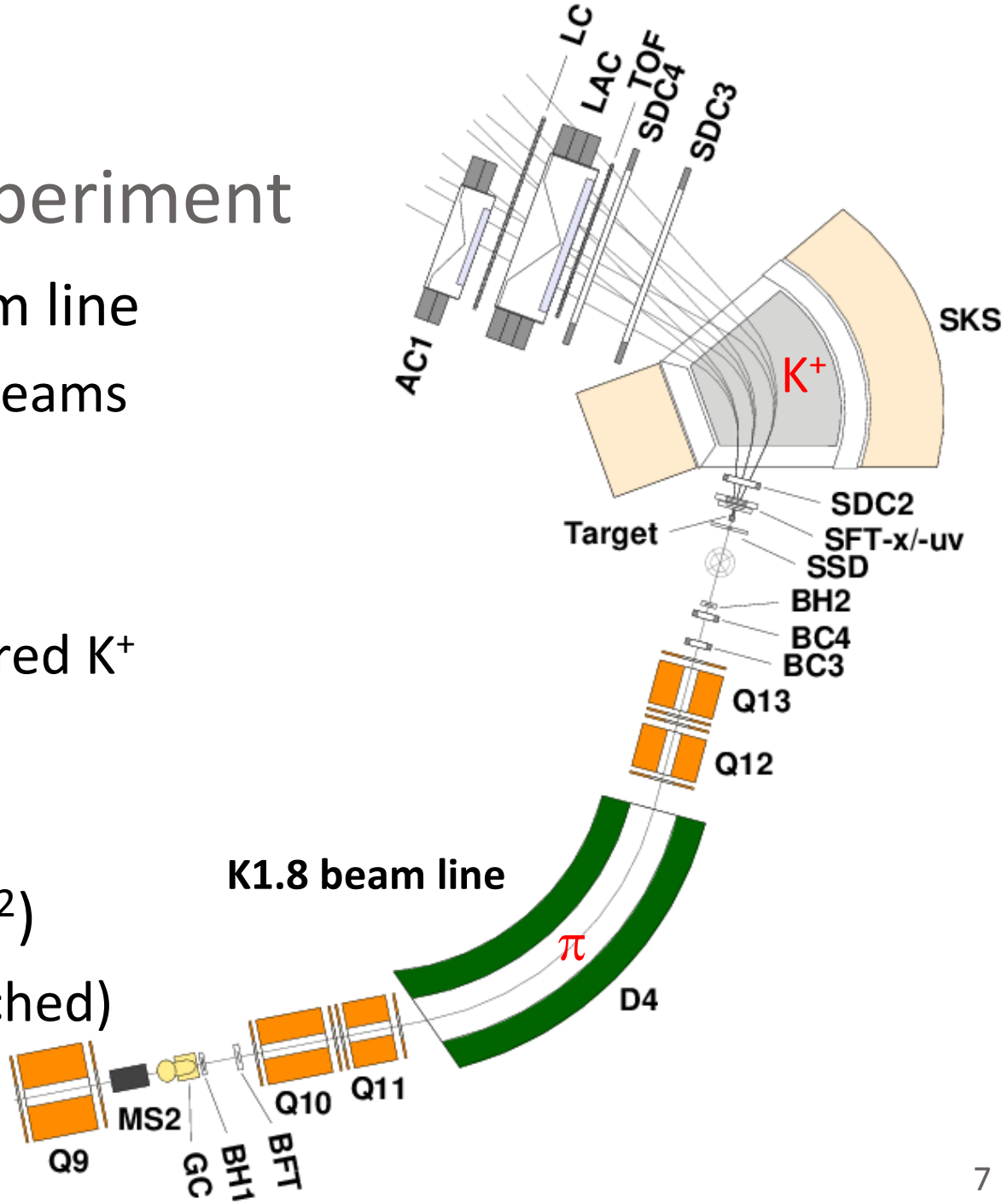
- Theoretical estimations compared with FINUDA data
- Sensitive to ΛN interaction and also properties of ^{5}H



More accurate measurement is awaited

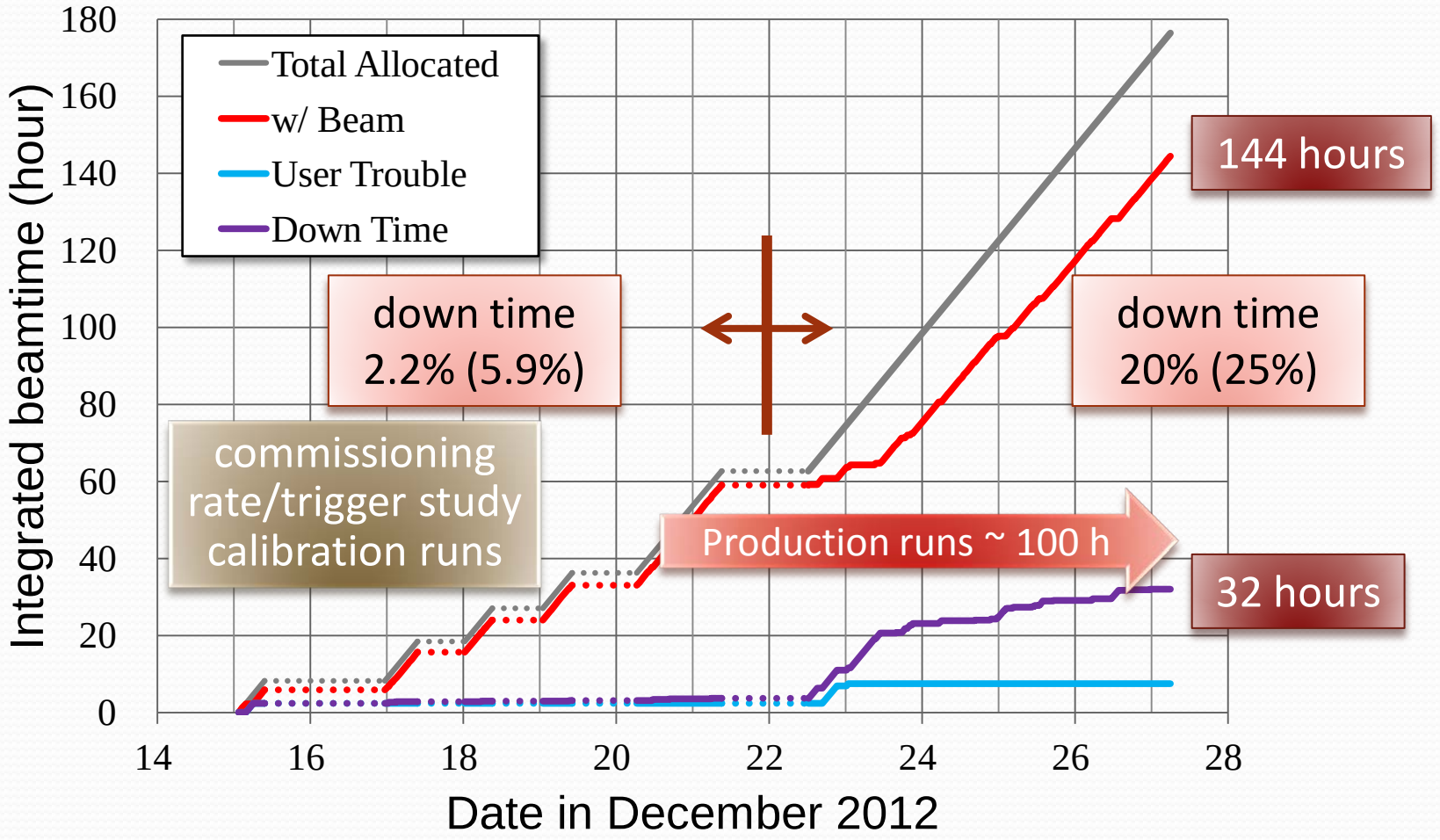
Setup of E10 experiment

- Done at K1.8 beam line
  - 1.2 GeV/c pion beams
  - dp/p ~ 3.3×10^{-4}
- SKS spectrometer
  - 0.9 GeV/c scattered K^+
  - dp/p ~ 10^{-3}
  - $d\Omega$ ~ 100 msr
- Target (~3.5 g/cm^2)
  - ^{6}Li (95.54% enriched)
  - C and $(CH_2)_n$



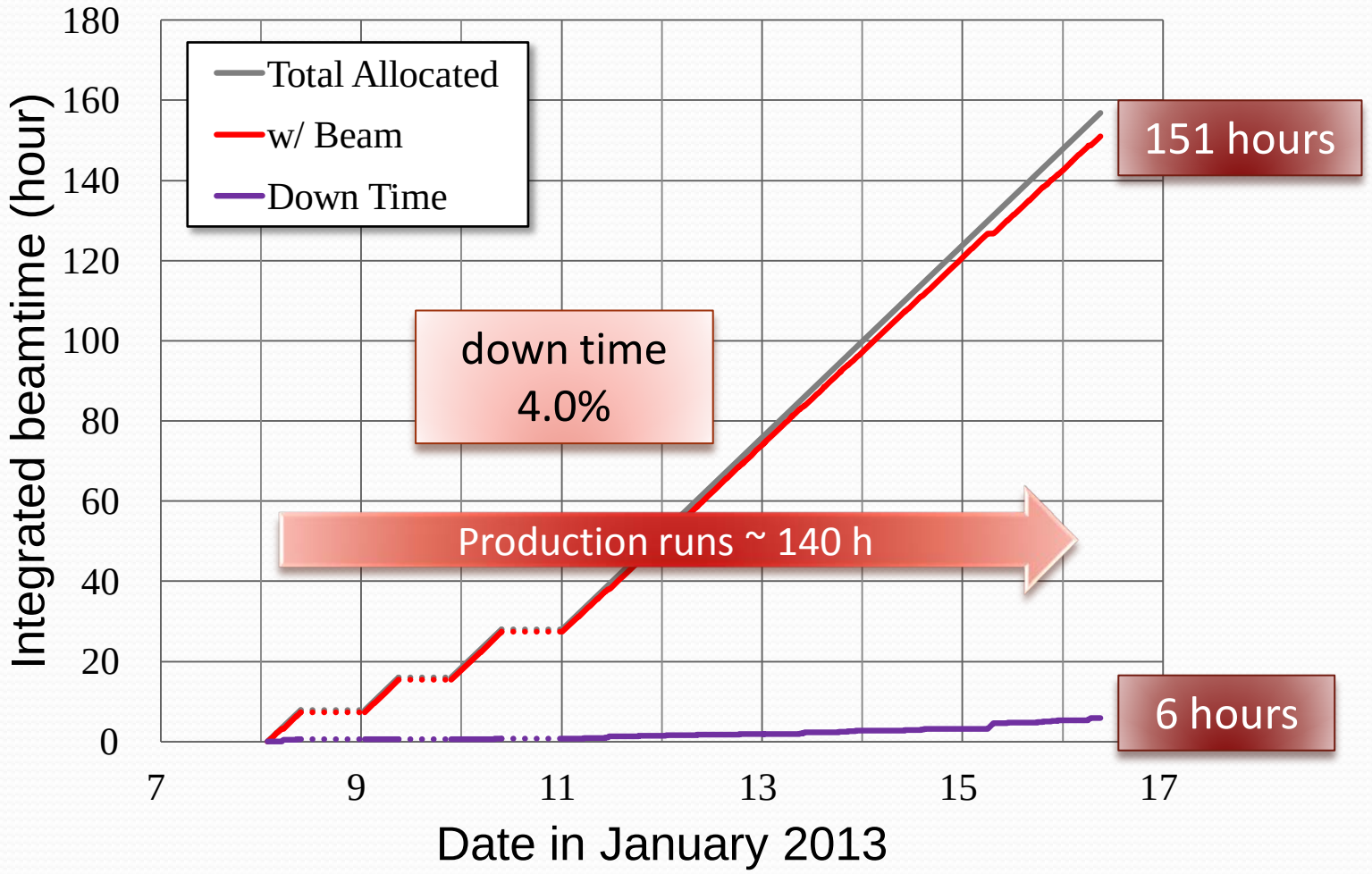
Summary of 2012 December beamtime

- Beamtime summary (from 15/Dec to 27/Dec)



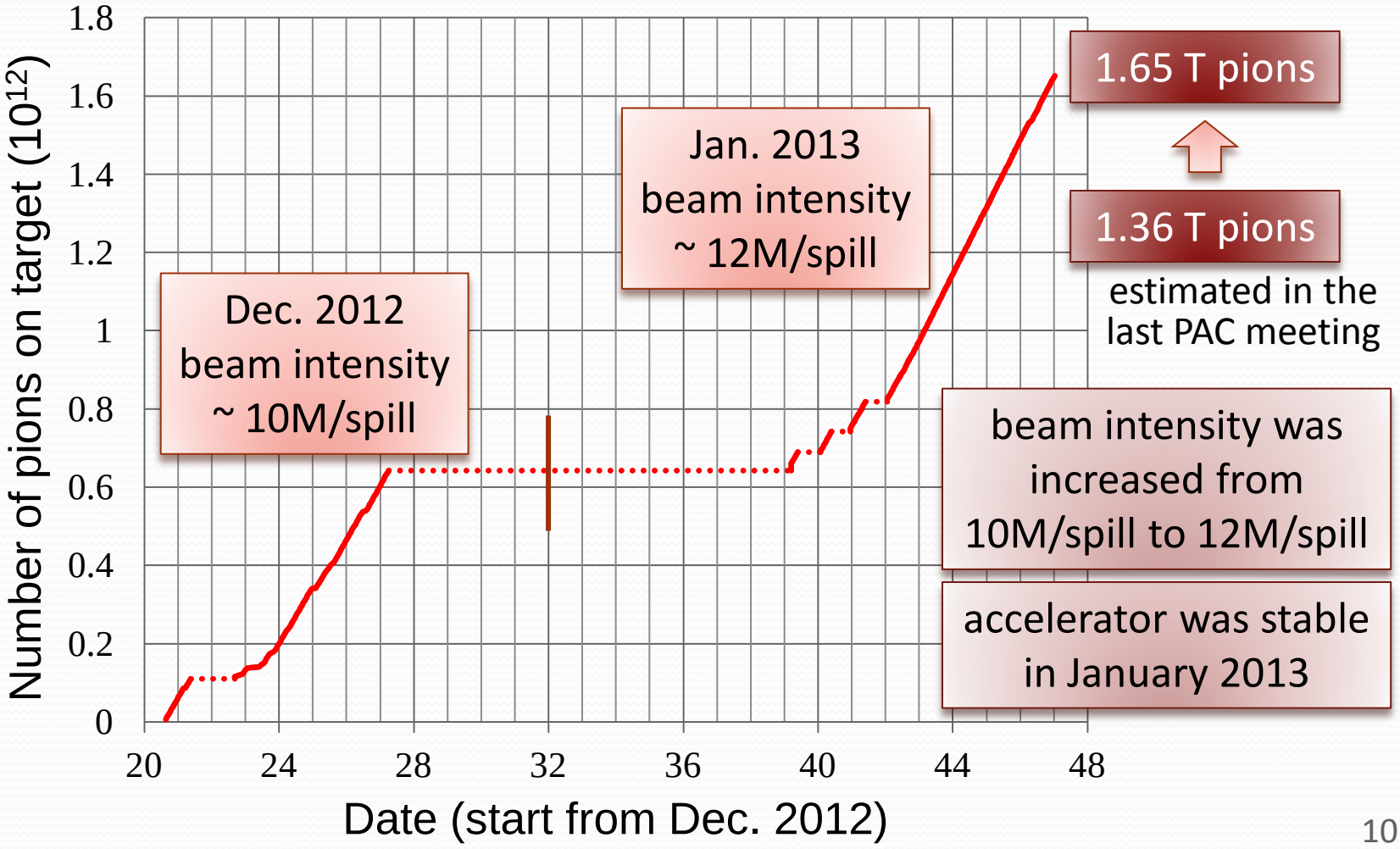
Summary of 2013 January beamtime

- Beamtime summary (from 8/Jan to 16/Jan)



Summary of E10 beamtime

- Number of pion beams on target in production runs

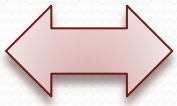


E10 proposal and actual run conditions

- High intensity pion beams could be used
- Production runs were performed efficiently

Proposed values

Parameters	Values
Pion beam momentum	1.2 GeV/c
Pion beam intensity	10M/spill
Beamtime for production run	500 hours
Total number of pion beams	3T pions
Target thickness (^{6}Li)	3.5 g/cm^2
DCX cross section (assumed)	10 nb/sr
SKS acceptance	100 msr
K decay loss	0.5
Analysis efficiency	0.5
Estimated $^{6}_{\Lambda}$H yield	265



Actual run conditions

Values
1.2 GeV/c
10M,12M/spill
240 hours
1.65T pions
3.5 g/cm^2
10 nb/sr
100 msr
0.5
0.3
90

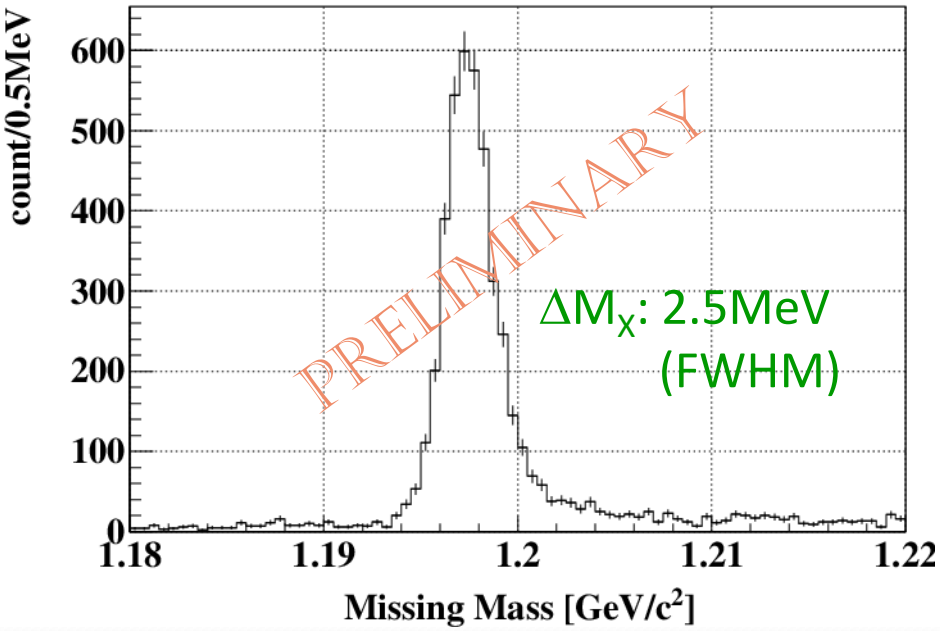
Sensitivity
~ 0.1 nb/sr

Results of calibration runs

- Calibration of momenta of beams and scatt. particles
  - Σ^- production, 1197.449 GeV/c^2 (missing-mass calib.)
  - Σ^+ production, 1189.37 GeV/c^2 (missing-mass calib.)

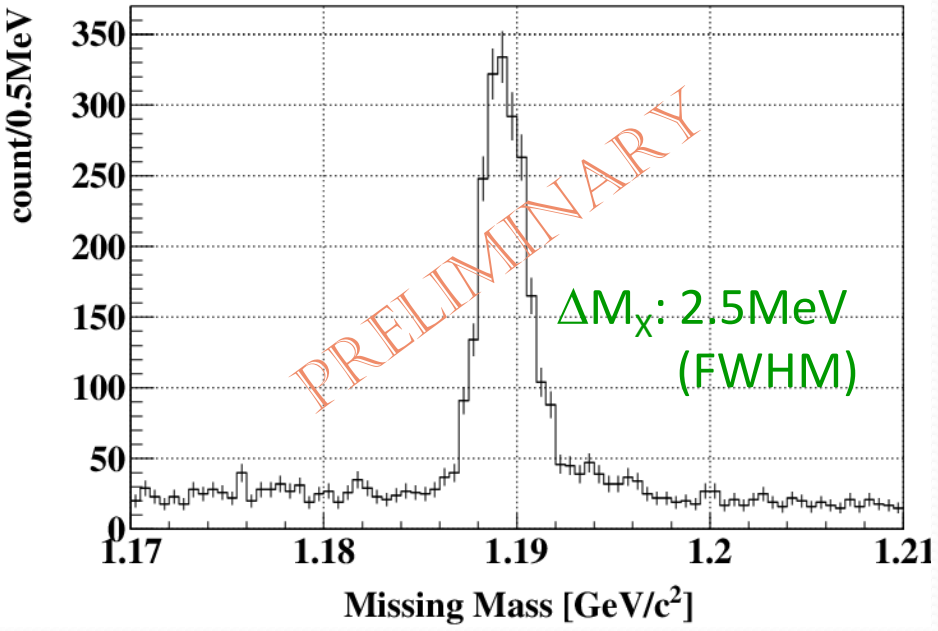
5 hours

$p(\pi^-,K^+)\Sigma^-$



1 hour

$p(\pi^+,K^+)\Sigma^+$

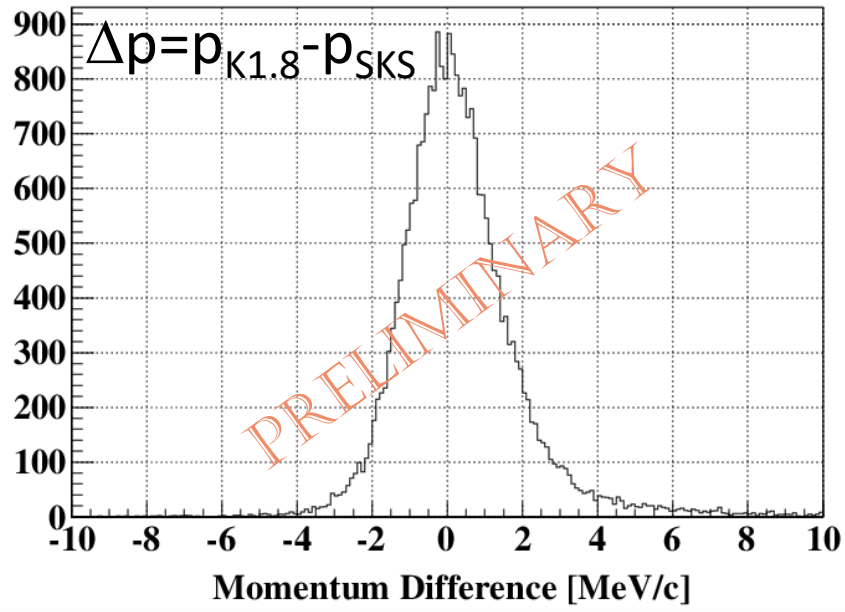


Results of calibration runs (2)

- Momentum calibrations and resolution estimation
  - Beam through runs (K1.8-SKS mom. mismatch)
  - $^{12}_{\Lambda}$C production (missing-mass resolution)

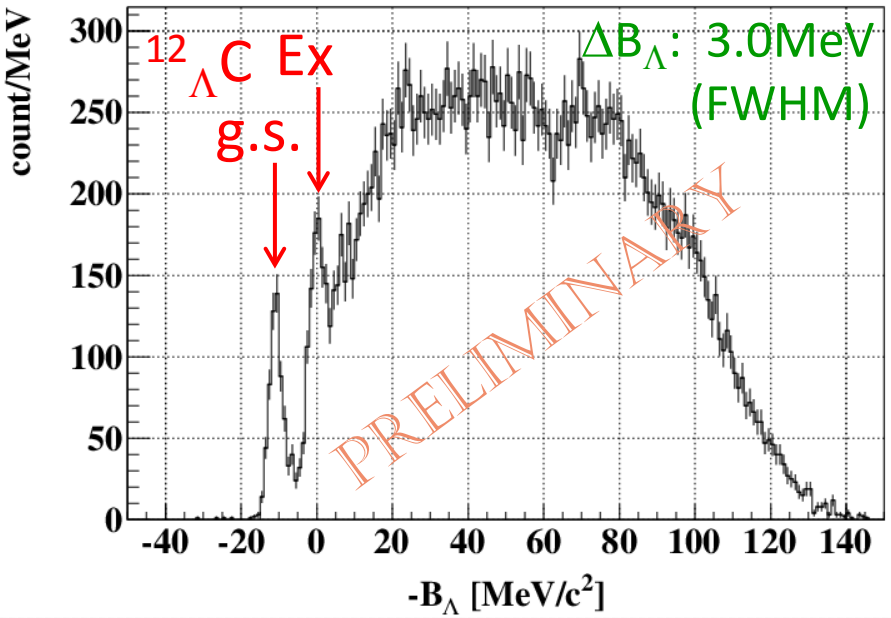
1 hour (8 settings)

π^+ beam through



13+6 hours

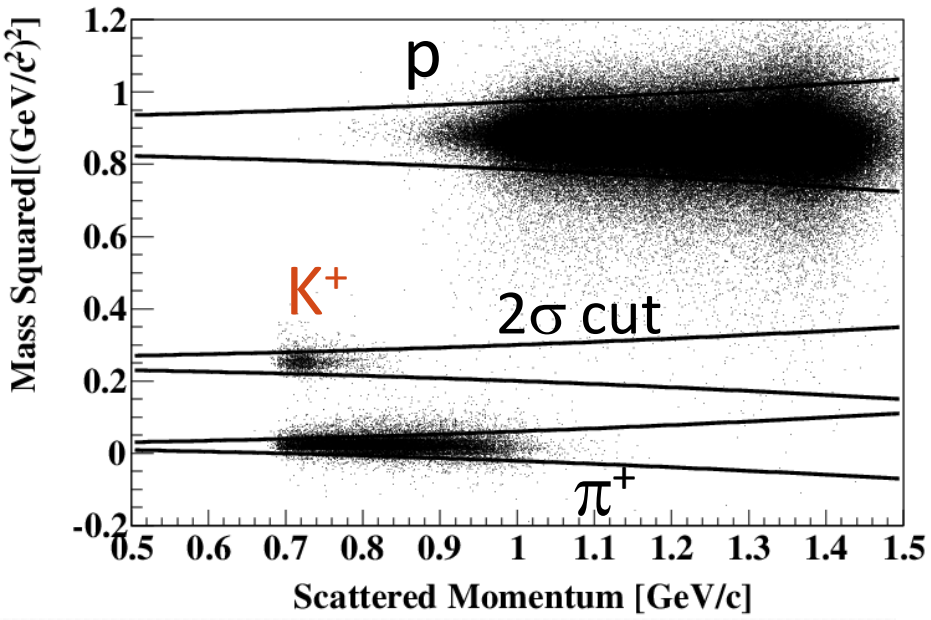
^{12}C(π^+,K$^+$)X



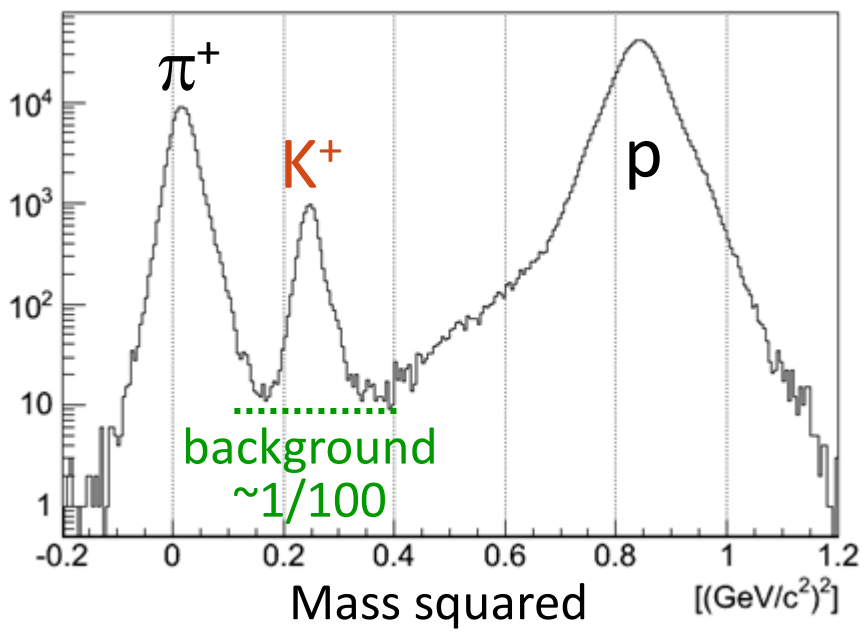
Results of production runs

- PID of scattered kaons
  - Momentum(SKS) + time of flight → Mass squared (m^2)
  - Momentum dependent selection of Kaon (2-3σ cuts)

^{6}Li(π^-,h^+)X

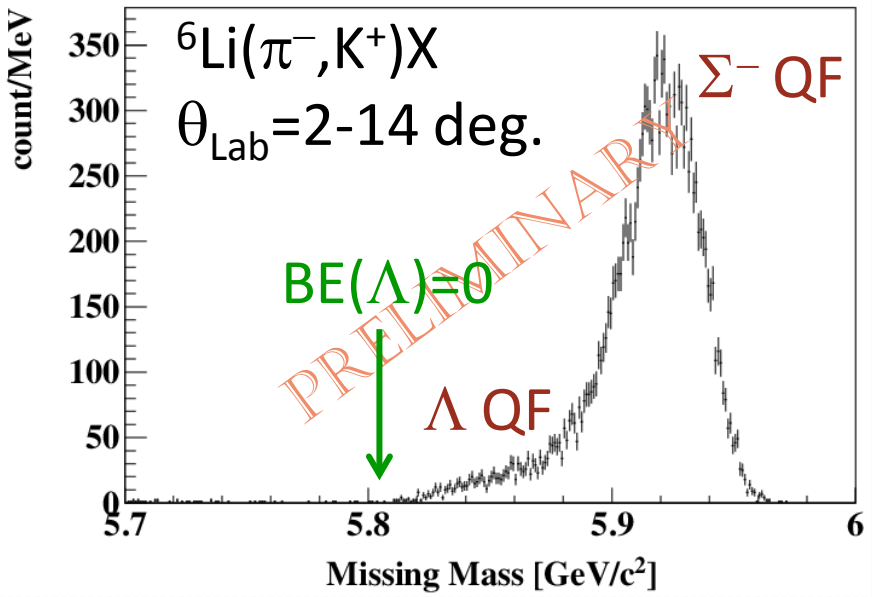


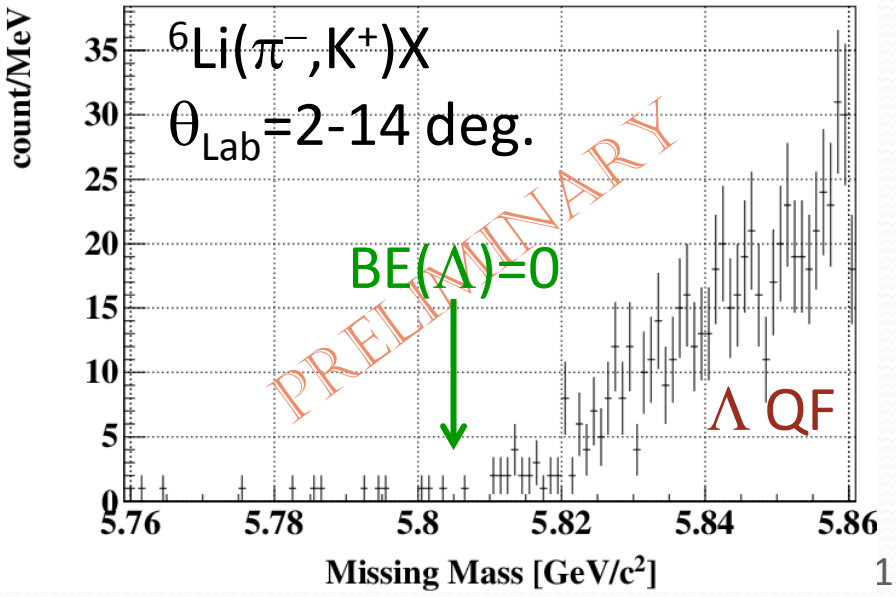
^{6}Li(π^-,h^+)X



Results of production runs (2)

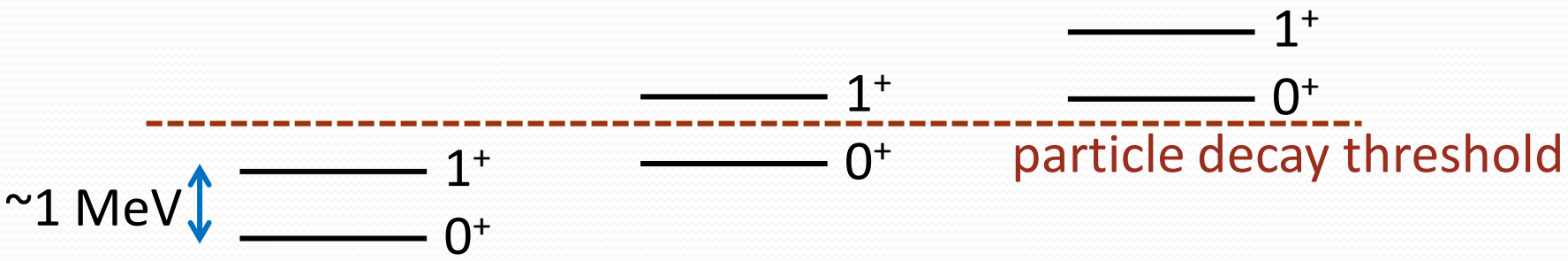
- Missing-mass spectra of the ^{6}Li(π^-,K$^+$)X reaction
  - Current precision of missing-mass is 1-2 MeV/c^2 level
  - No significant peak structure in the threshold region
    - Cross section looks smaller than we assumed (< 1nb/sr)
  - Studies are in progress to improve the sensitivity





Possible discussion on bound states

- Possible bound states are ${}^{6}_{\Lambda}\mathrm{H}(0^+)$ and ${}^{6}_{\Lambda}\mathrm{H}(1^+)$
- Transition from ${}^{6}\mathrm{Li}(1^+)$ to ${}^{6}_{\Lambda}\mathrm{H}_{g.s.}(0^+)$ need spin-flip amp.
- 3 possible scenarios



Scenario-1	Scenario-2	Scenario-3
(FINUDA Exp.) observe 1^+	possible observation of 0^+	cross sections are vanishing

- Theoretical estimation of production cross sections is necessary for more quantitative discussions

Summary

- 2012-Dec./2013-Jan. beamtimes done successfully
  - Run at high beam intensity 10M-12M/spill
  - Measured ^{6}Li(π^{-},K^{+})X reaction as phase-1 of E10
  - 1.65 T pion beams on target (55% of proposal)
- All calibration runs were also done successfully
  - $\Sigma^{\pm}$ and $^{12}_{\Lambda}$C production and beam through runs
  - Current precision of missing-mass scale is 1-2MeV/c^2
  - Missing-mass resolution is 3.0 MeV/c^2 (FWHM)
- Analyses of $^{6}_{\Lambda}$H production data are in progress
  - No significant peak structure in the threshold region
  - Studies are in progress to improve the sensitivity