

Staging strategy of E15

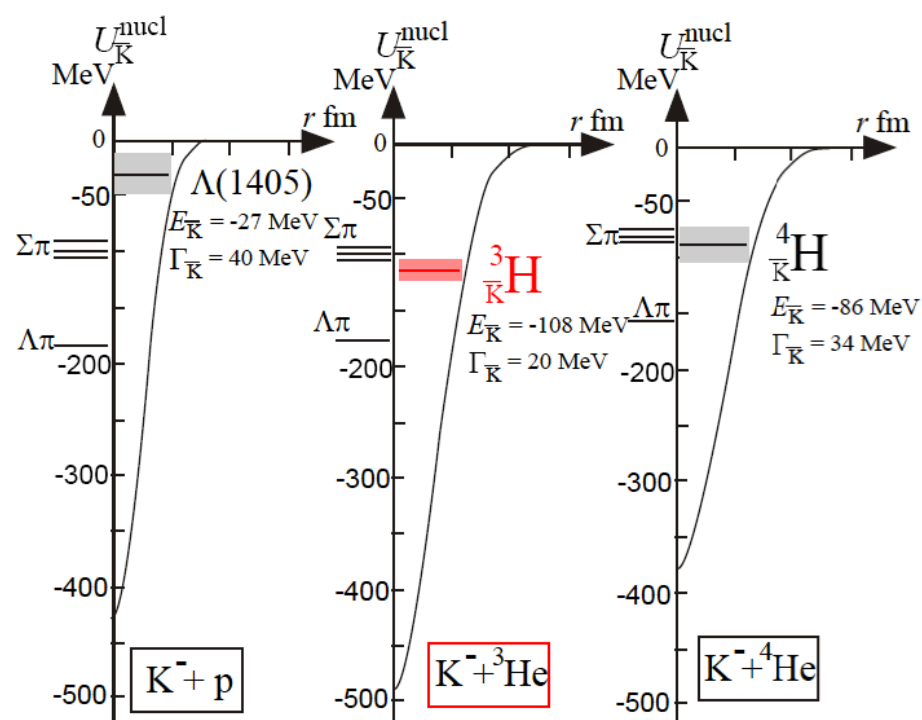
M. Iwasaki

RIKEN Nishina Center & TITech

for J-PARC E15 Collaboration

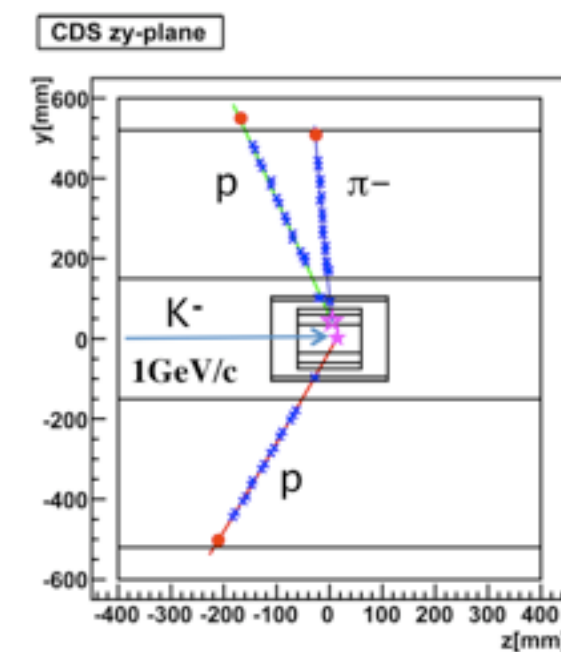
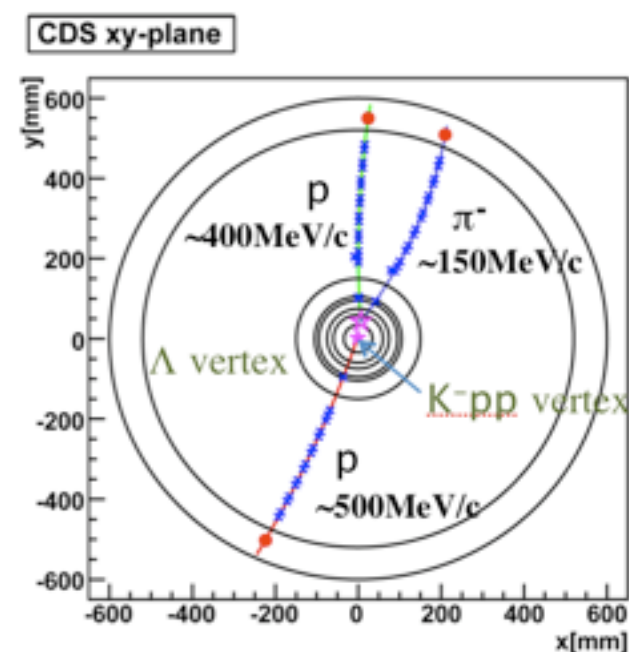
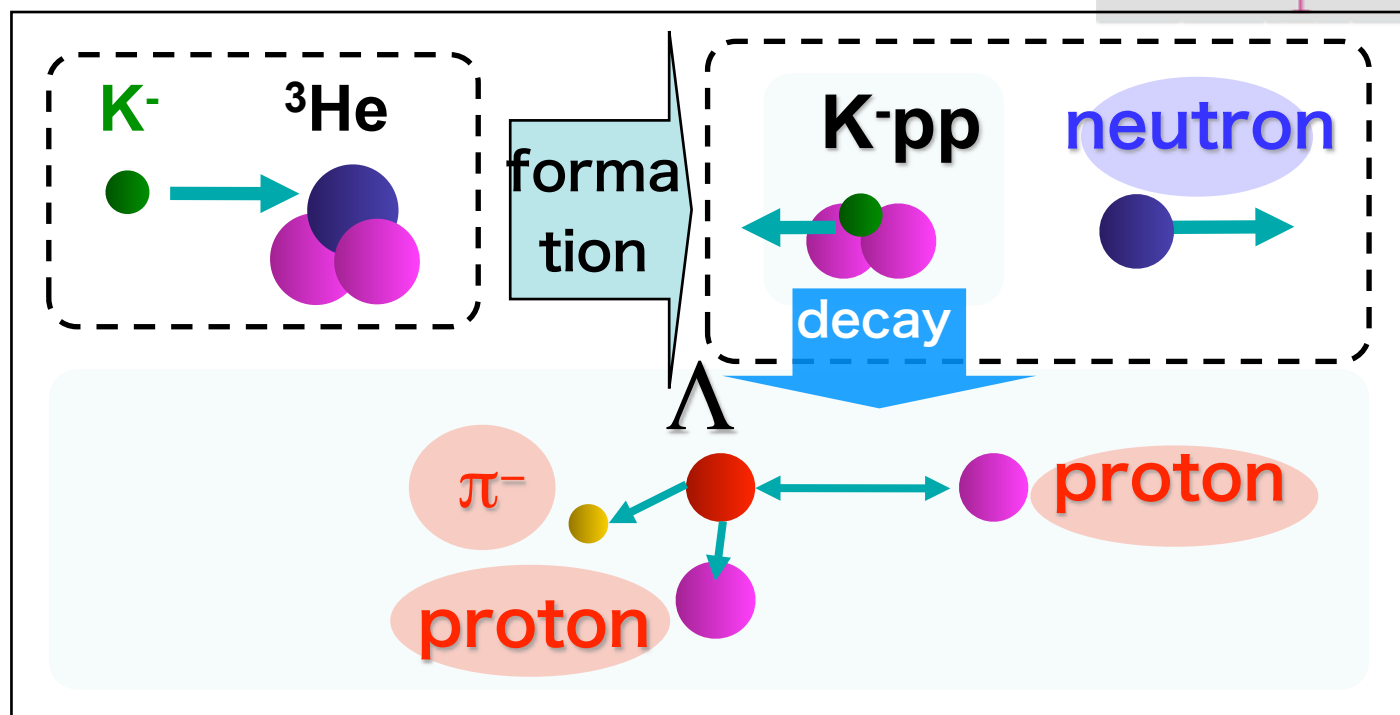
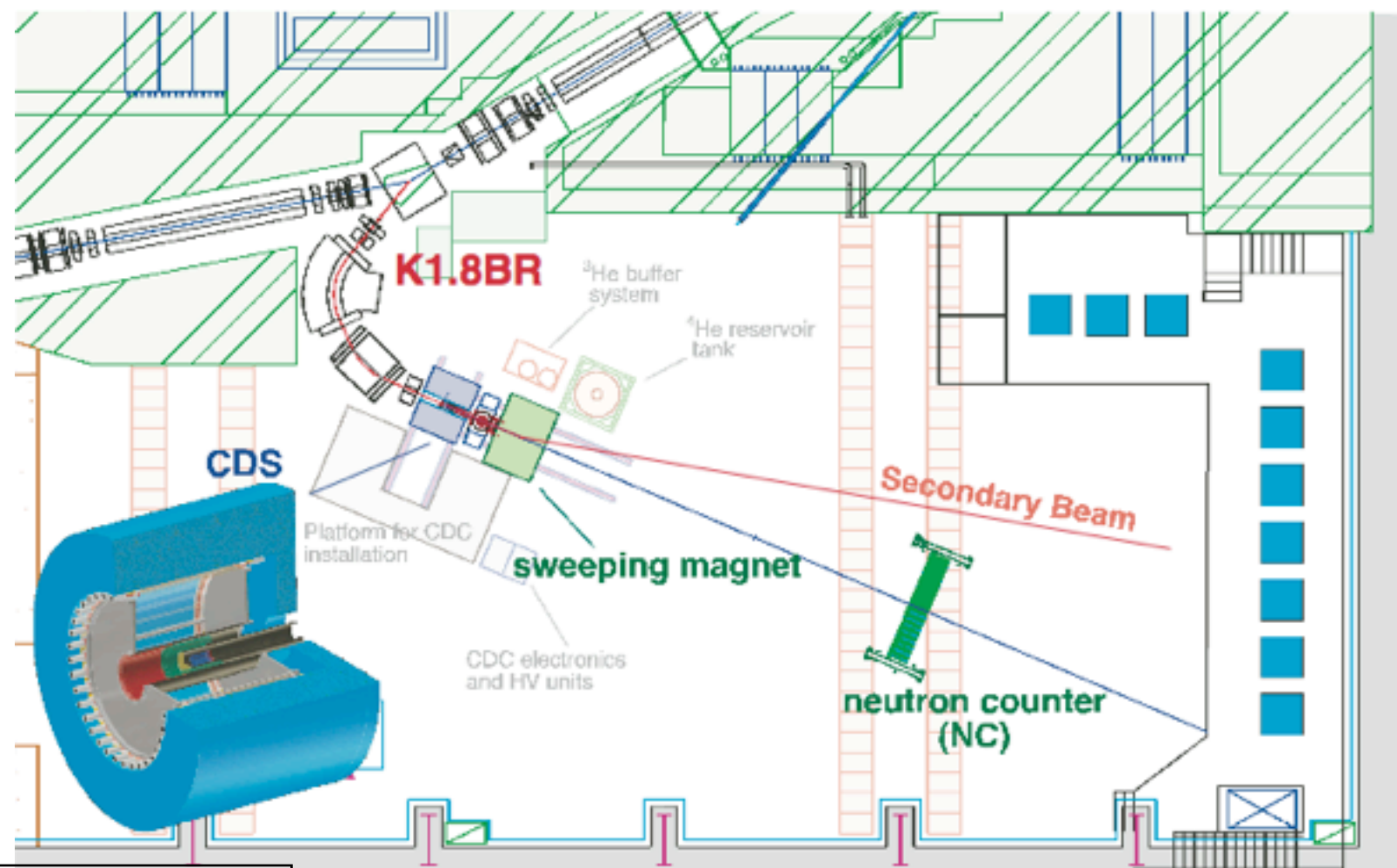


E15: $\bar{K}N$ interaction study by nuclear bound state



$\bar{K} + {}^3\text{He} \rightarrow \text{"pp } \bar{K}\text{"} + n$

at 1 GeV/c by both missing & invariant mass





E15 staging strategy

E15^{1st} ~ 30kW*week



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motivated by



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*1) Production cross section
can be as large as
few mb/sr in bound region!*



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T. Koike, T. Harada, Phys. Rev. C80, 055208 (2009)



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T. Yamazaki, M. Maggiora, P. Kienle, et al, PRL 104, 132502 (2010)



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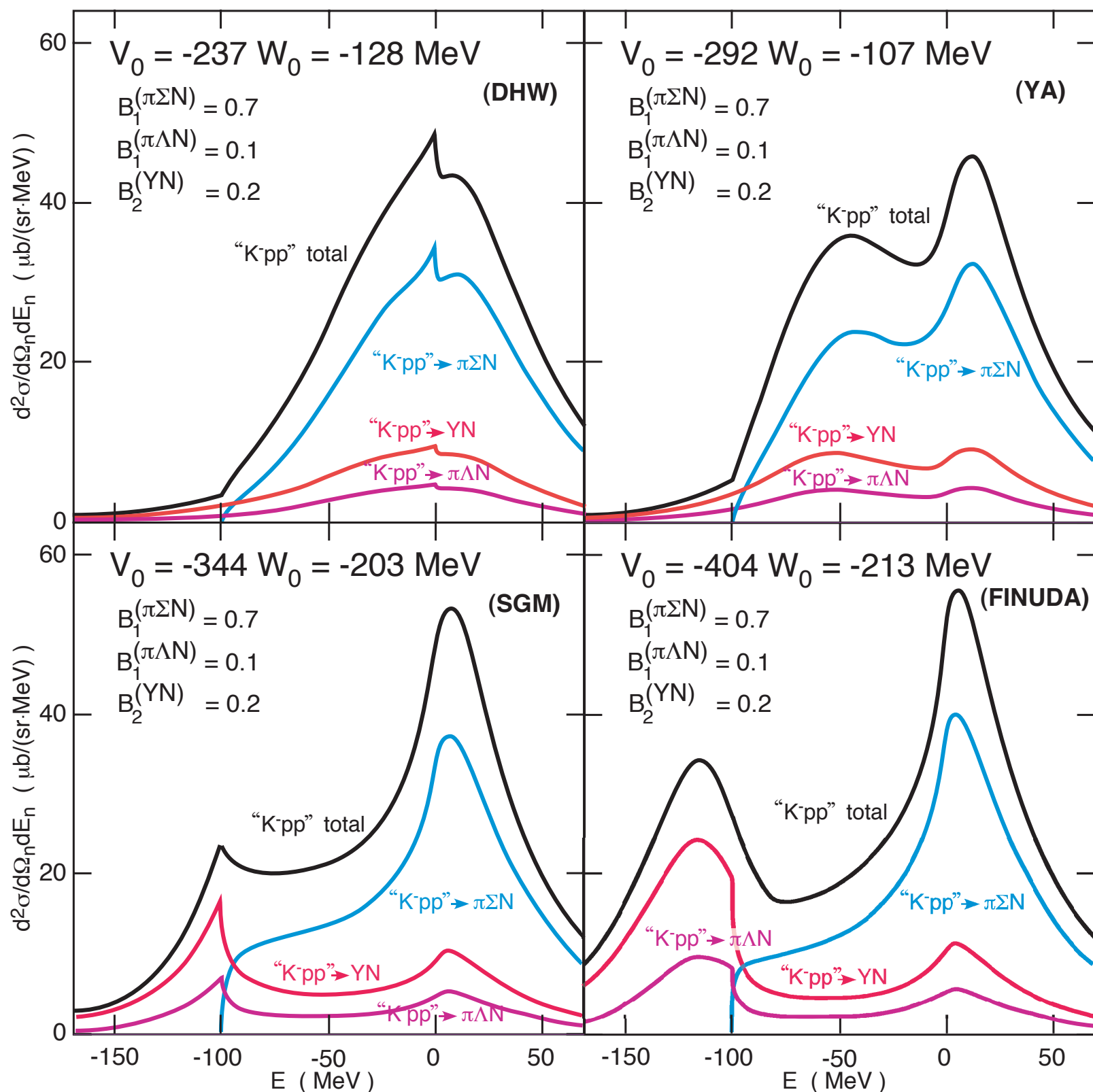
T. Yamazaki, M. Maggiora, P. Kienle, et al, PRL 104, 132502 (2010)

3) *Background Study*



Production cross section (KH)

$^3\text{He} (\text{K}^-, n) X$ @ 1 GeV/c **Excluding K⁻ escape process** T. Koike, T. Harada, Phys. Rev. C80, 055208 (2009)



DHW: A. Dote, T. Hyodo, and W. Weise,
 Nucl. Phys. A804, 197 (2008);
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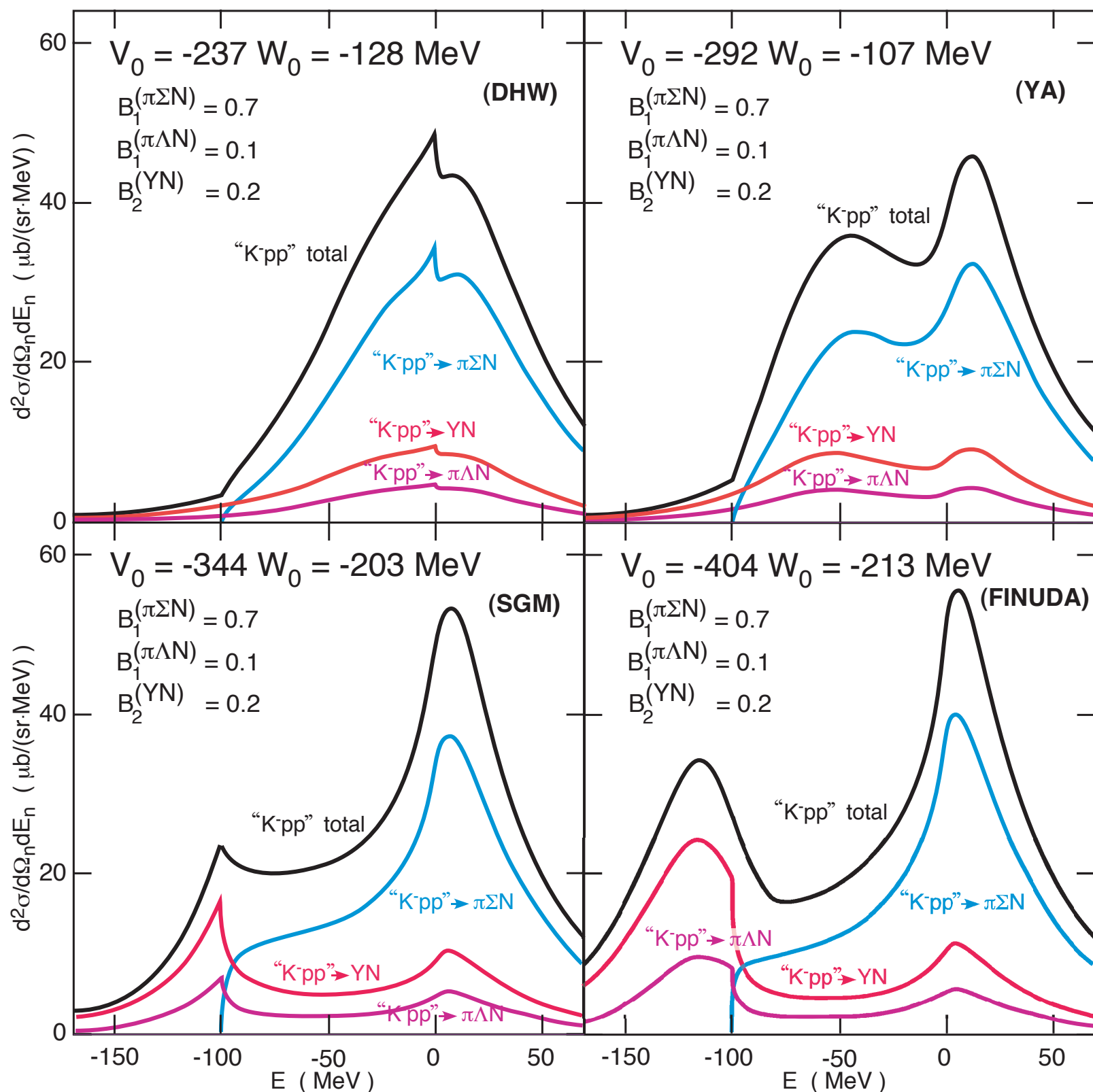
SGM: N.V. Shevchenko, A. Gal, and J. Mareš,
 Phys. Rev. Lett. 98, 082301 (2007);
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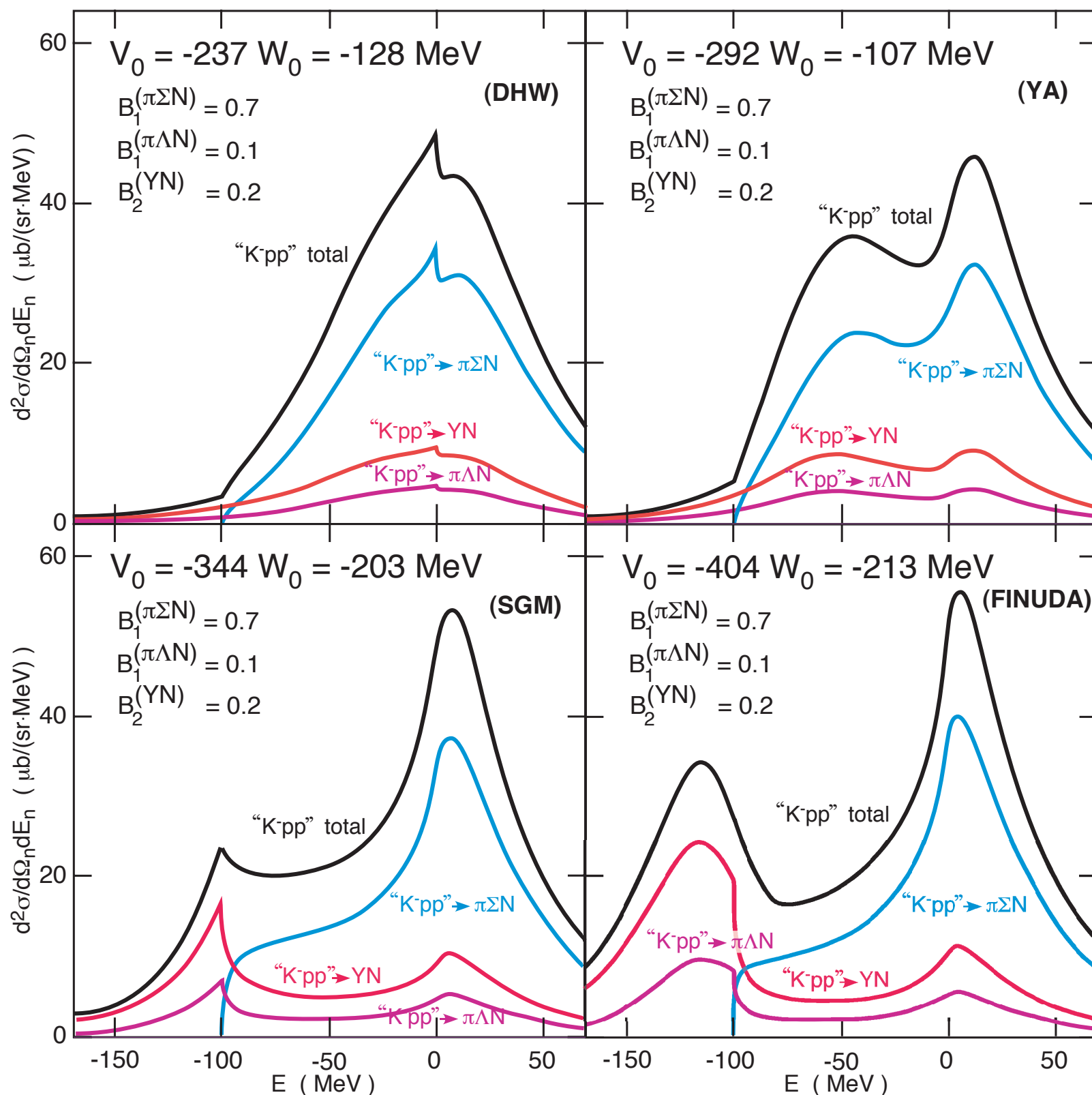
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few mb/sr in bound region!
cf. 10 μb/sr assumed in prop.



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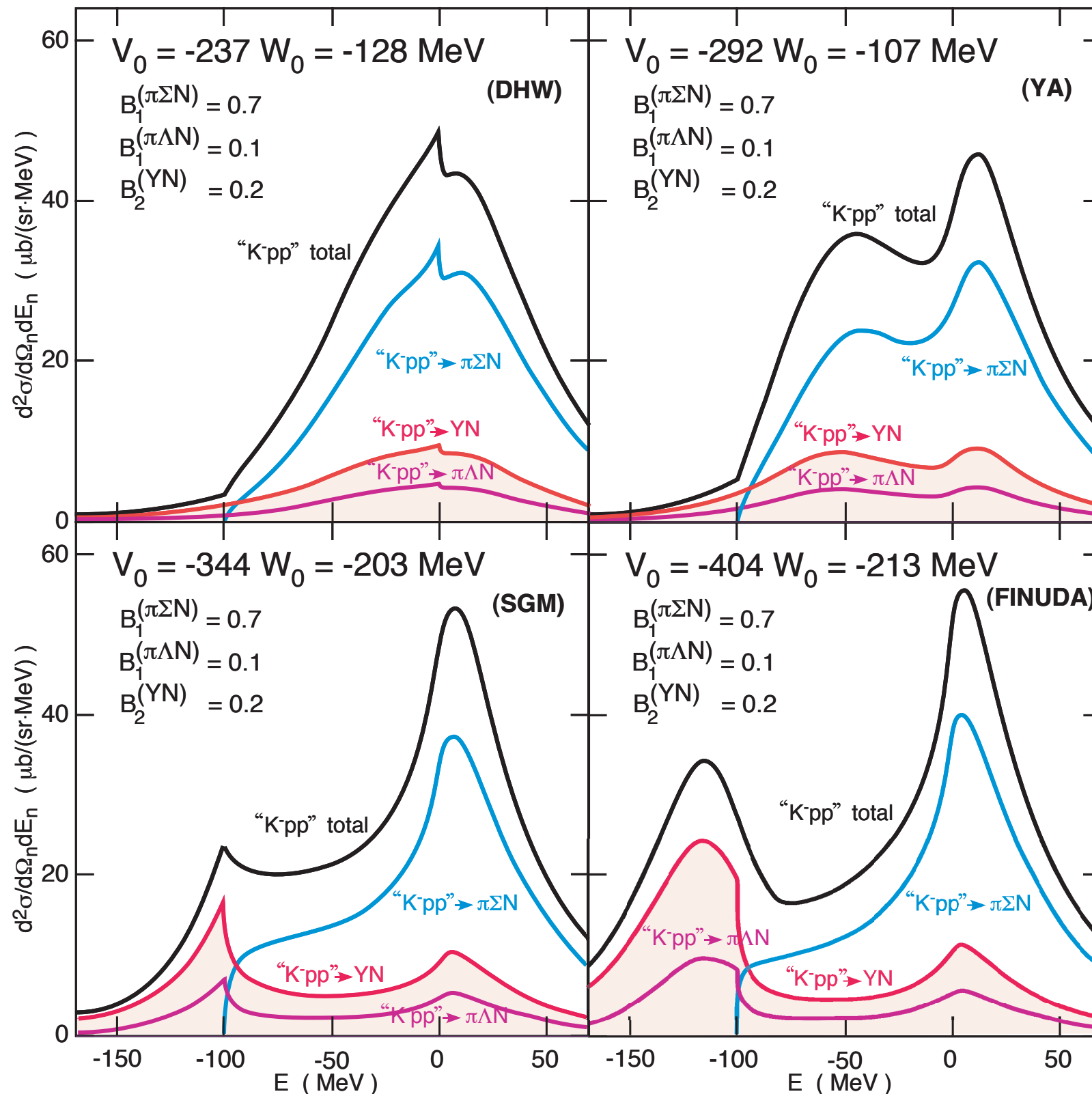


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*few mb/sr in bound region!
cf. 10 $\mu\text{b}/\text{sr}$ assumed in prop.*

**limiting to nYN final states
 $\gtrsim 1\text{mb}/\text{sr}$!**



DISTO DATA

exclusive

$pp \rightarrow K^+ \Lambda p$ at $T_p = 2.85$ GeV

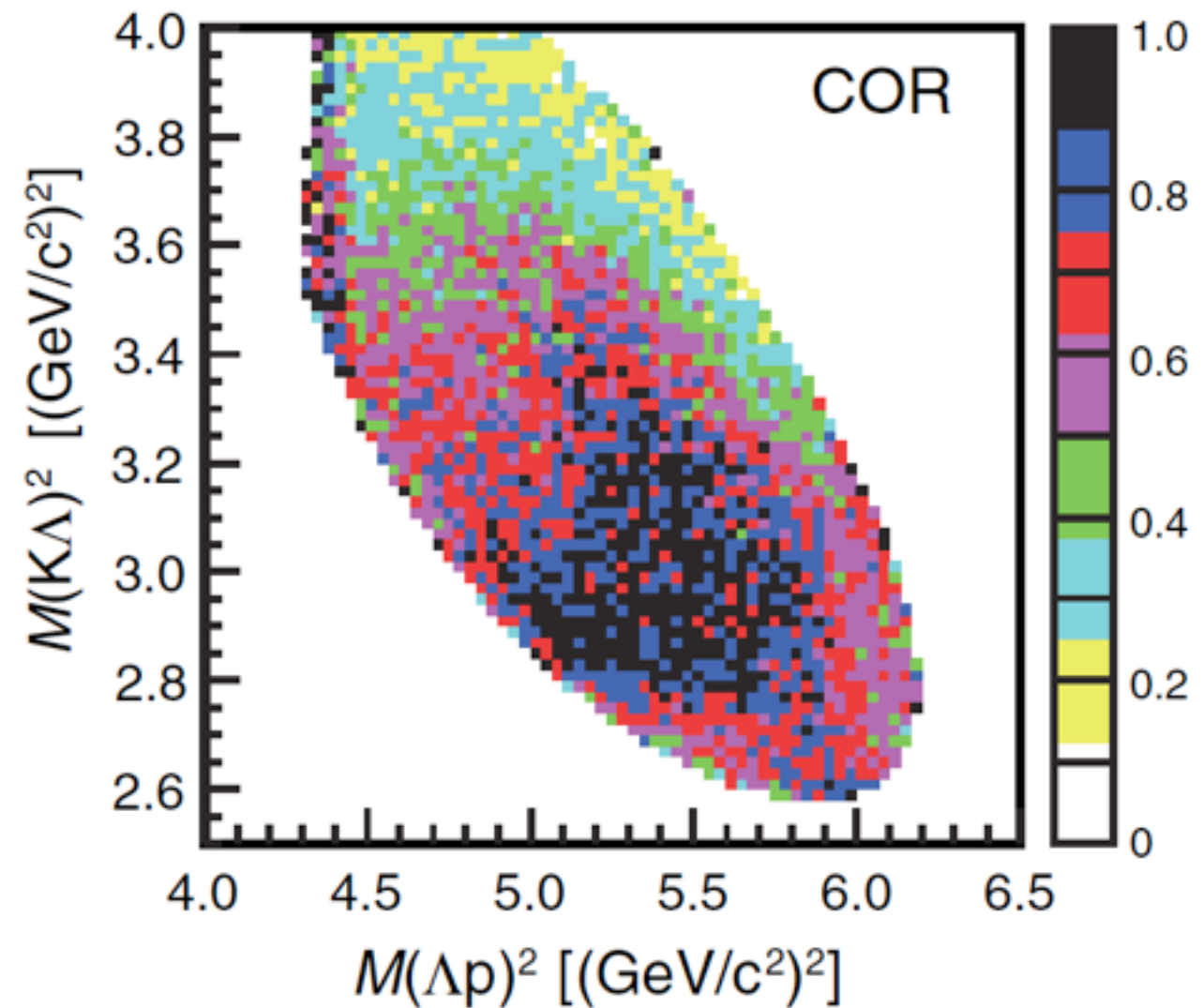
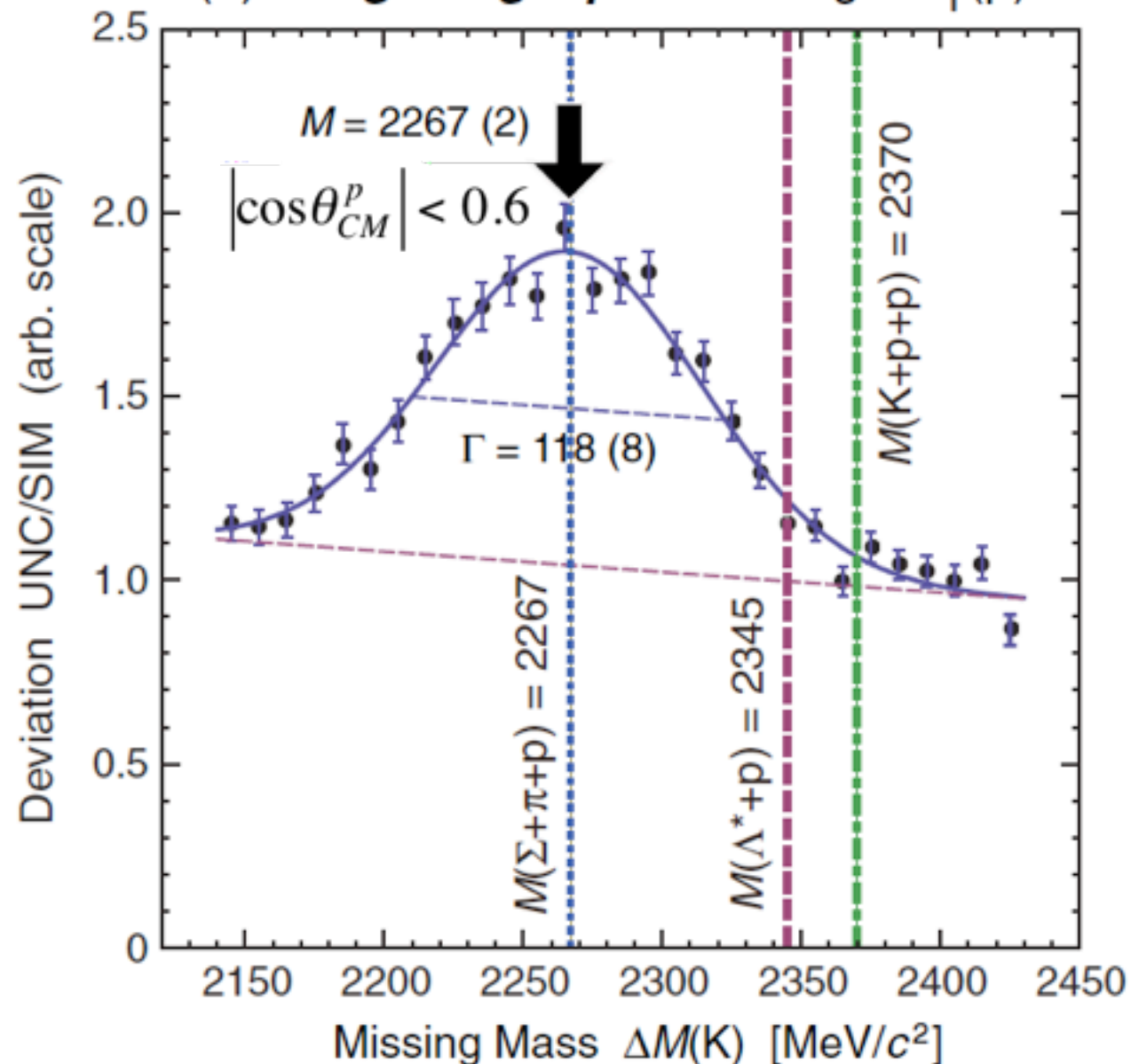
$B(K^+ pp)$ [MeV]

200

100

0

(a) *large-angle proton: high- $P_T(p)$*

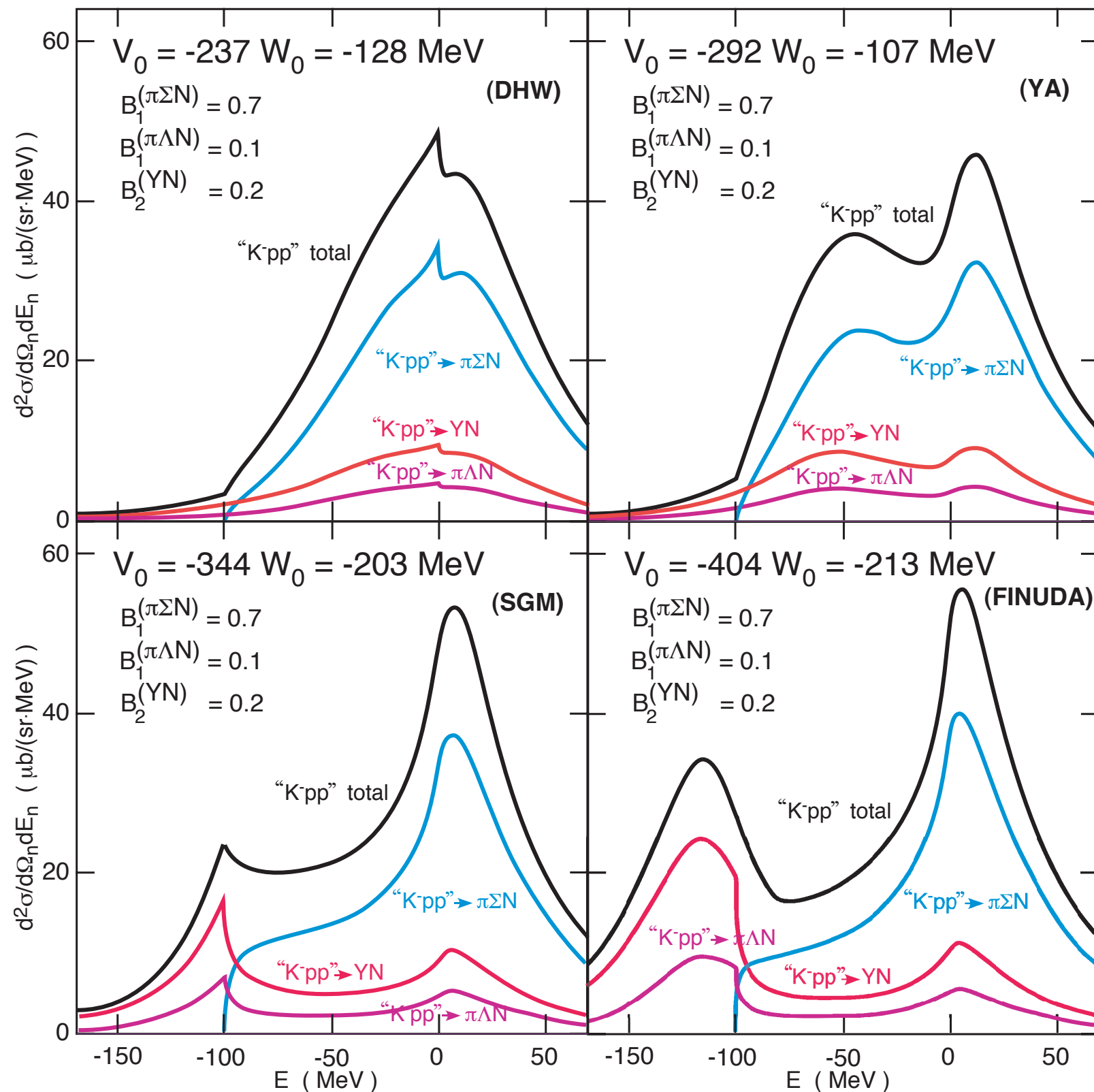


T. Yamazaki, M. Maggiora, P. Kienle, et al,
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$B_K \sim 100$ MeV and $\Gamma_K \sim 100$ MeV



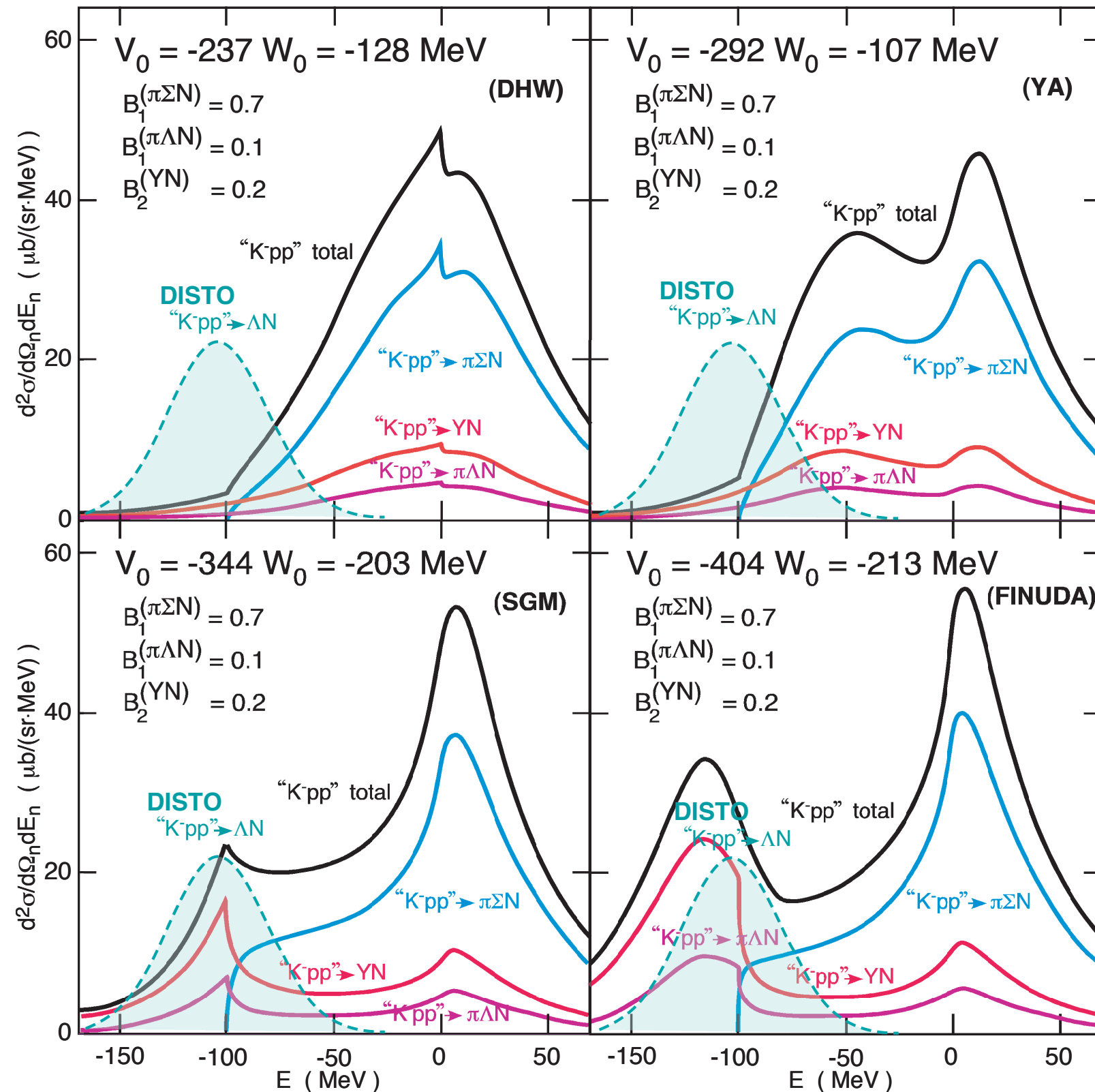
KH vs DISTO





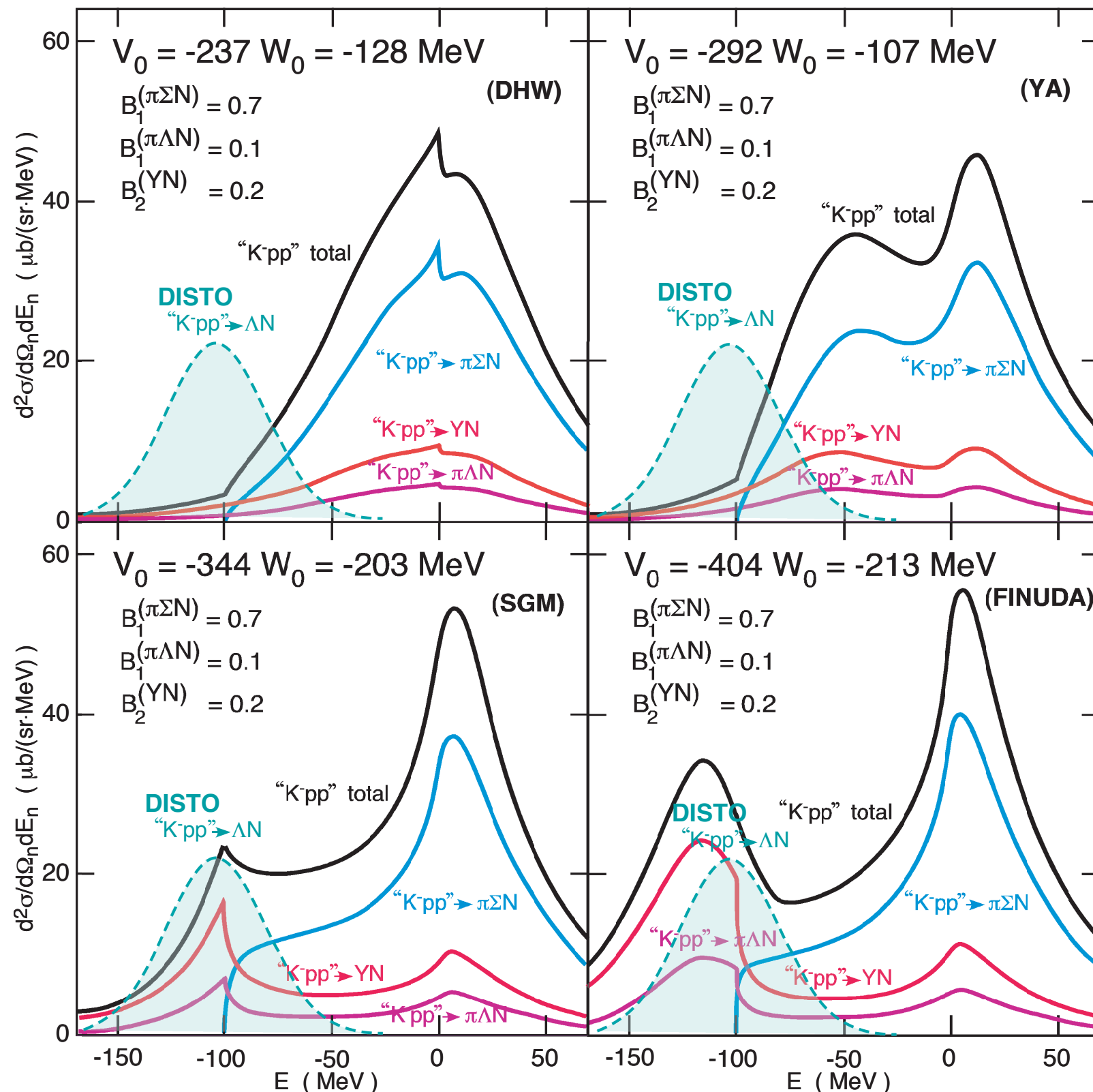
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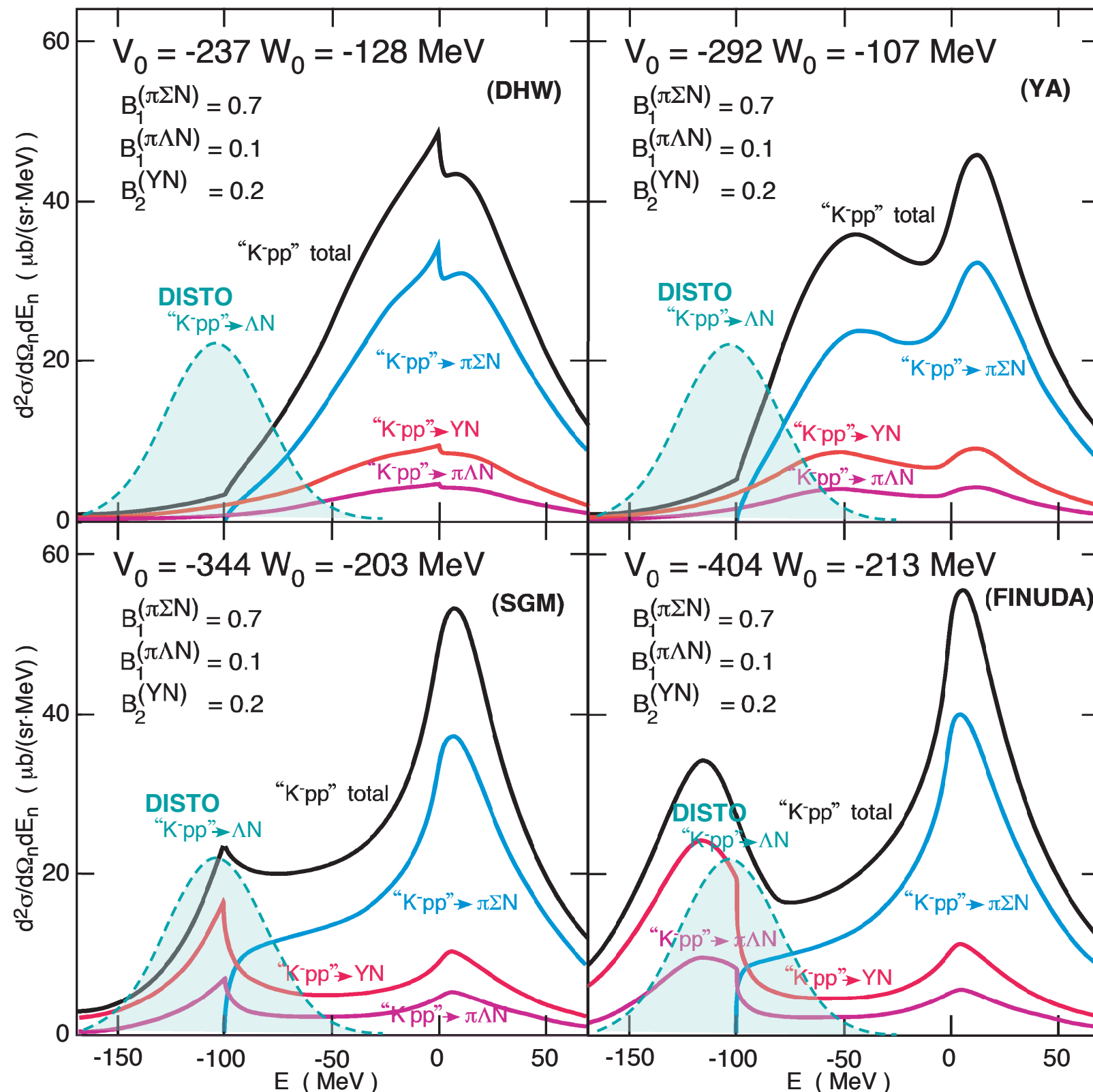
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$B_K \sim 100 \text{ MeV}$ and $\Gamma_K \sim 100 \text{ MeV}$

- only for Λp decay ch.
private communication
- does not fit in KH scheme



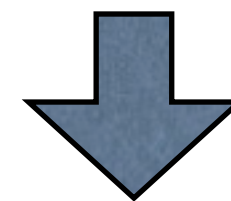
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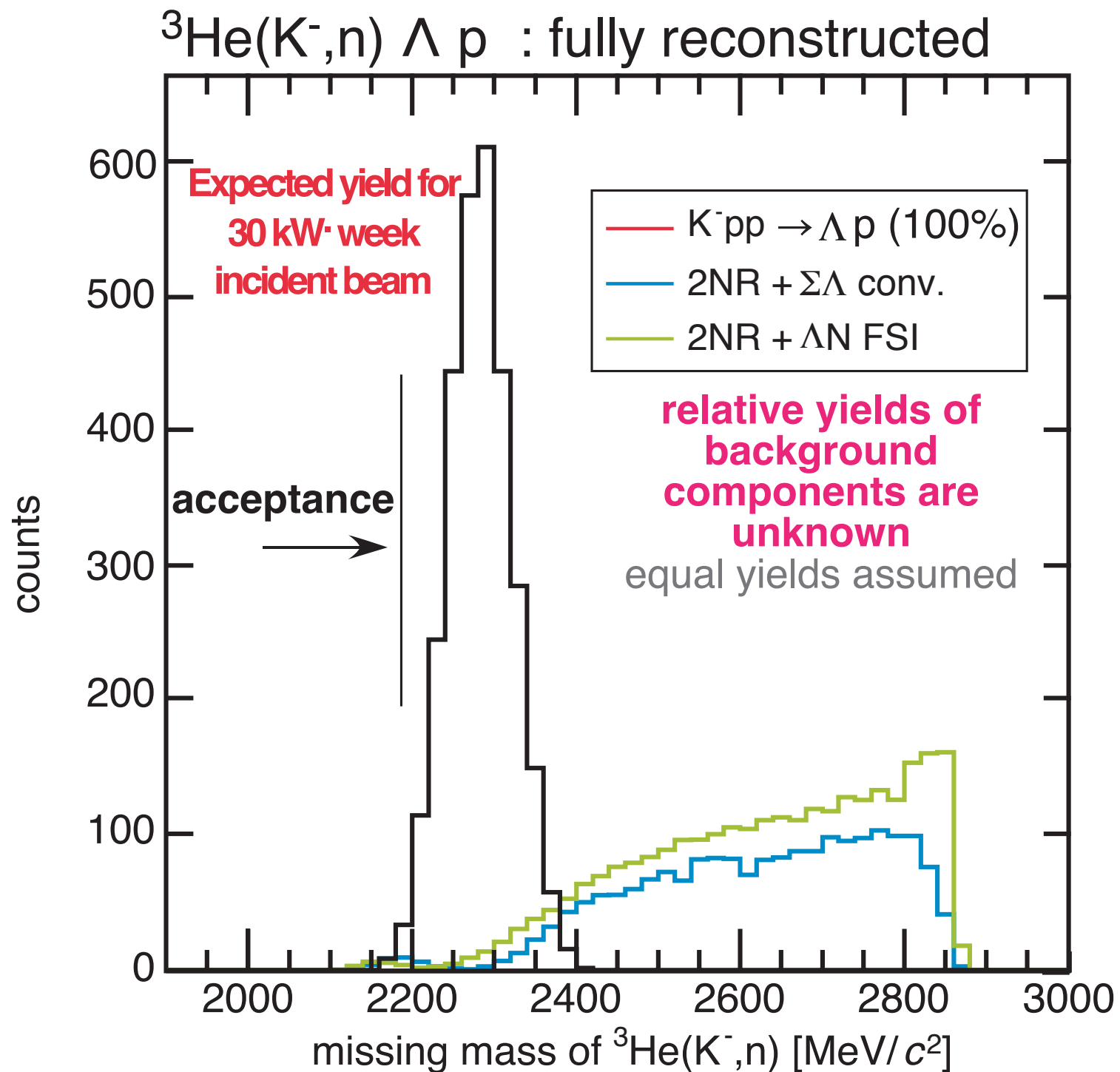
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easy to observe,
if $d\sigma/d\Omega \gtrsim 1$ mb/sr
and Λp decay channel
($n + \Lambda p$ final state)

Neutron missing mass spectra @ 30kW*week



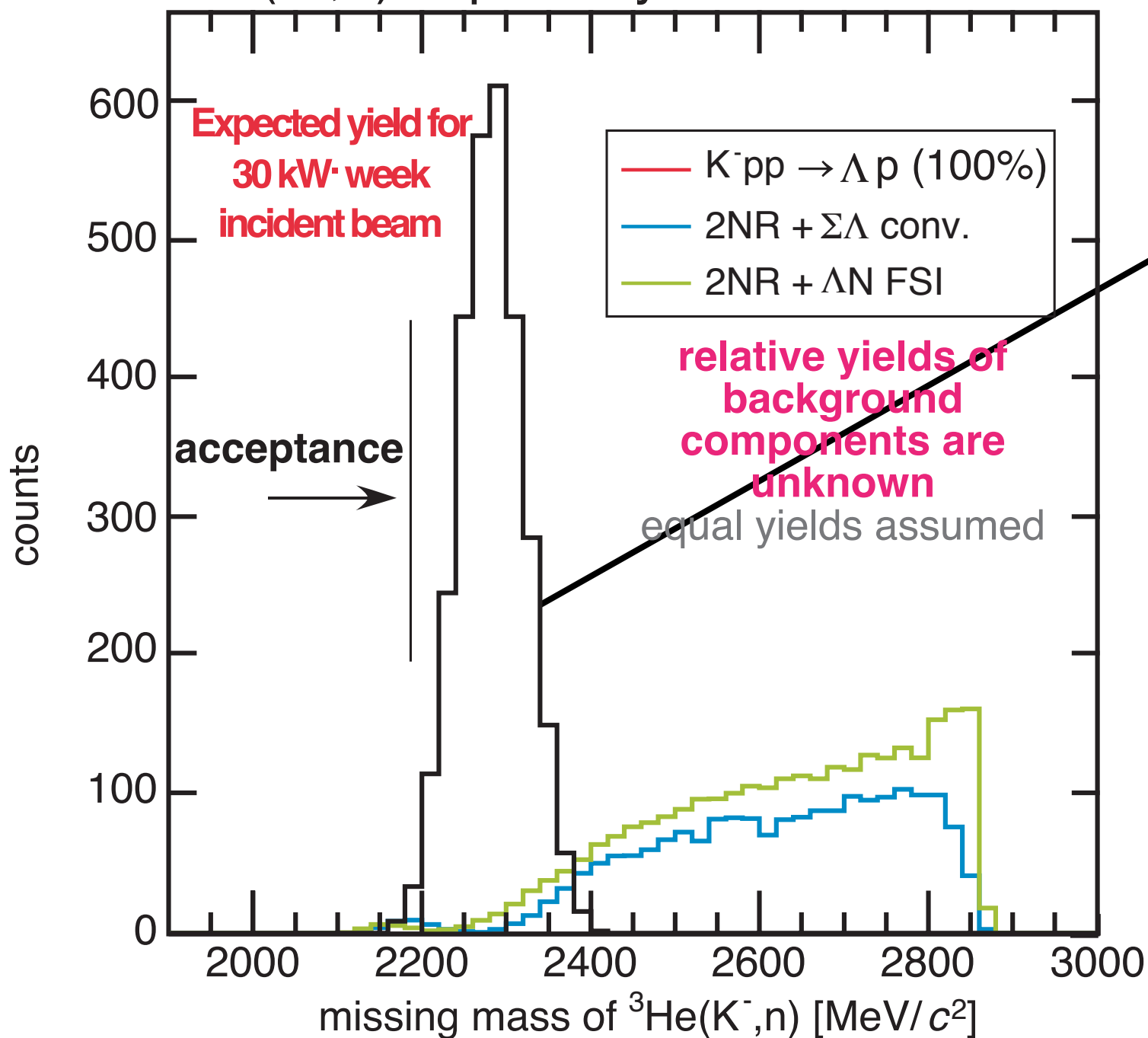
simulated by T. Hiraiwa



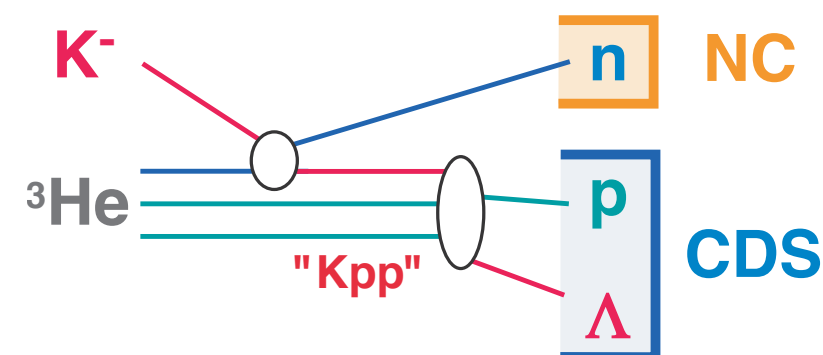
Neutron missing mass spectra @ 30kW*week

signal

$^3\text{He}(K^-,n) \Lambda p$: fully reconstructed

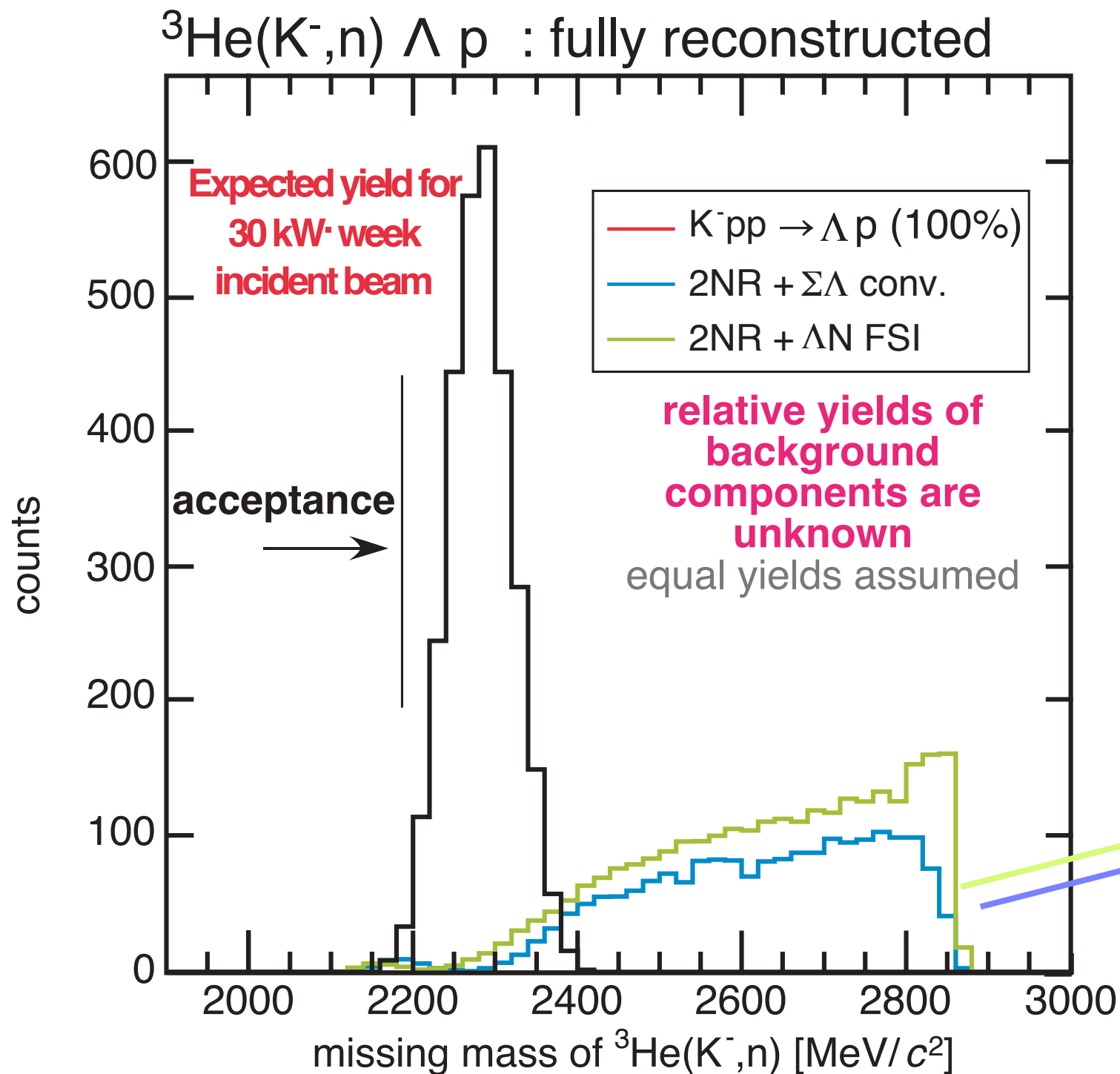


Assume DISTO like data,
 $B_K \sim 100 \text{ MeV}$ and $\Gamma_K \sim 100 \text{ MeV}$
 $d\sigma/d\Omega^{\theta=0} = 1 \text{ mb/sr}$
 $\text{BR}(\Lambda p) = 100 \%$
for simplicity



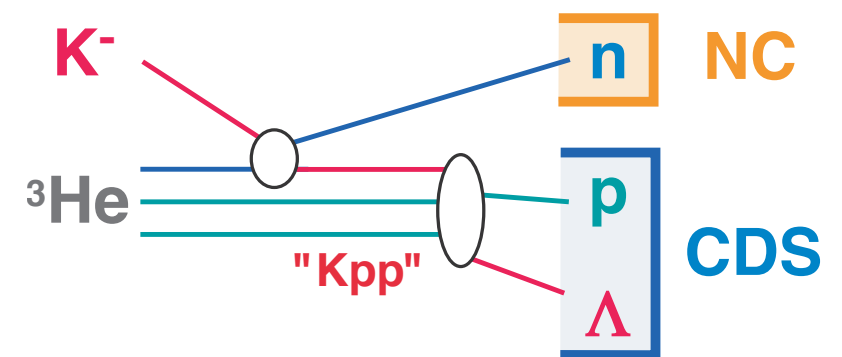
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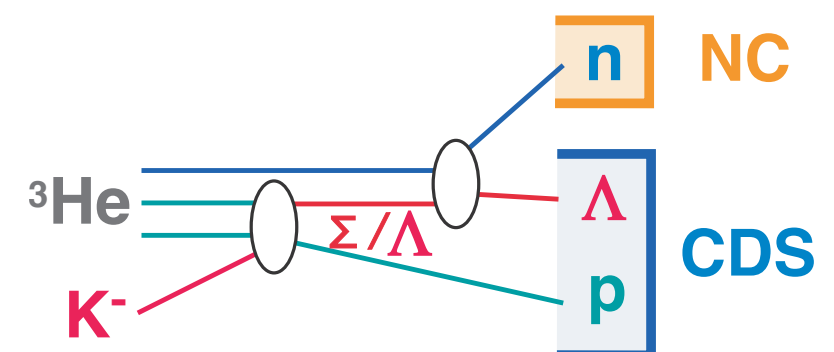
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backgrounds

2NR initiated reactions
 $\sigma \sim 10 \text{ mb}$ each



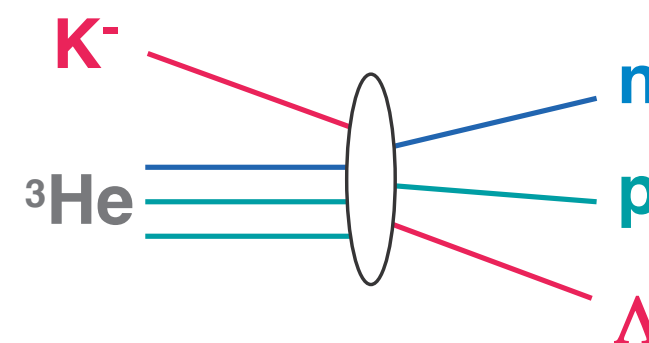
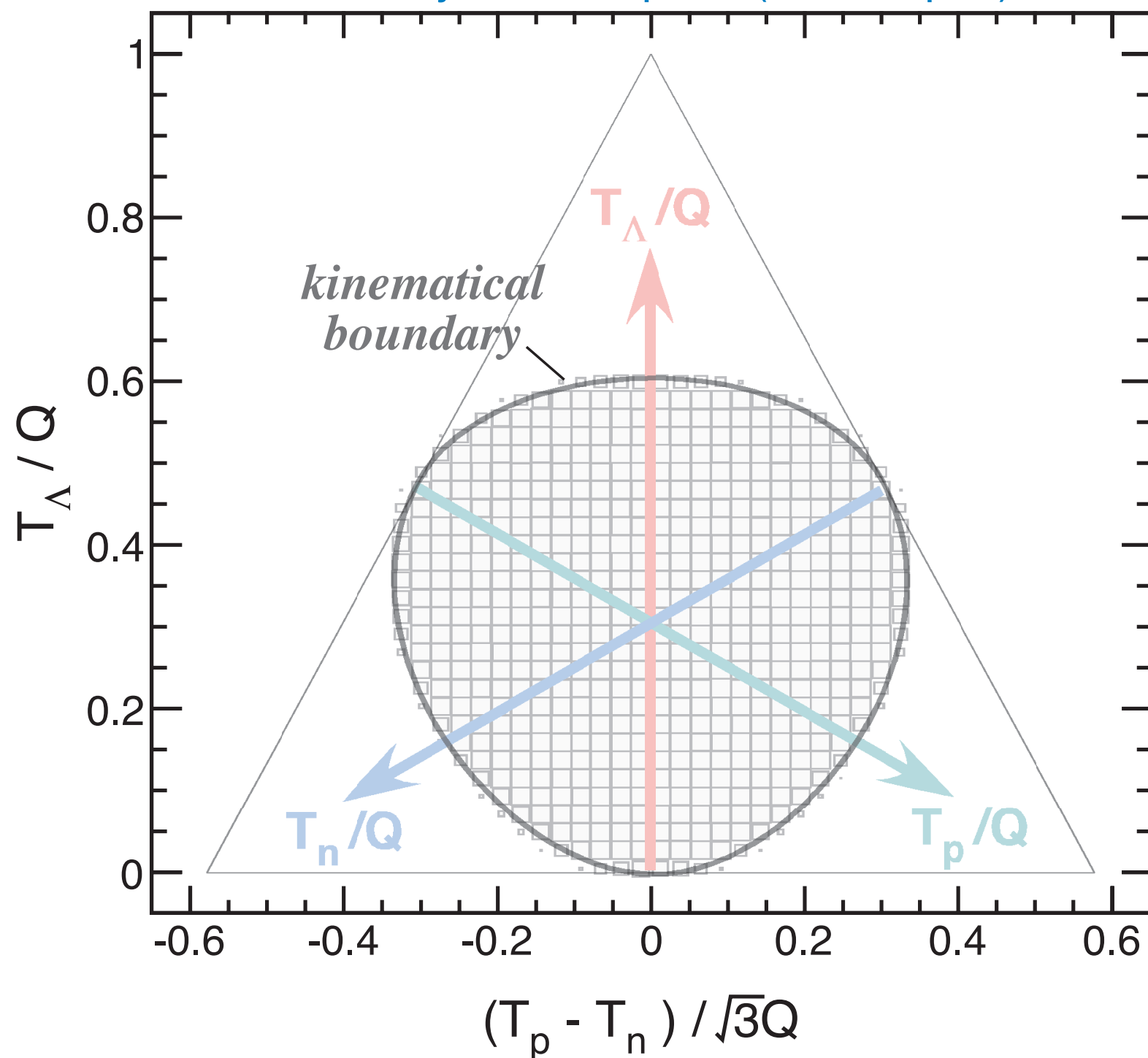
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Λ pn event distribution on Phase Space

In-flight Kinematics

3-body Phase Space (Dalitz's plot) at CM



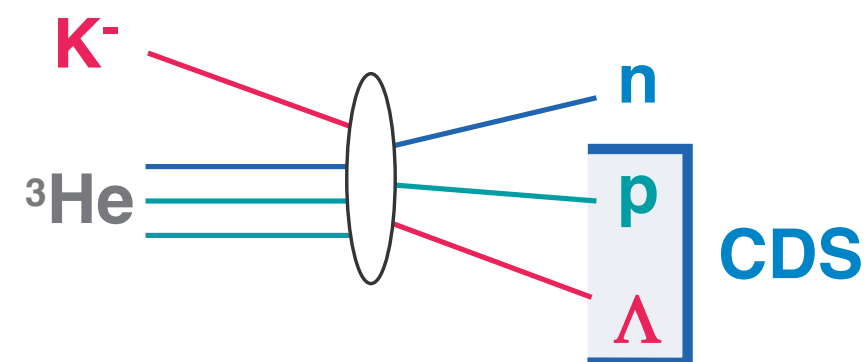
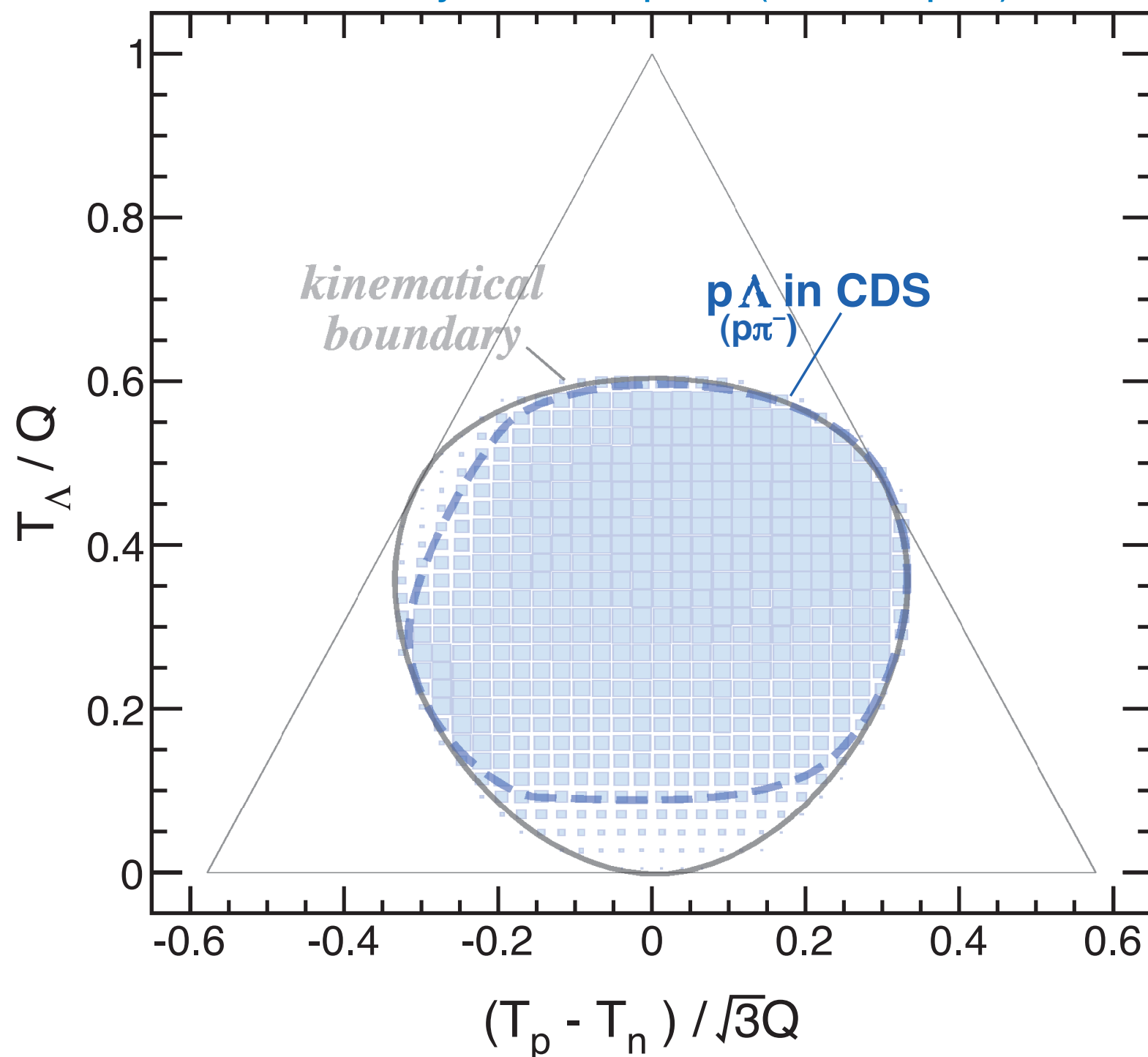
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CDS Acceptance

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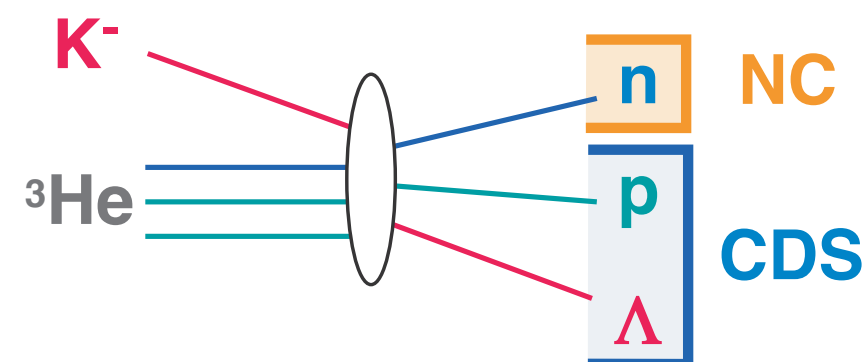
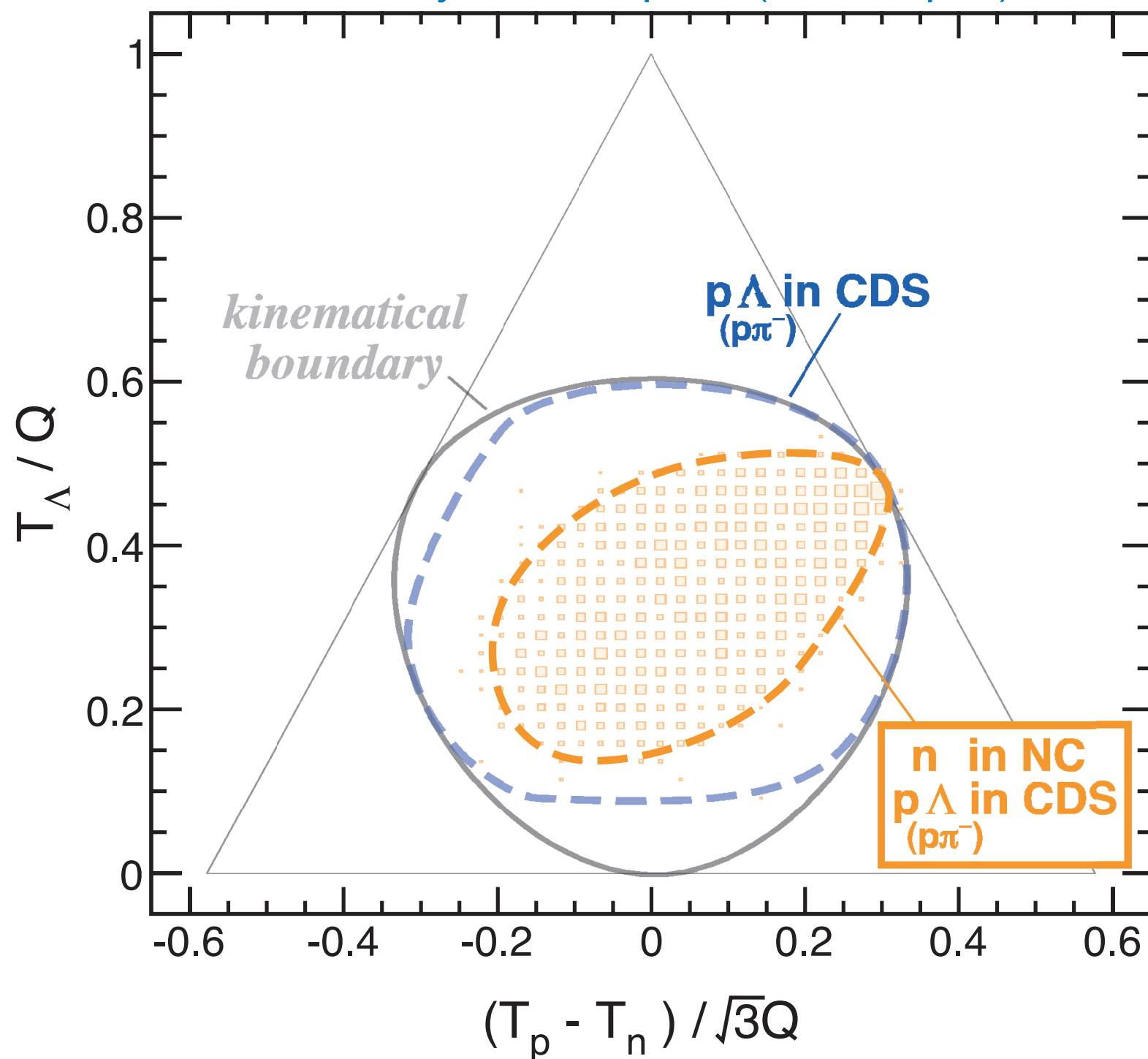
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CDS & NC Acceptance

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3-body Phase Space (Dalitz's plot) at CM



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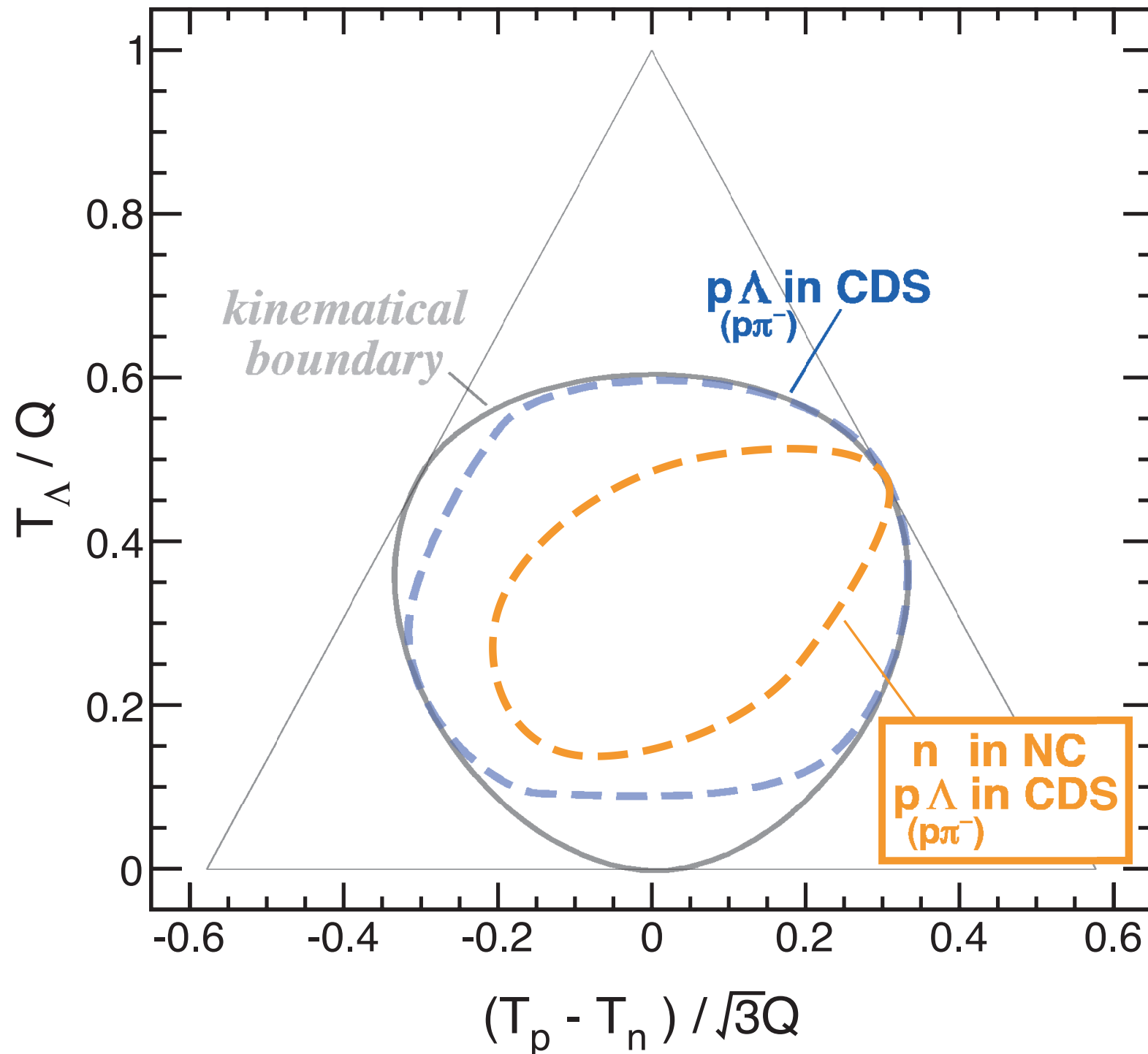


Background?

Two Nucleon Reaction and FSI (Σ - Λ conversion)

CDS & NC Acceptance

on 3-body Phase Space (Dalitz's plot) at CM

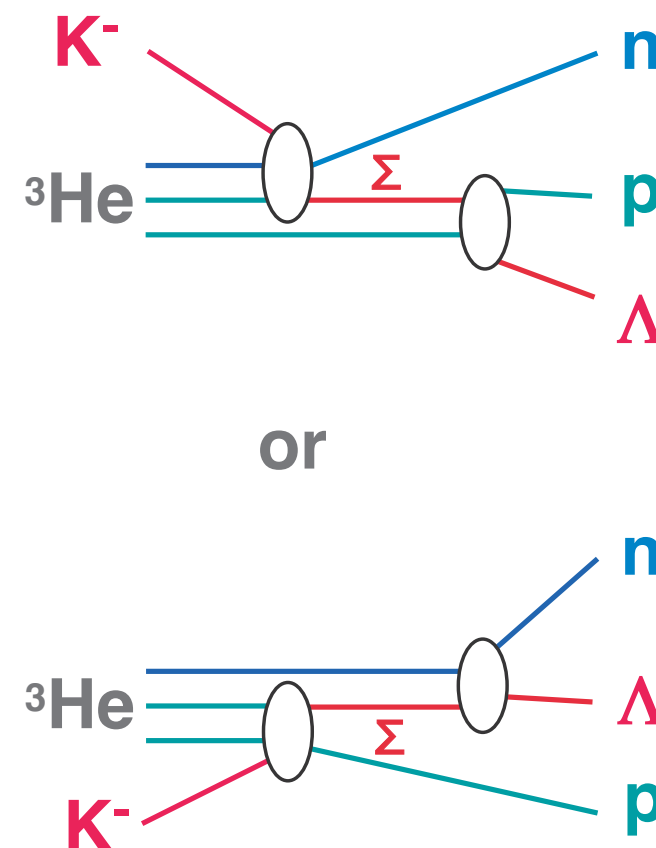
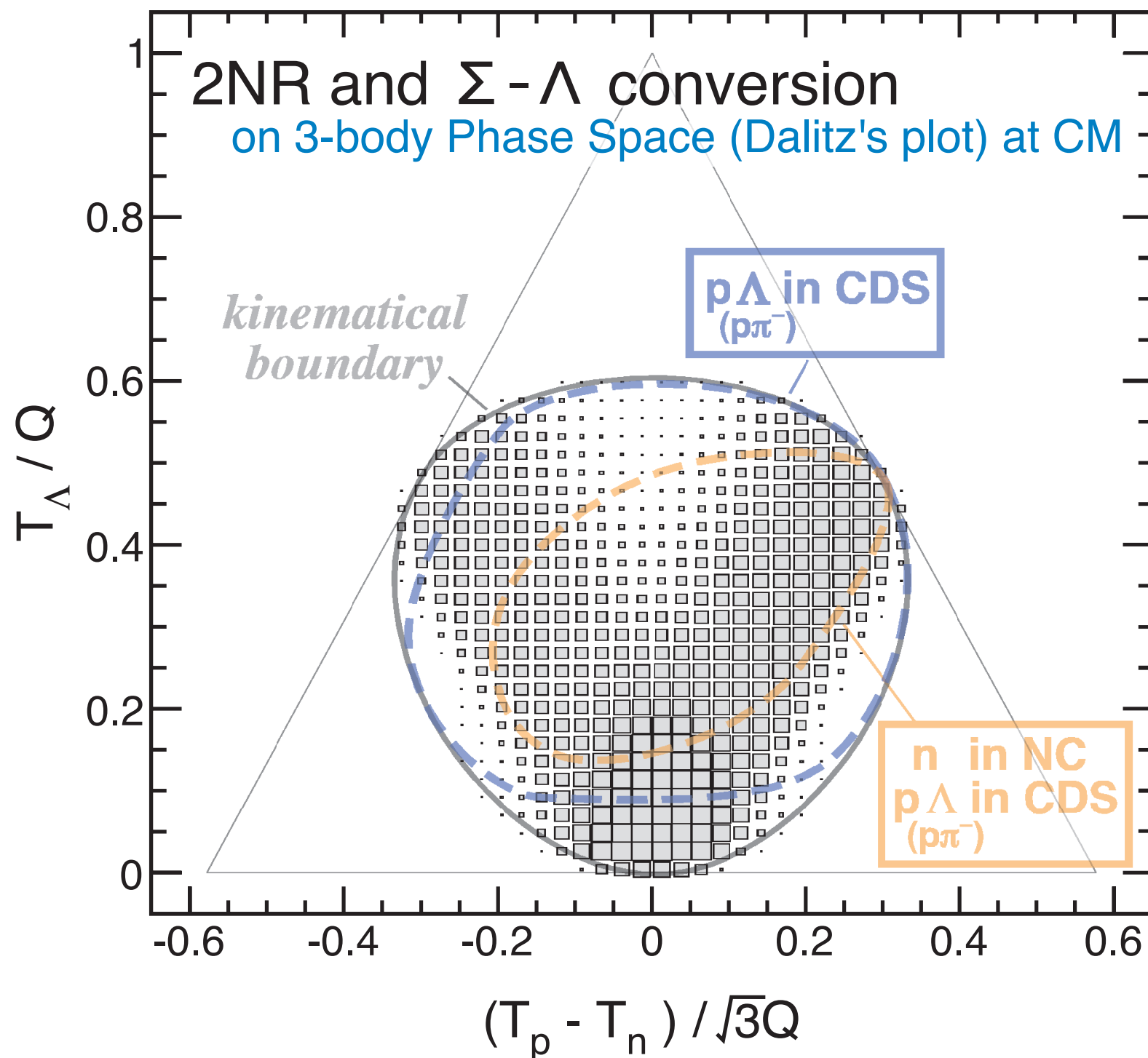


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Background?

Two Nucleon Reaction and FSI (Σ - Λ conversion) *multi-step PWIA*

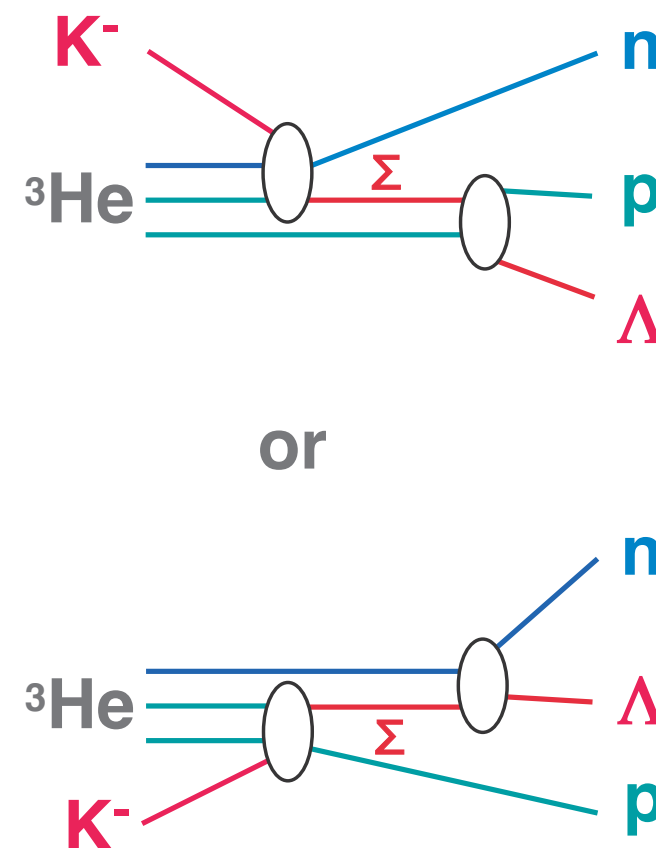
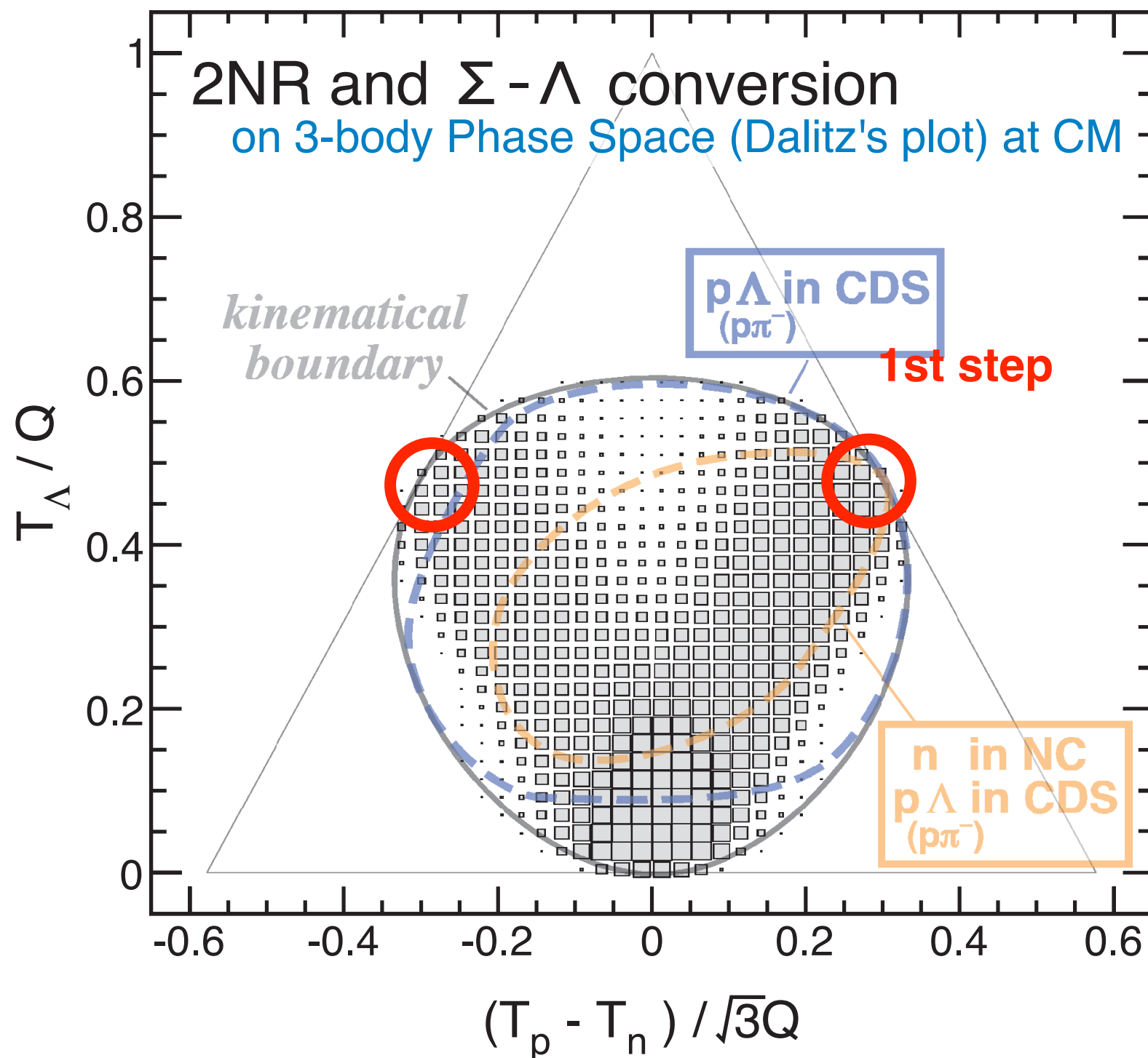


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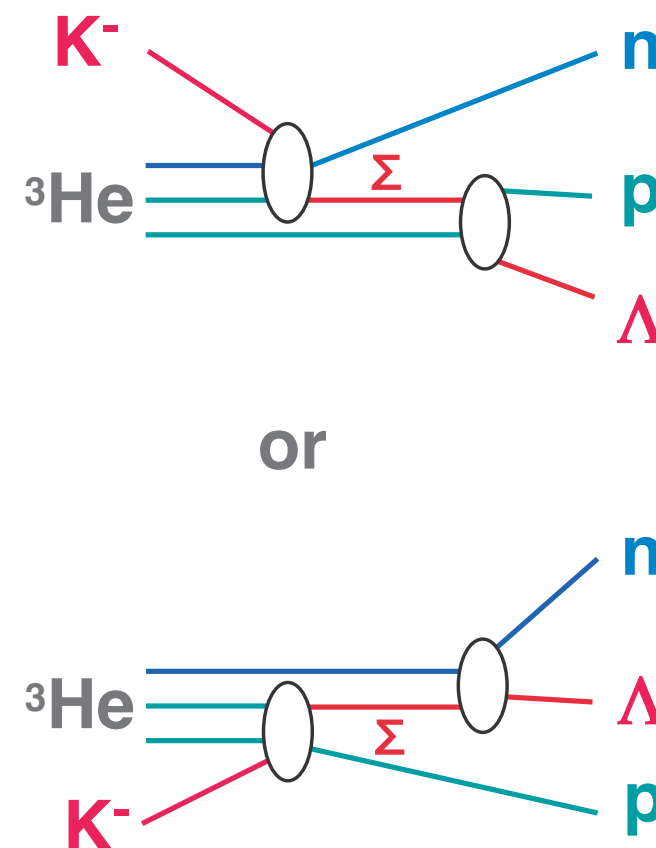
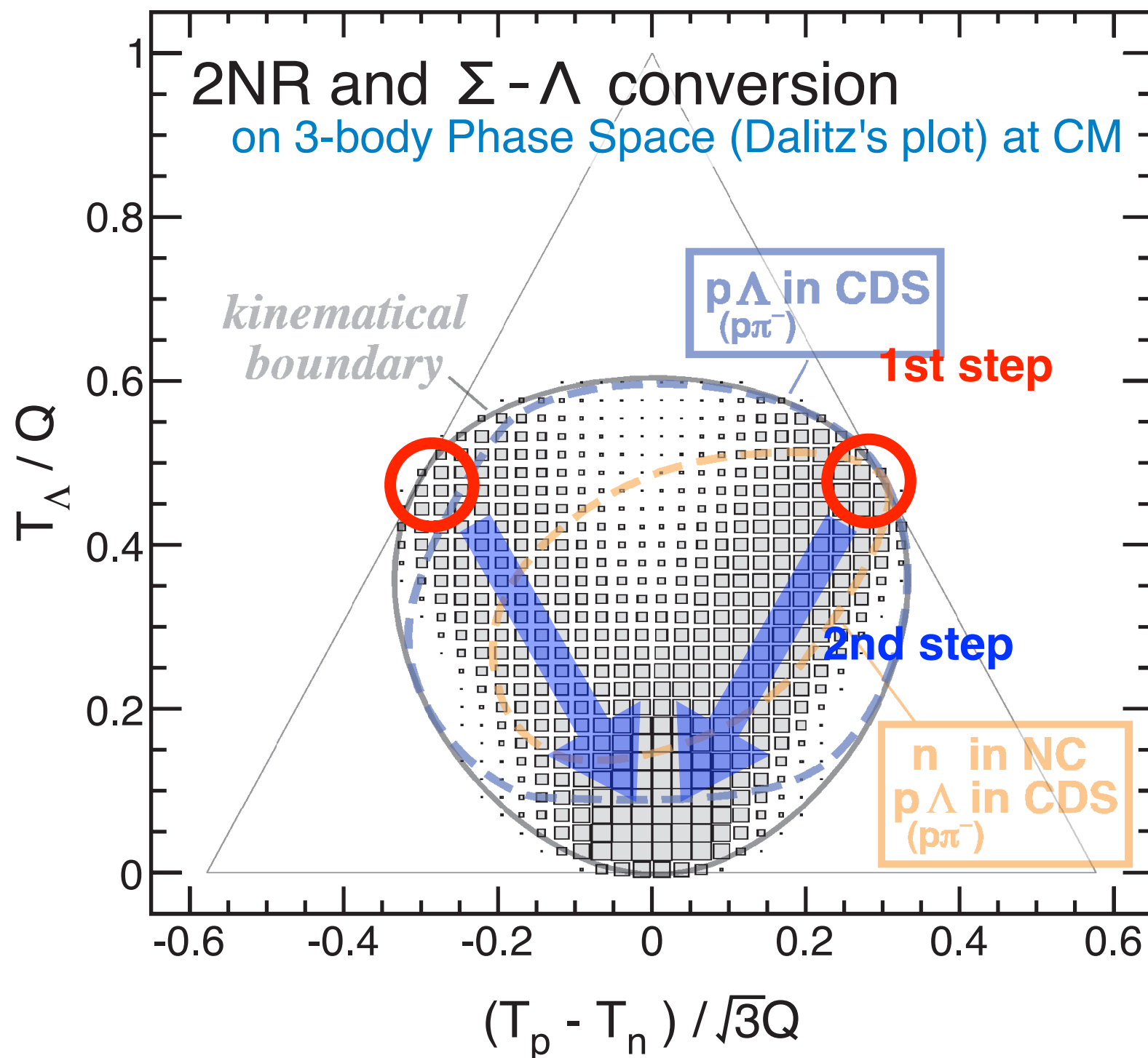


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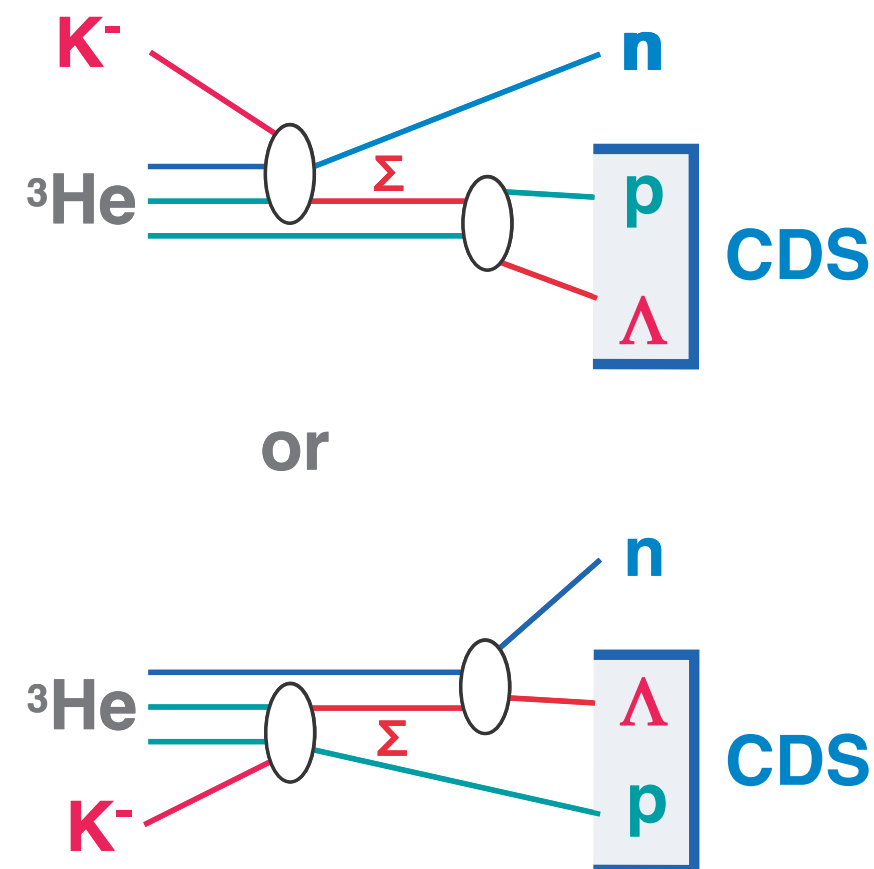
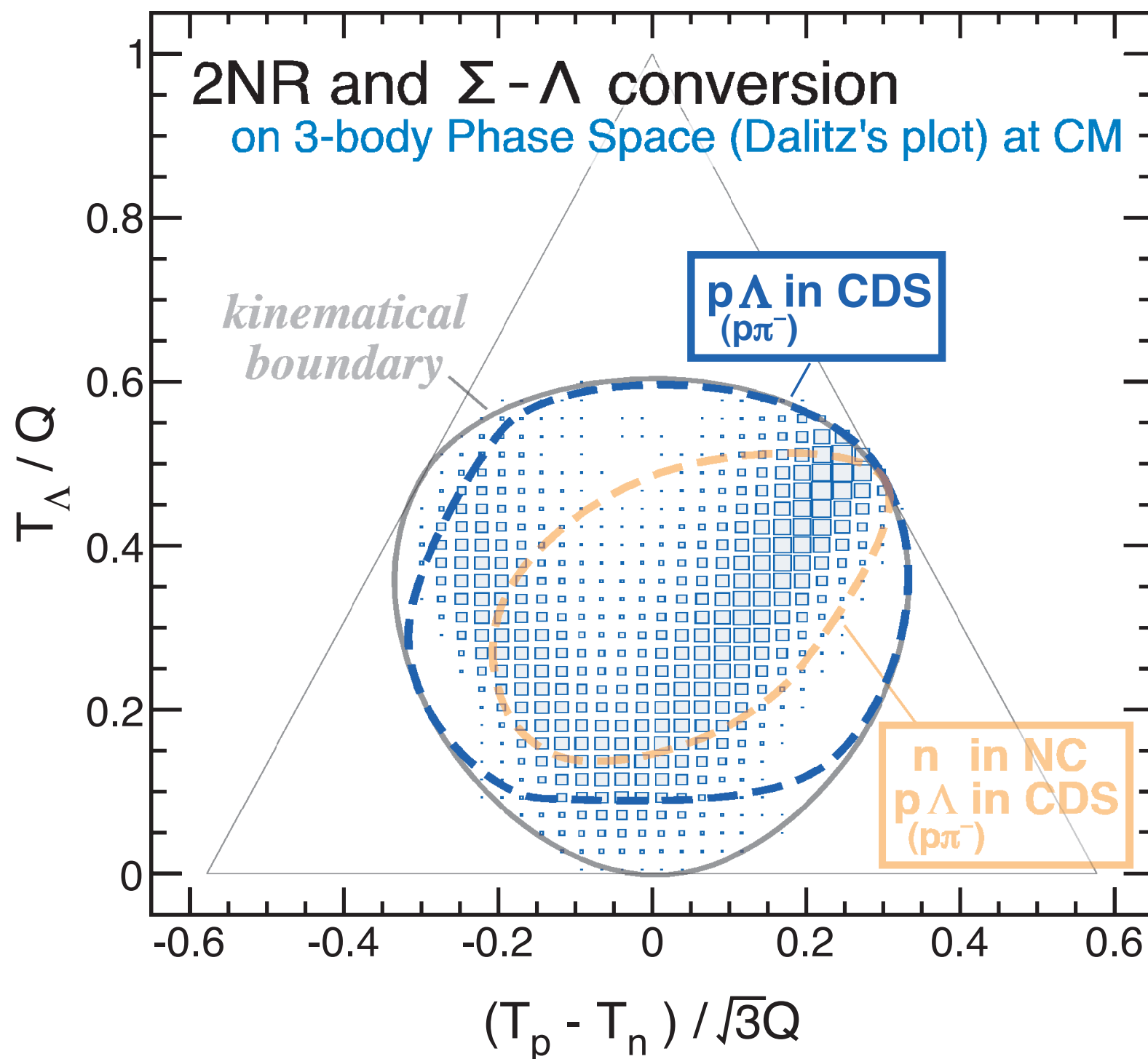


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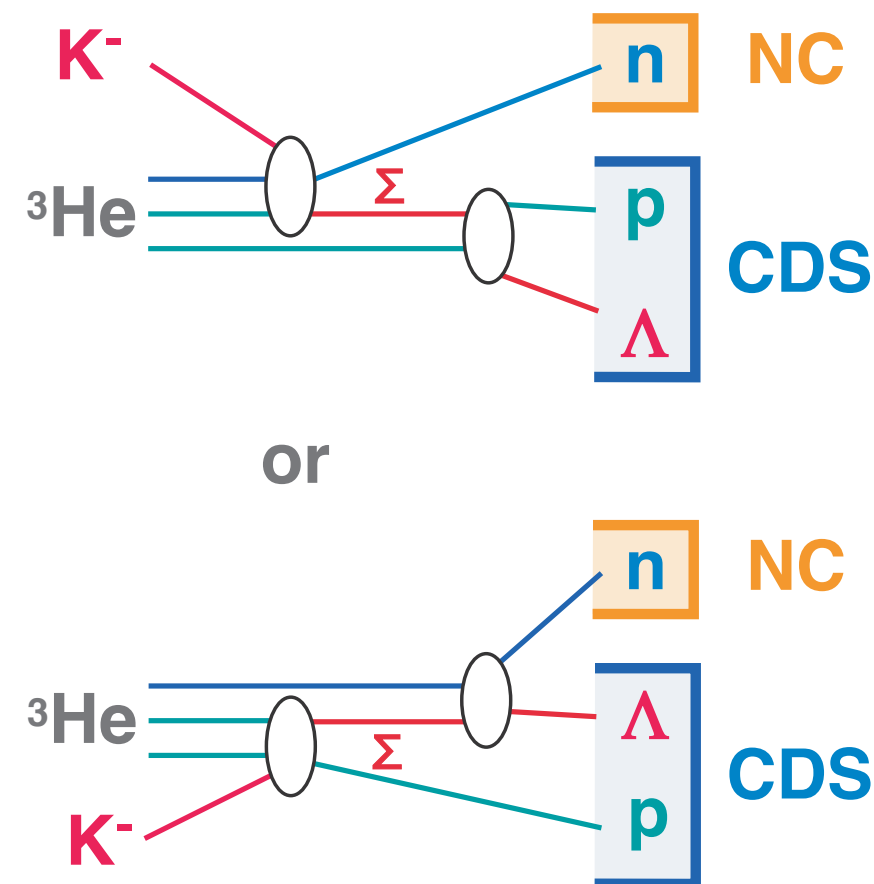
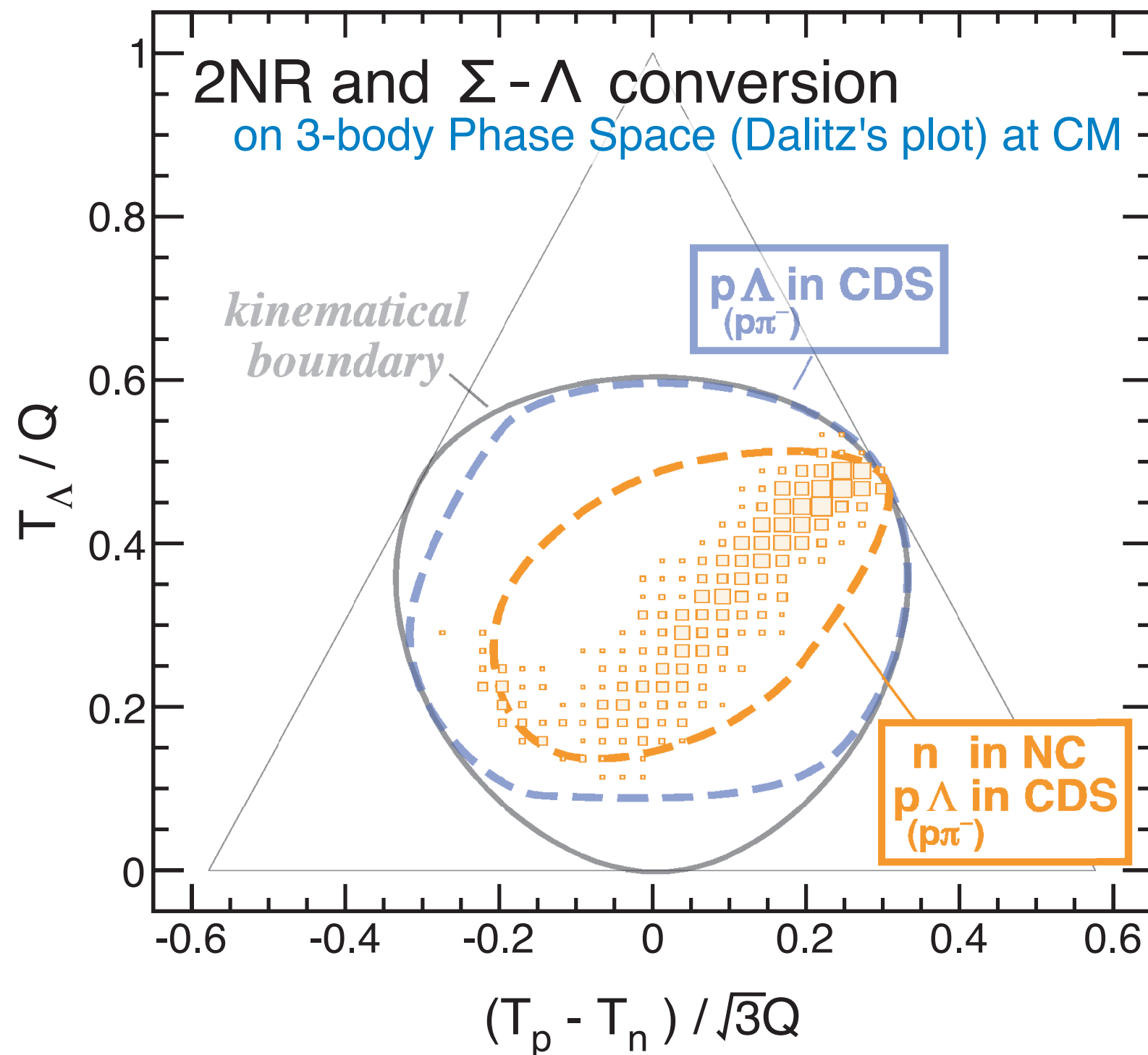


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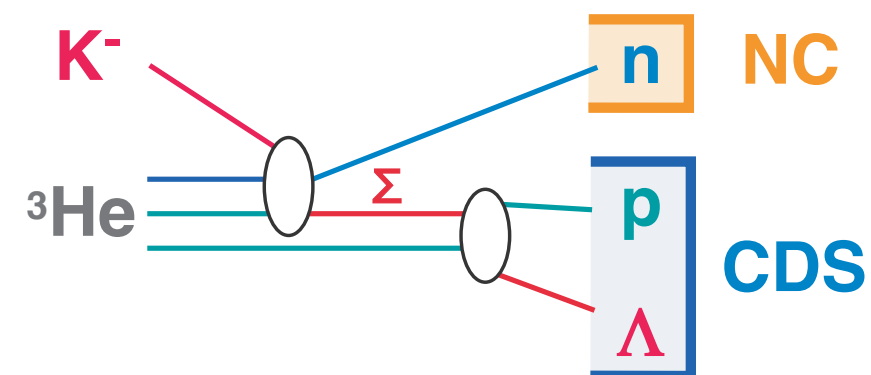
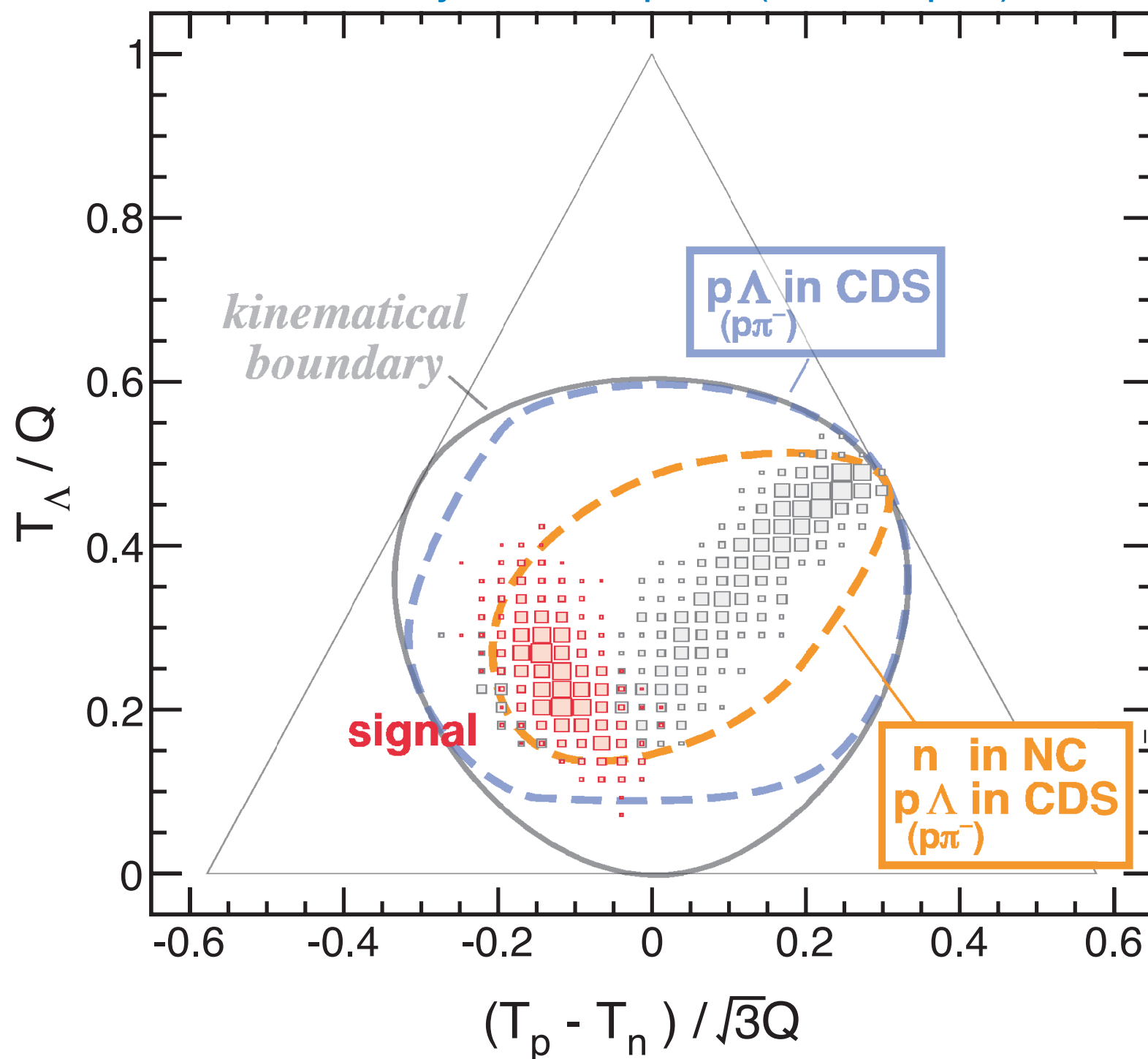


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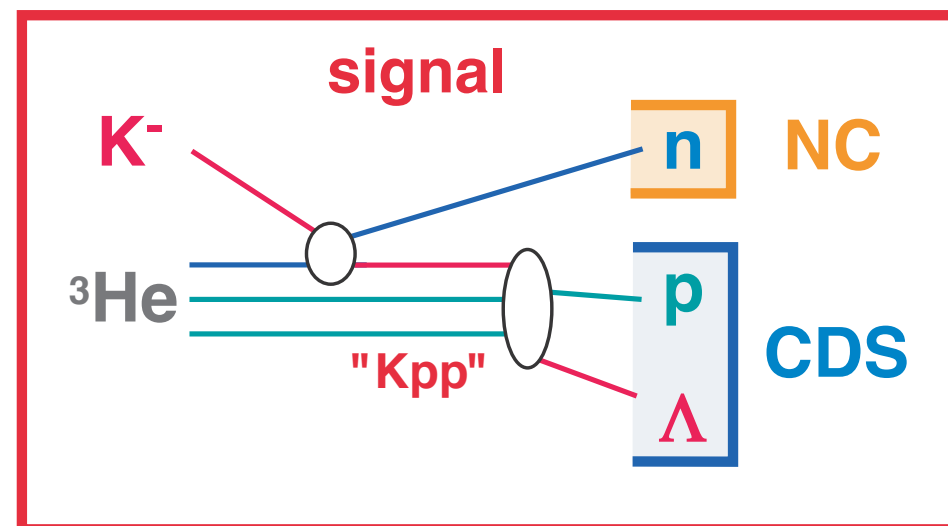
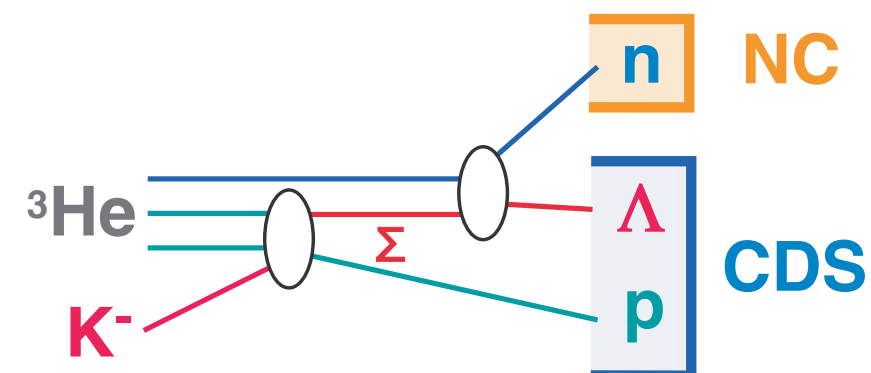
vs **signal** (*ratio arbitrary*)

Two Nucleon Reaction and FSI (Σ - Λ conversion) multi-step PWIA

2NR and Σ - Λ conversion
on 3-body Phase Space (Dalitz's plot) at CM



or



simulated by T. Hiraiwa

Is two nucleon reaction possible? *in in-flight kinematics @ 1 GeV/c*

Not very likely... cf.

De Broglie wave length @ 1 GeV/c ~ 1.2 fm
 Λ

Nucleon distance ~ 1.5 fm

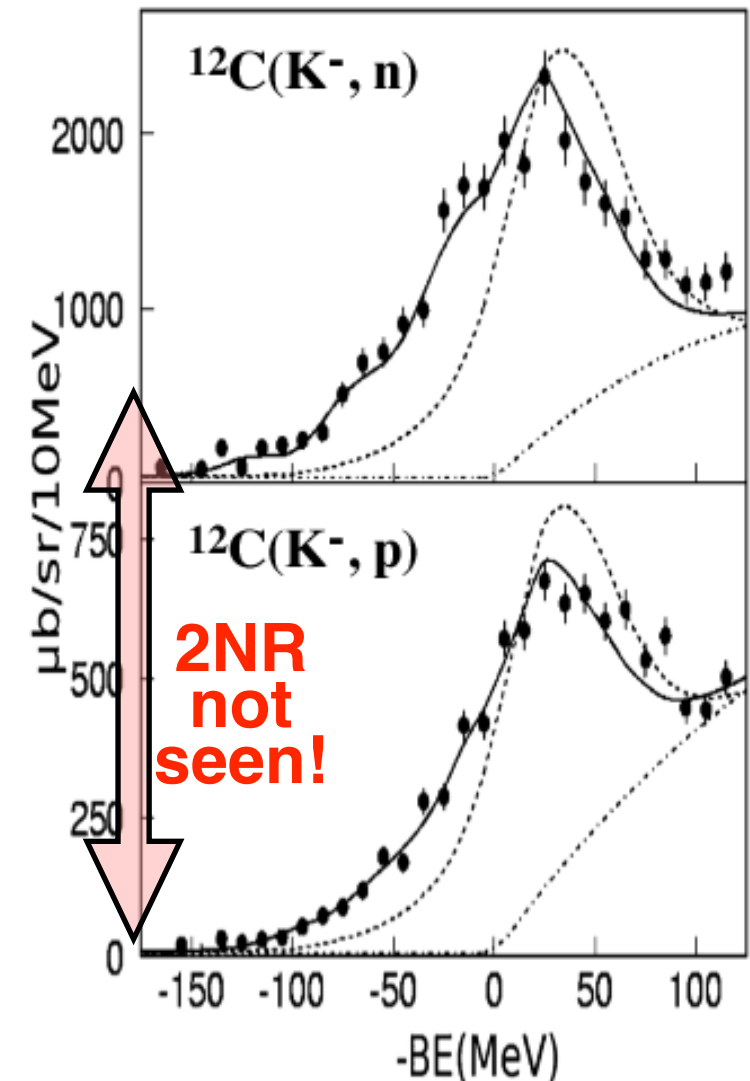
although 2NR process should be examined on

Two successive reaction after KNN

1) nucleon or hyperon scattering

2) $\Sigma \rightarrow \Lambda$ conversion

by reducing the trigger level.



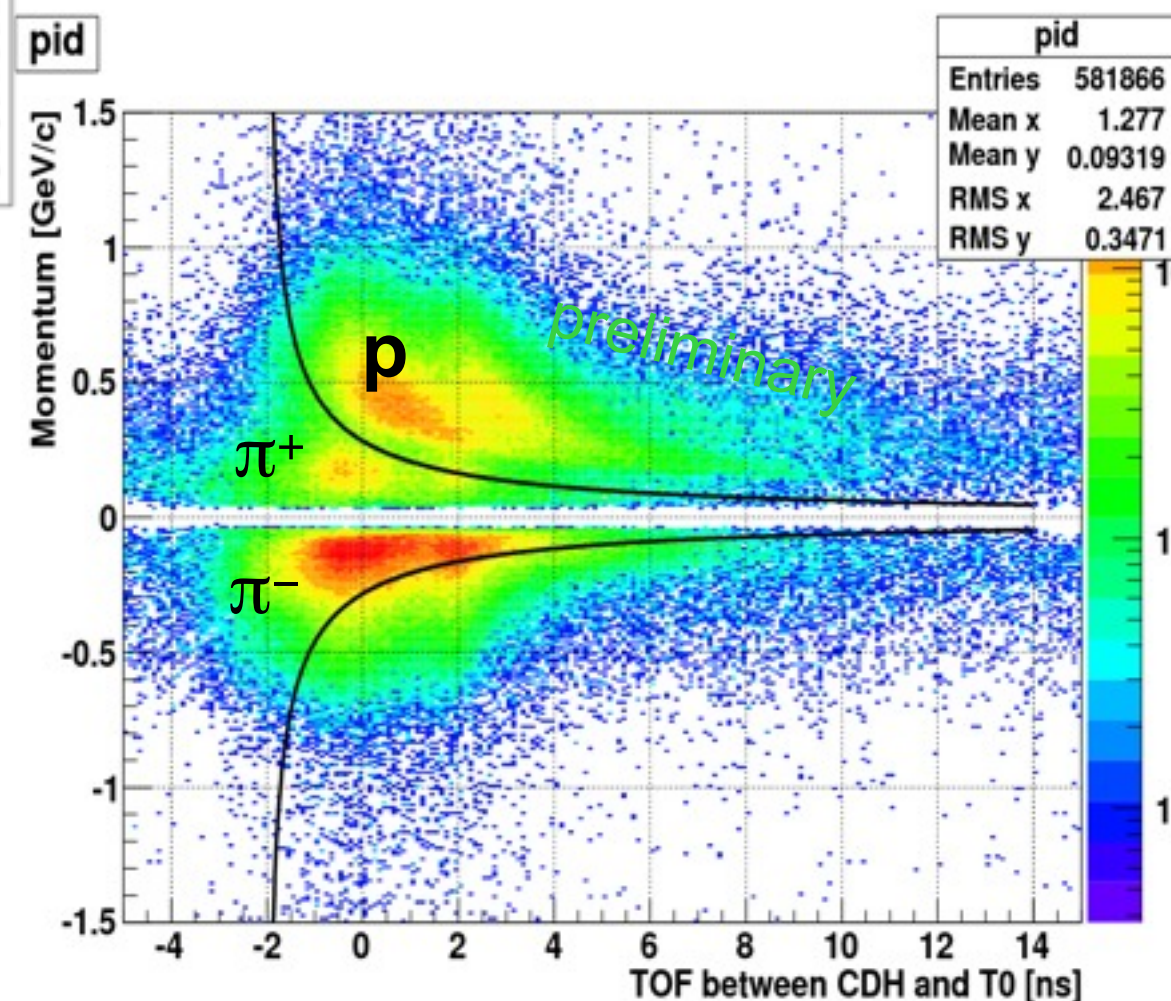
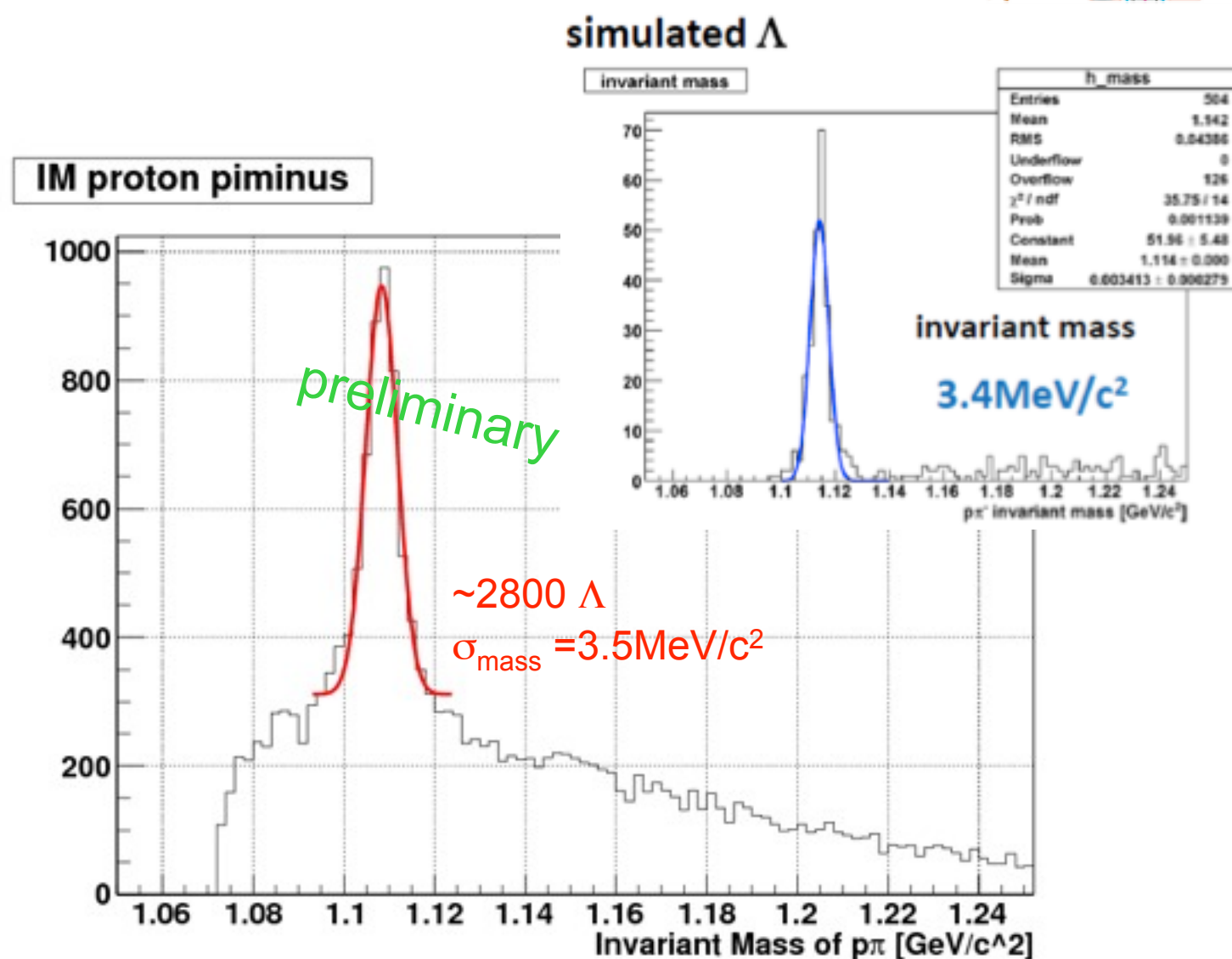
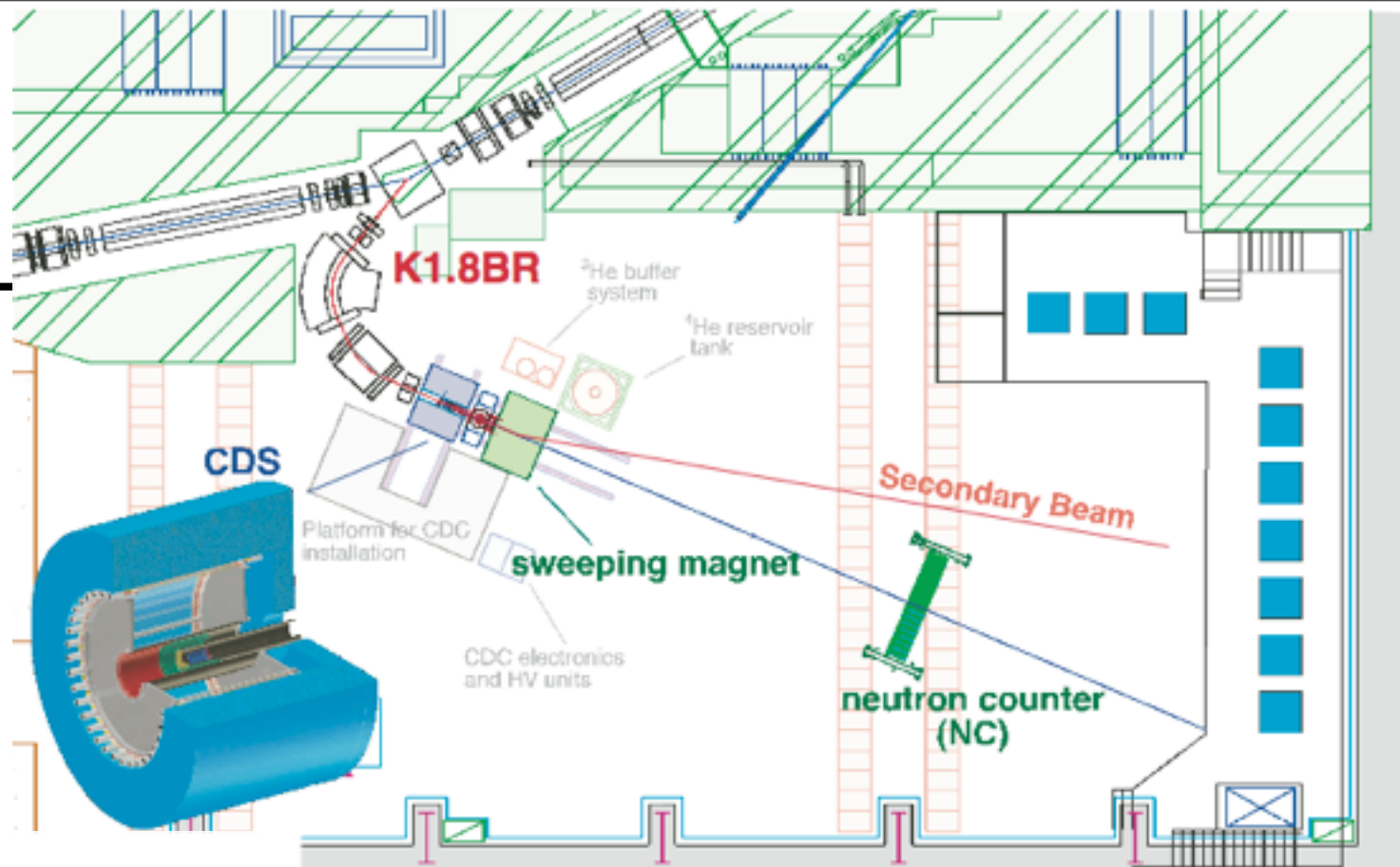
T. Kishimoto et al., Prog. Theor. Phys. 118 (2007) 181

**Note: Simple KNN channel excluded:
 Because it is easy to discriminate**



Present?

missing:
transportation of
SW Magnet and NC





E15 staging strategy

apparatus preparation is ready

E15 approved = 1500kW*week (@ Pt equiv.)

not easy to realize

E15^{1st} ~ 30kW*week (2% in terms of proton on target)

- 1) to know the background processes
- 2) to evaluate the realistic beam time for E15^{full}
- 3) present an information of the $\bar{K}N$ interaction
 ${}^3\text{He}(K^-, n)$ spectrum below $\bar{K}N$ threshold
- 4) a hint of signal in $\Lambda + p + n$ final states

E15^{1st} realize before long shutdown in 2012



E15 staging strategy

apparatus preparation is ready

E15 approved = 1500kW*week (@ Pt equiv.)

not easy to realize

divide into 3 periods

E15^{1st} ~ 30kW*week (2% in terms of proton on target)

- 1) to know the background processes
- 2) to evaluate the realistic beam time for E15^{full}
- 3) present an information of the $\bar{K}N$ interaction
 ${}^3\text{He}(K^-, n)$ spectrum below $\bar{K}N$ threshold
- 4) a hint of signal in $\Lambda + p + n$ final states

E15^{1st} realize before long shutdown in 2012



J-PARC E15 Collaboration

<http://ag.riken.jp/J-PARC/collaboration/>

S. Ajimura^a, G. Beer^b, H. Bhang^c, M. Bragadireanu^e, P. Buehler^f, L. Busso^{g,h}, M. Cargnelli^f, S. Choi^c, C. Curceanu^d, S. Enomotoⁱ, D. Faso^{g,h}, H. Fujioka^j, Y. Fujiwara^k, T. Fukuda^l, C. Guaraldo^d, T. Hashimoto^k, R. S. Hayano^k, T. Hiraiwa^j, M. Iioⁿ, M. Iliescu^d, K. Inoueⁱ, Y. Ishiguro^j, T. Ishikawa^k, S. Ishimoto^o, T. Ishiwatari^f, K. Itahashiⁿ, M. Iwai^o, M. Iwasaki^{m,n}, P. Kienle^p, H. Kou^m, J. Marton^f, Y. Matsuda^q, Y. Mizoi^l, O. Morra^g, T. Nagae^j, H. Noumi^a, H. Ohnishiⁿ, S. Okada^d, H. Outaⁿ, D. Pietreanu^d, M. Poli Lener^d, A. Romero Vidal^d, Y. Sada^j, A. Sakaguchiⁱ, F. Sakumaⁿ, M. Sato^k, M. Sekimoto^o, H. Shi^k, D. Sirghi^{d,e}, F. Sirghi^{d,e}, K. Suzuki^f, S. Suzuki^o, T. Suzuki^k, H. Tatsuno^k, M. Tokuda^m, D. Tomonoⁿ, A. Toyoda^o, K. Tsukadaⁿ, O. Vazquez Doce^d, E. Widmann^f, T. Yamazaki^{k,n}, H. Yim^r, and J. Zmeskal^f

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(r) Korea Institute of Radiological and Medical Sciences (KIRAMS), Seoul, 139-706, South Korea 

(*) Spokesperson

**Thank you
for attention!**

spare



KI.8BR with Pt (@50% loss)

All K incident experiments:

Present Duty Factor will be OK up to few 10th of kW

required power

E17 ~ 10kW*week

> 2kW?

KN by x-ray via K-³He

E15^{1st} ~ 30kW*week (first stage)

> 10kW?

cf. 1500kW*week (E15 full @ Pt equiv.)

> 100kW?

KN by bound state via K-³He

E31 ~ 180kW*week

> 20~40kW?

Λ(1405) via K-d

**Signal can be easily discriminated
from signal in both FSI cases !**

Two successive reaction after KNN

1) nucleon or hyperon scattering

2) $\Sigma \rightarrow \Lambda$ conversion

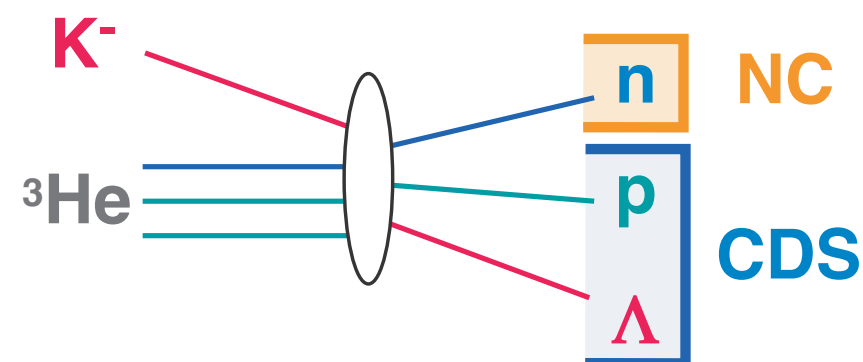
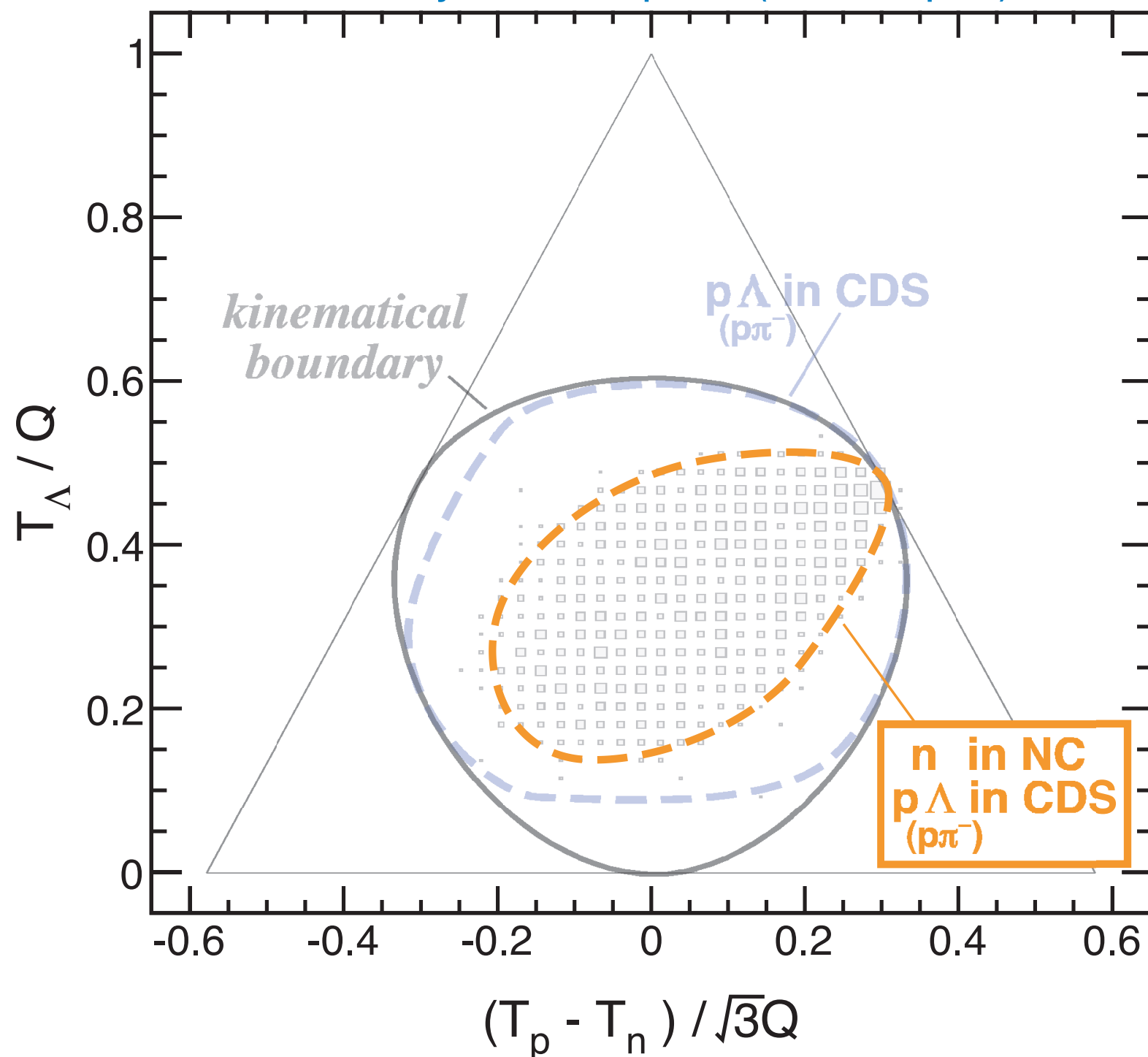
**Note: Simple KNN channel excluded:
Because it is easy to discriminate**



Can we extend the detection capability?

CDS & NC Acceptance

3-body Phase Space (Dalitz's plot) at CM

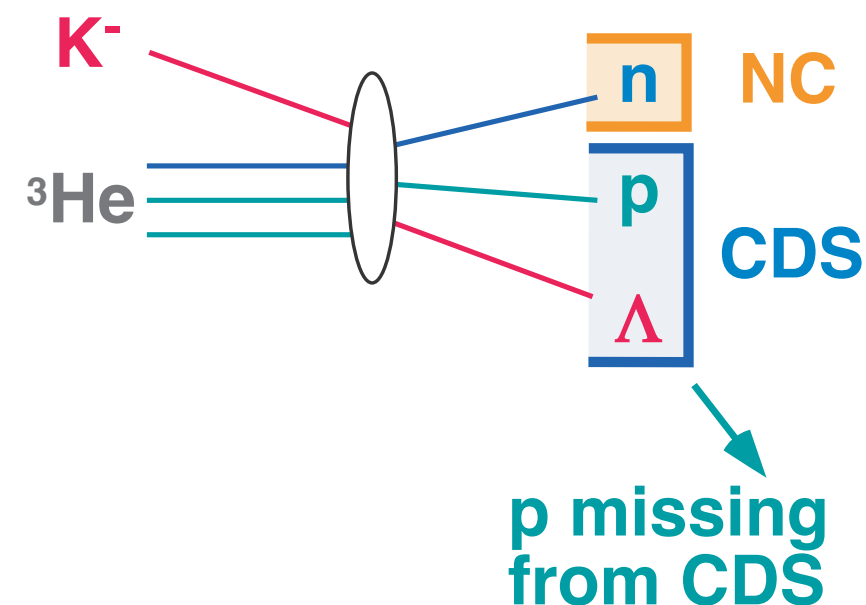
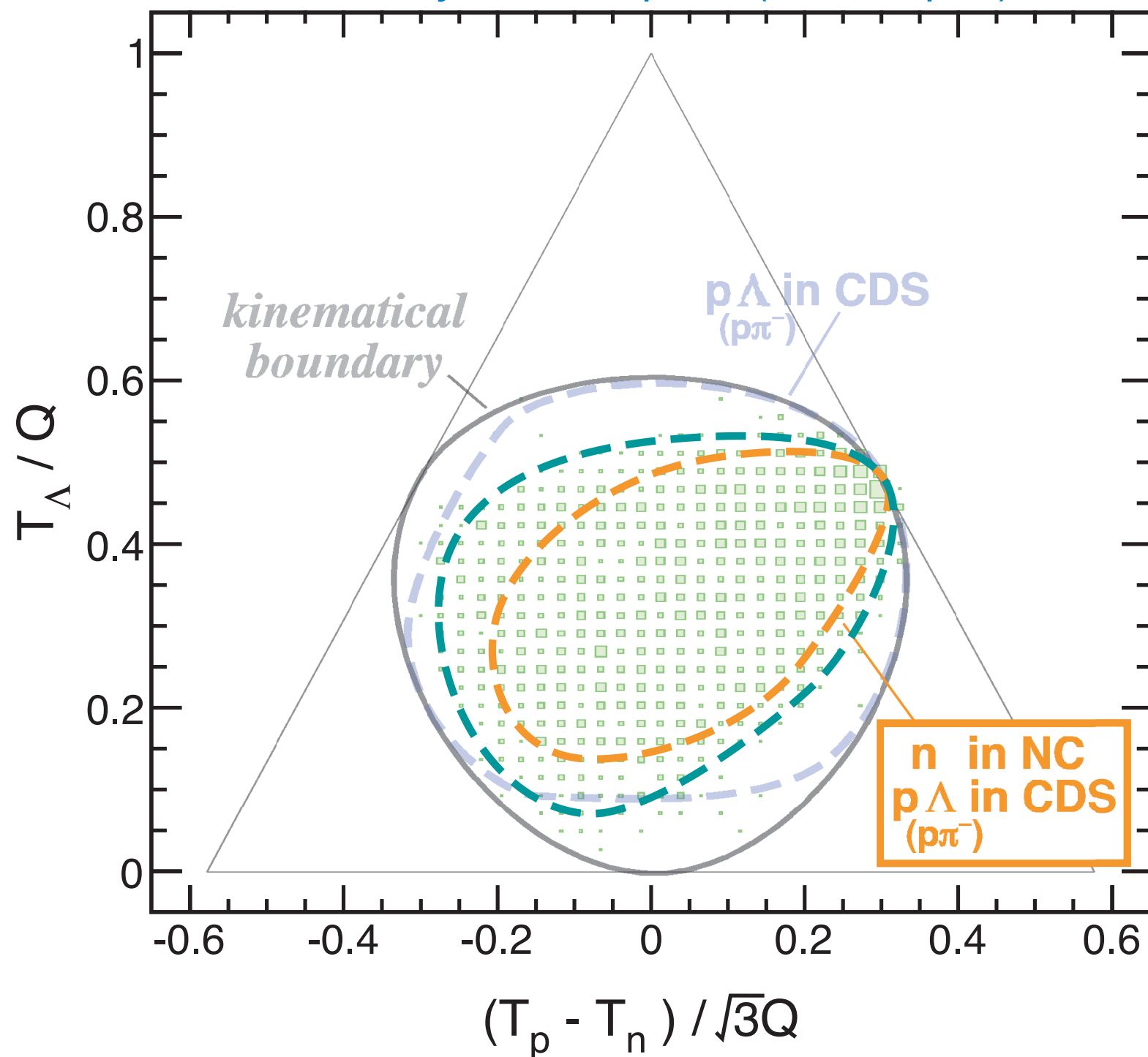


simulated by T. Hiraiwa



Can we extend the detection capability?

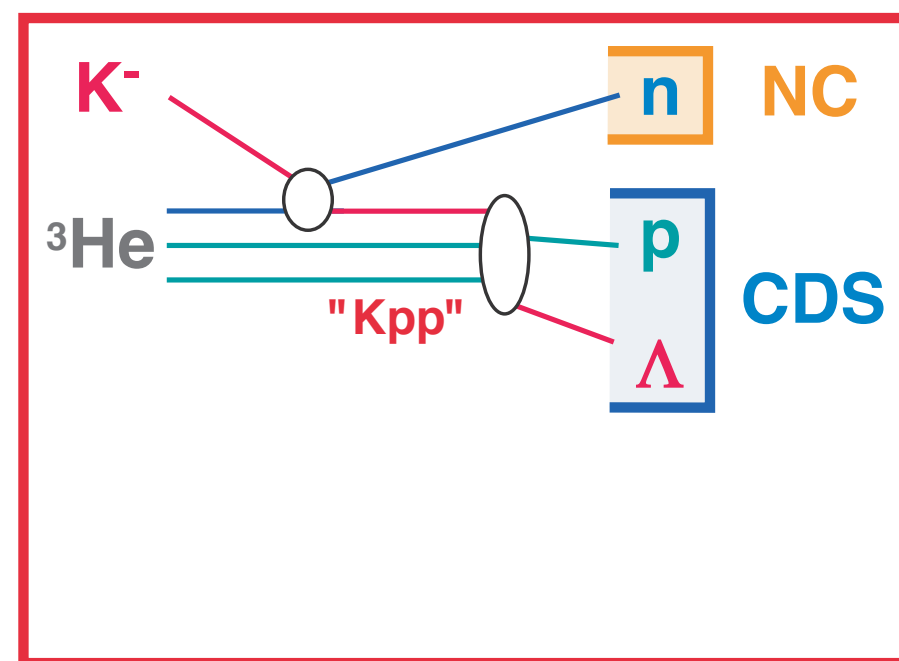
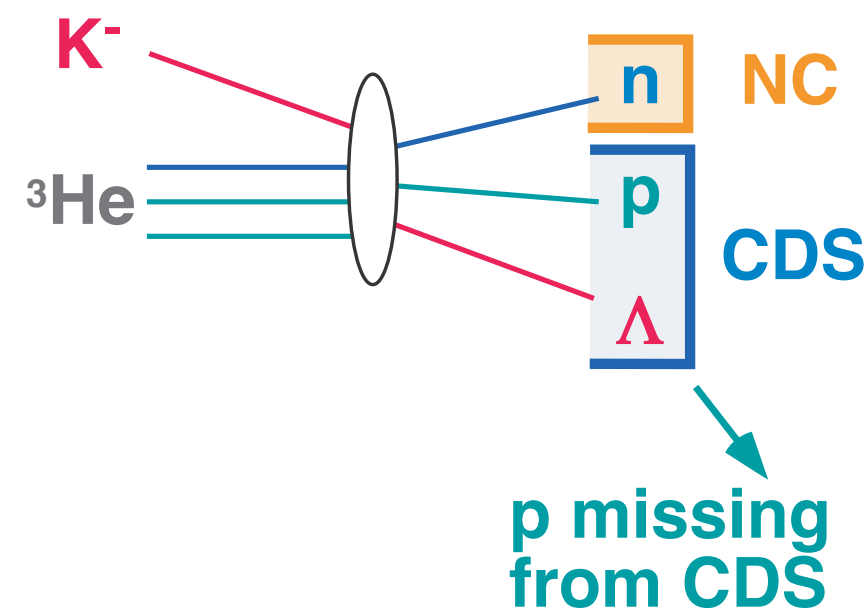
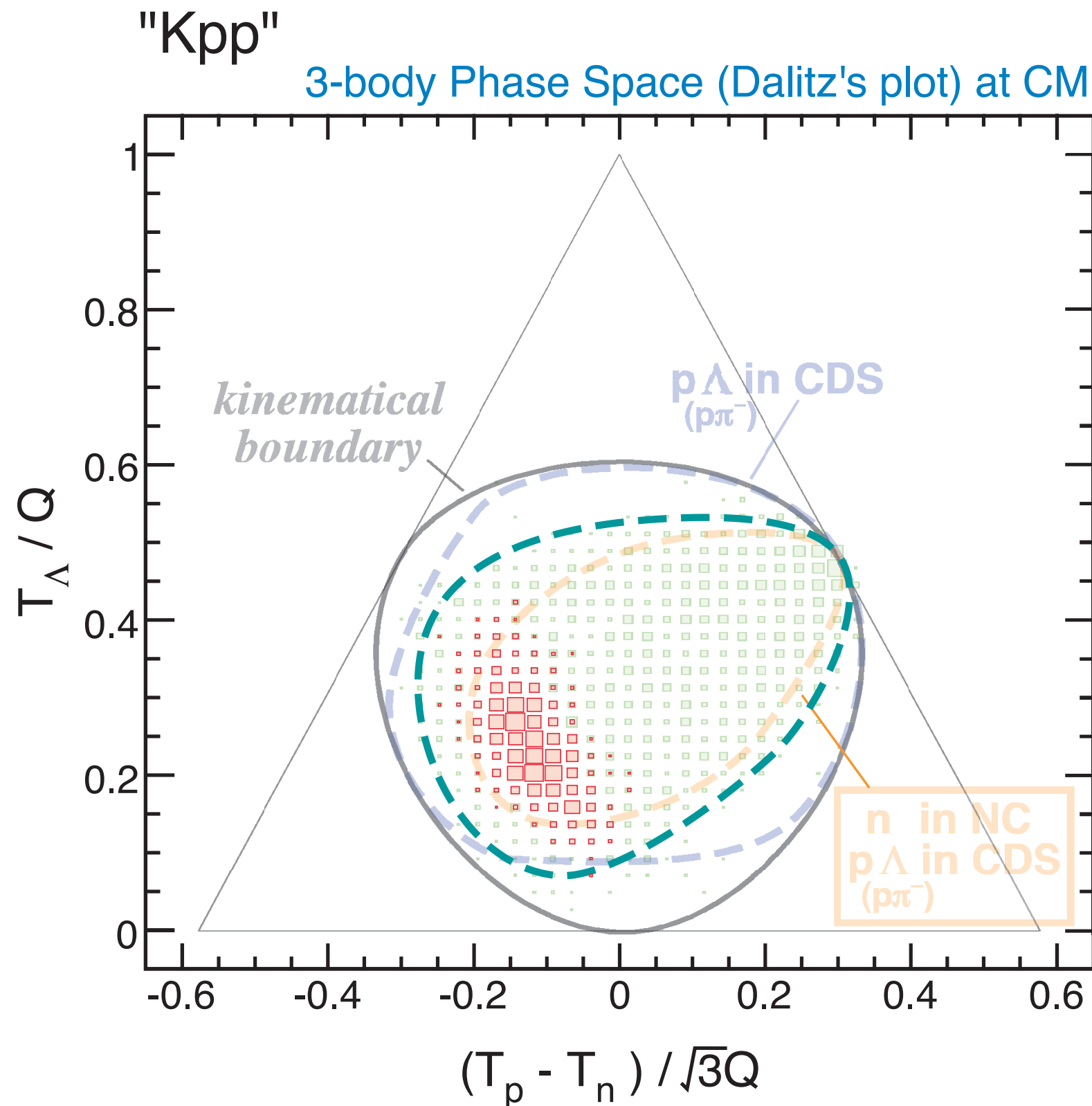
CDS & NC Acceptance **with one proton missing**
3-body Phase Space (Dalitz's plot) at CM



simulated by T. Hiraiwa



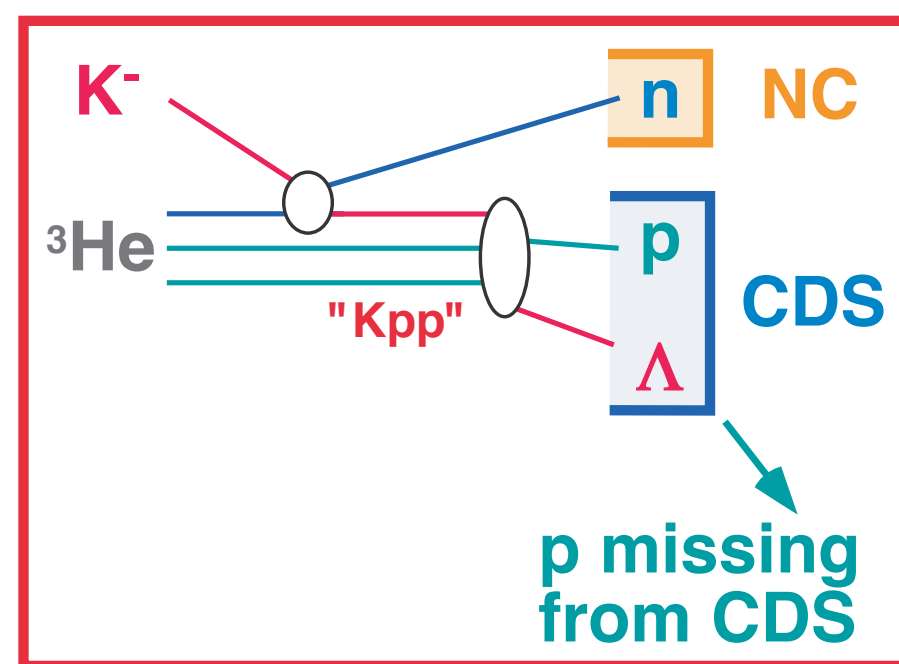
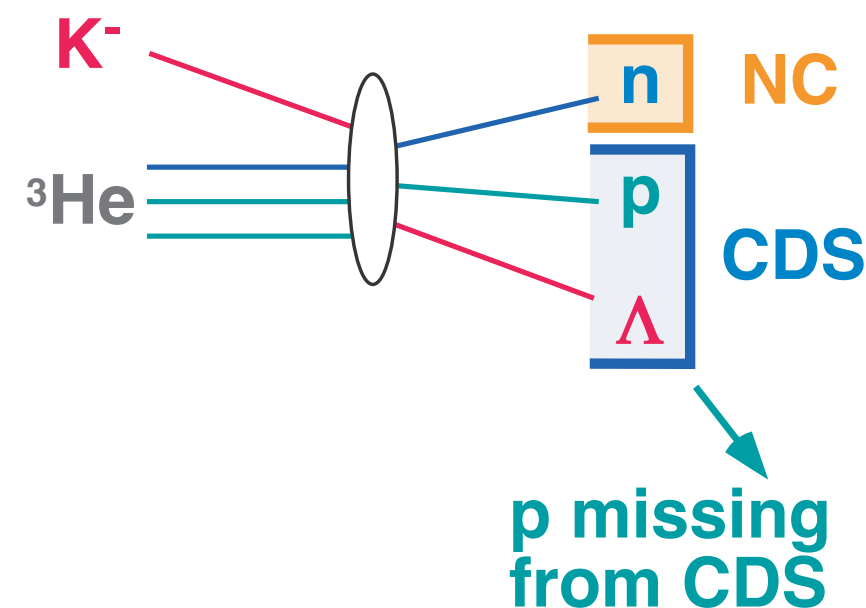
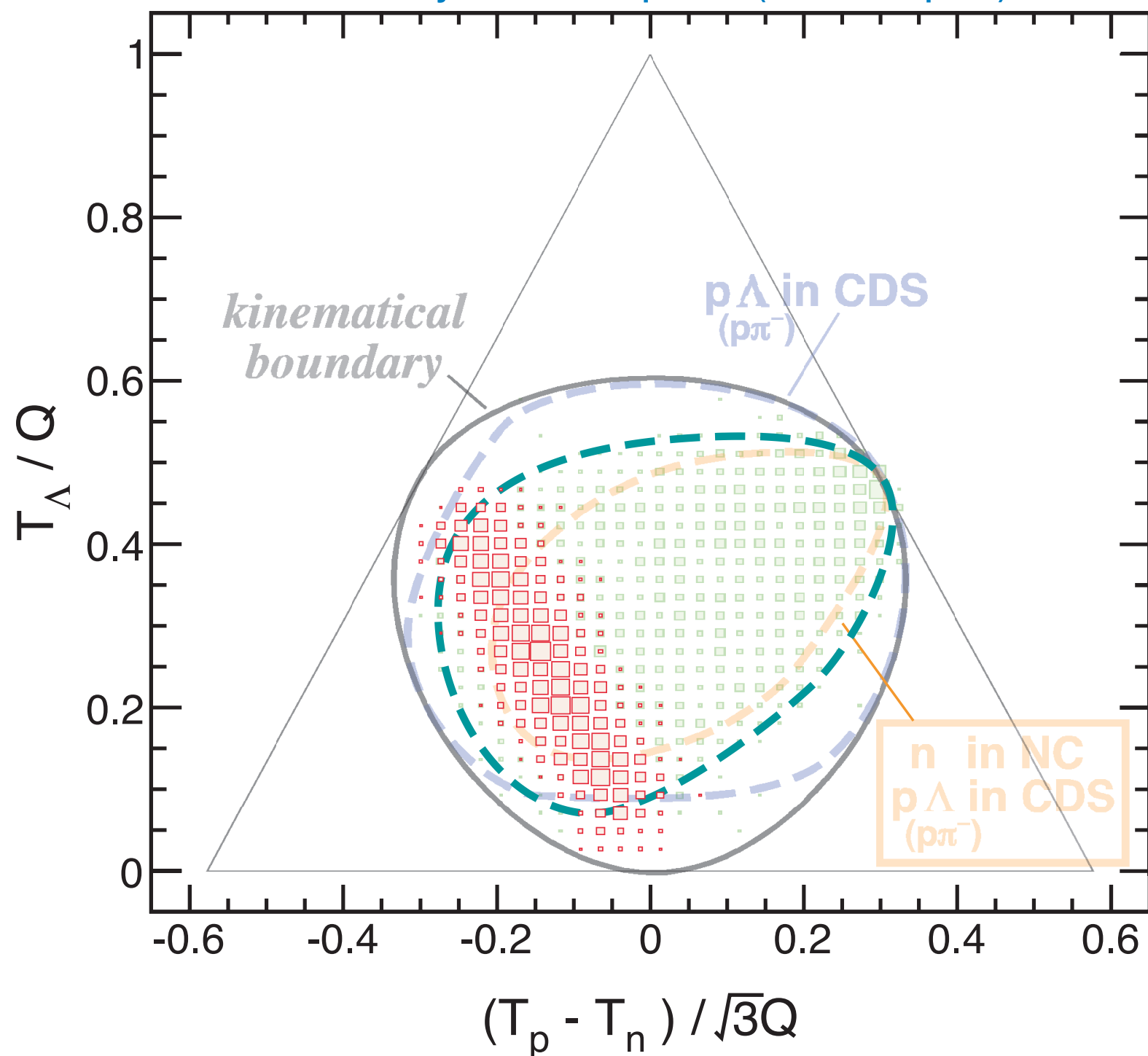
Can we extend the detection capability?



$B_K \sim 100\text{MeV}, \Gamma_K \sim 100\text{MeV}$
(like DISTO data)

simulated by T. Hiraiwa

"Kpp" **with one proton missing**
3-body Phase Space (Dalitz's plot) at CM



$B_K \sim 100 \text{ MeV}$, $\Gamma_K \sim 100 \text{ MeV}$
(like DISTO data)

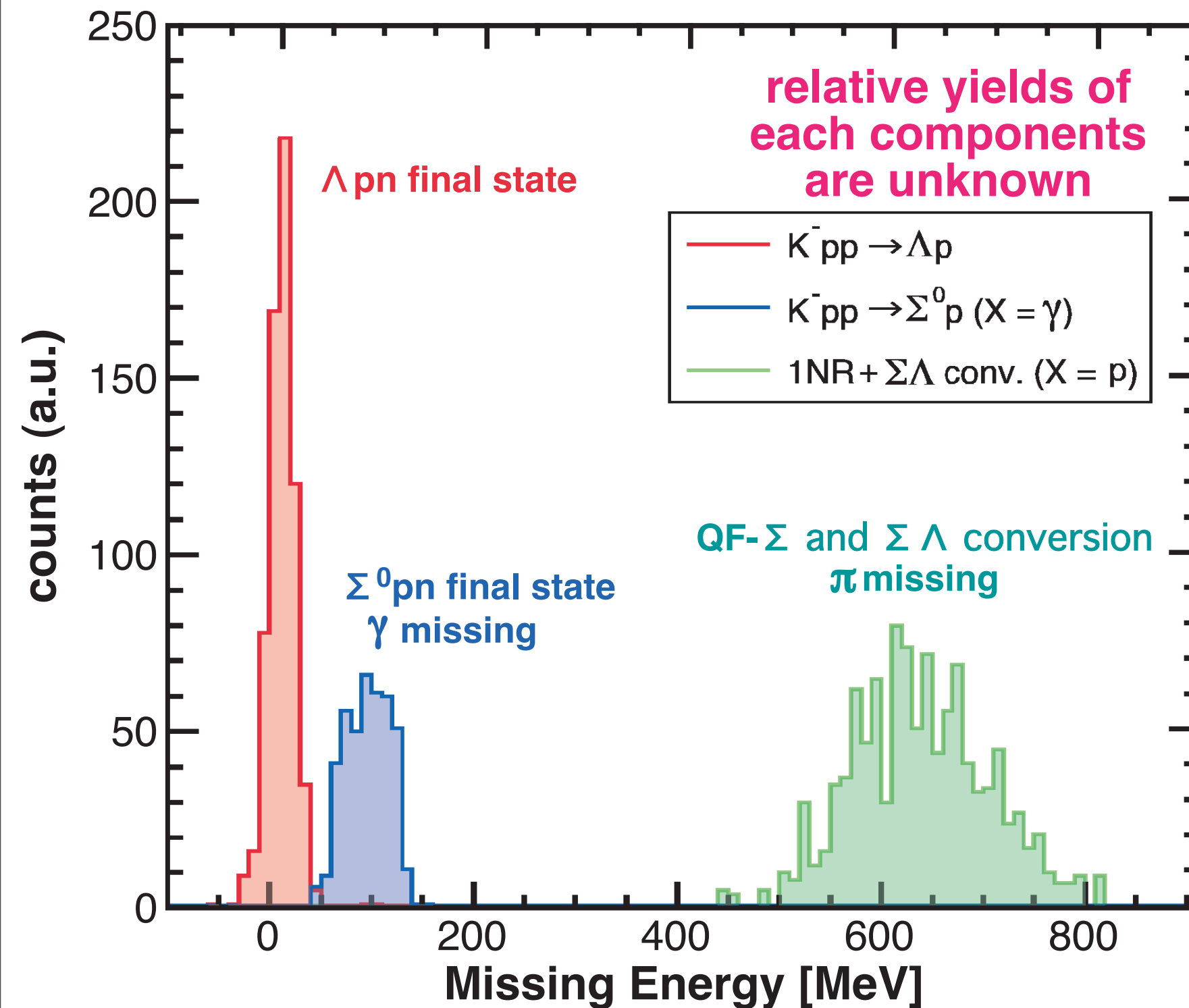
simulated by T. Hiraiwa



Λ pn final state selection by CDS & NC

What happens if we miss other particles?

other than Λ pn



**Other processes
can be clearly
separated!**

simulated by T. Hiraiwa



Improvement by one proton missing

- Missing proton resolution: $28.4 \pm 0.3 \text{ MeV}/c^2$
- Efficiency (NC eff. Is not included.)-

3body phase space $\rightarrow 0.079 \%$ (all detected)

$\rightarrow 0.12\%$ (one proton missing)

“Kpp”(B=100MeV $\Gamma=100\text{MeV}$) $\rightarrow 0.042 \%$ (all detected)

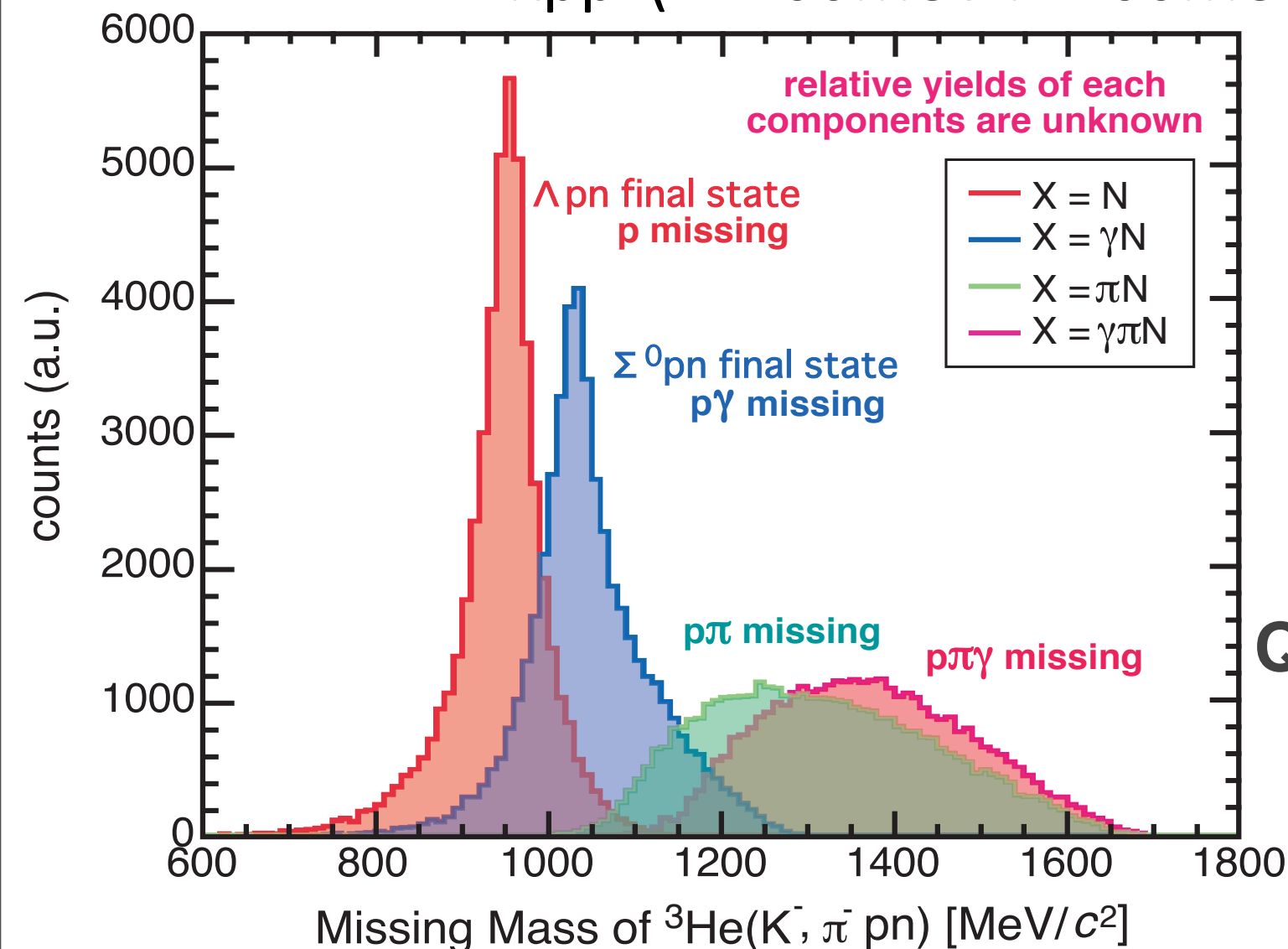
$\rightarrow 0.098 \%$ (one proton missing)

||
x 2 improvement

Are they perfect?

Λ pn / Σ^0 pn still be separated

QF-Y production also separated
but partial overlap with **p π missing**



simulated by T. Hiraiwa



Summary of the beam time requirement of the E15 first-stage run

Beamline: K1.8BR

Primary beam: ~ 10 kW proton

Secondary beam : $1.0 \text{ GeV}/c \text{ K}^-$

Reaction : In-flight (K^- ,n)

Target : Liquid ^3He

Primary beam : integrated proton of $30 \text{ kW}\cdot\text{week}$

Duration : more than three weeks including beam tuning for $1 \text{ GeV}/c$ kaon

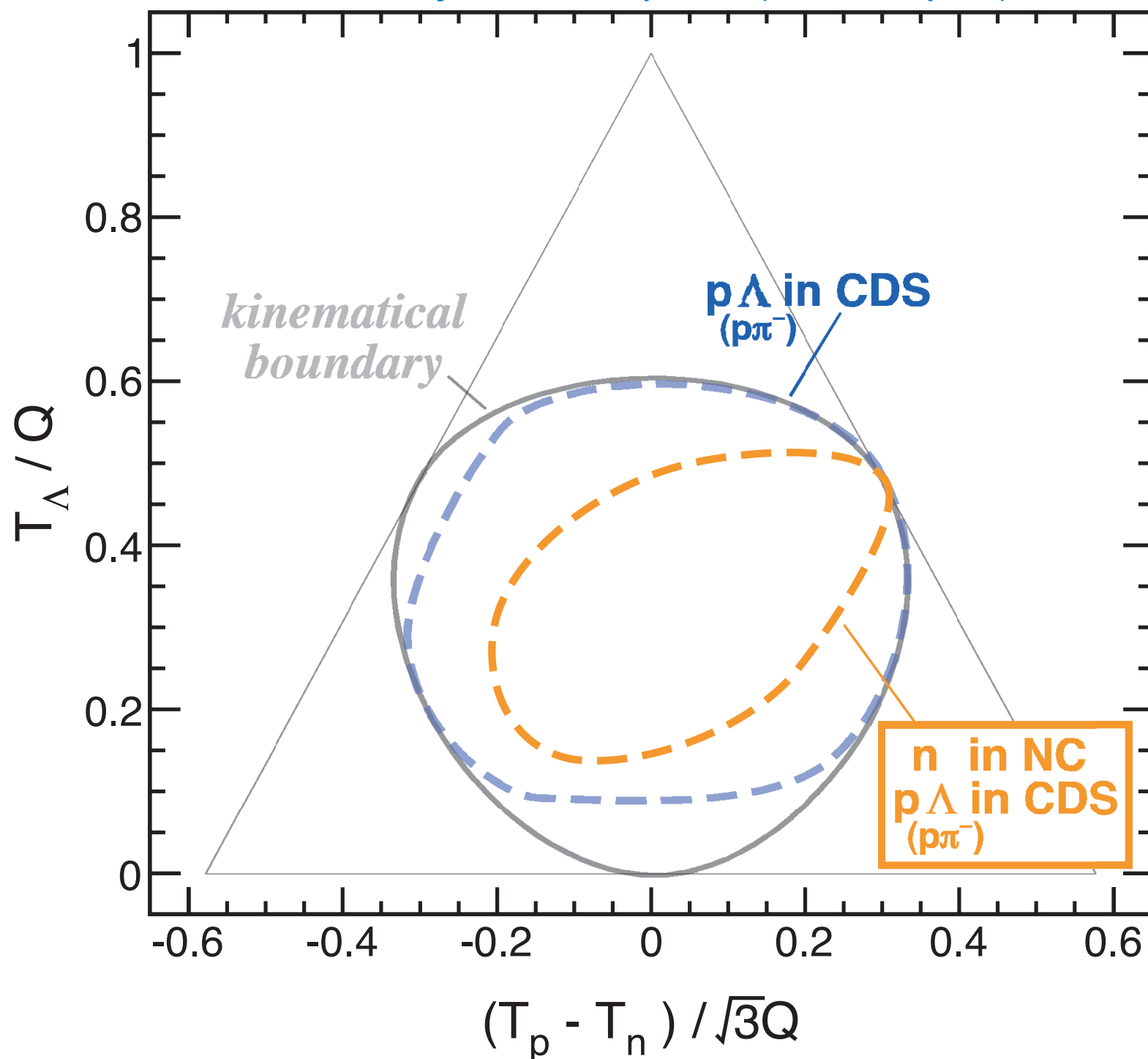


Background?

Two Nucleon Reaction and FSI (Σ - Λ conversion)

CDS & NC Acceptance

on 3-body Phase Space (Dalitz's plot) at CM



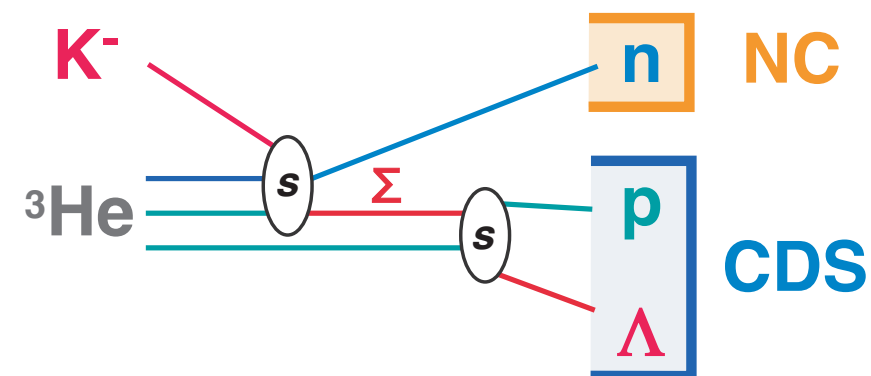
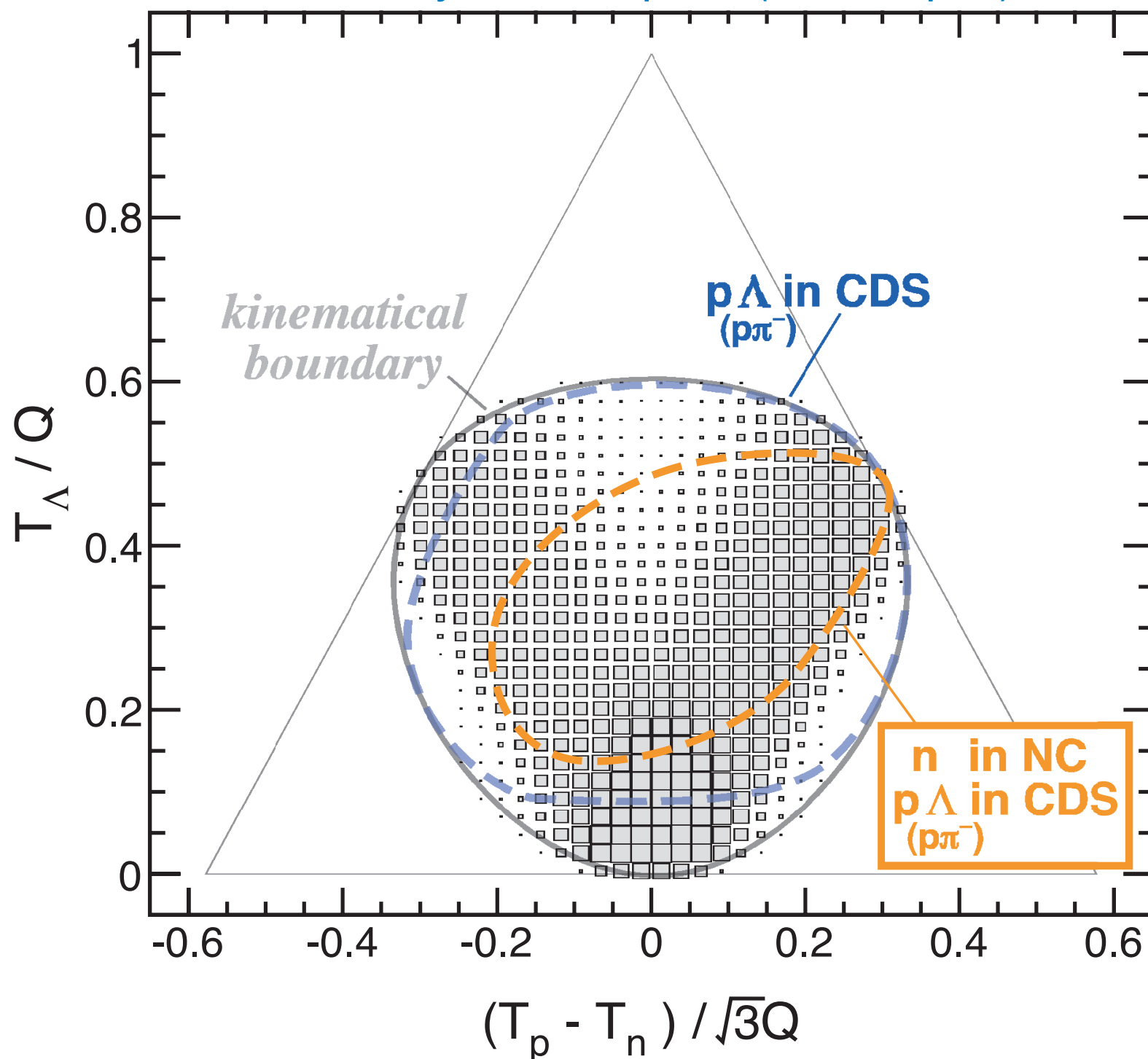
simulated by T. Hiraiwa



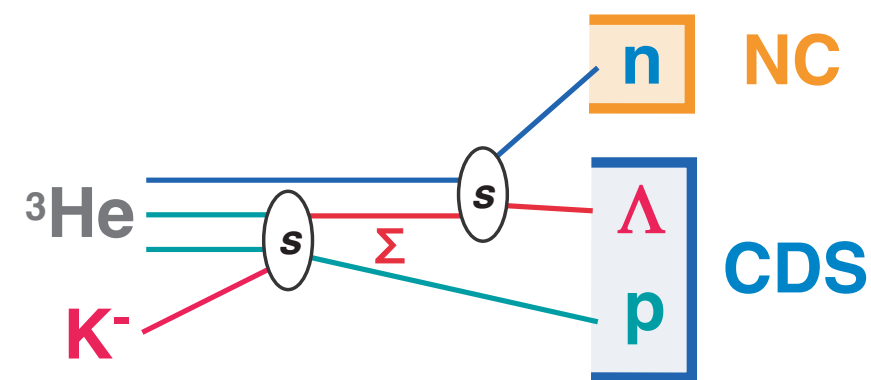
Background?

Two Nucleon Reaction and FSI (Σ - Λ conversion)

2NR and Σ - Λ conversion
on 3-body Phase Space (Dalitz's plot) at CM



or



multi-step PWIA

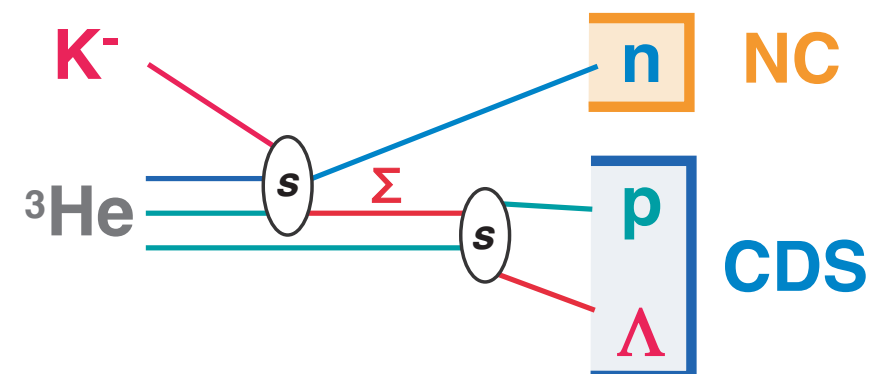
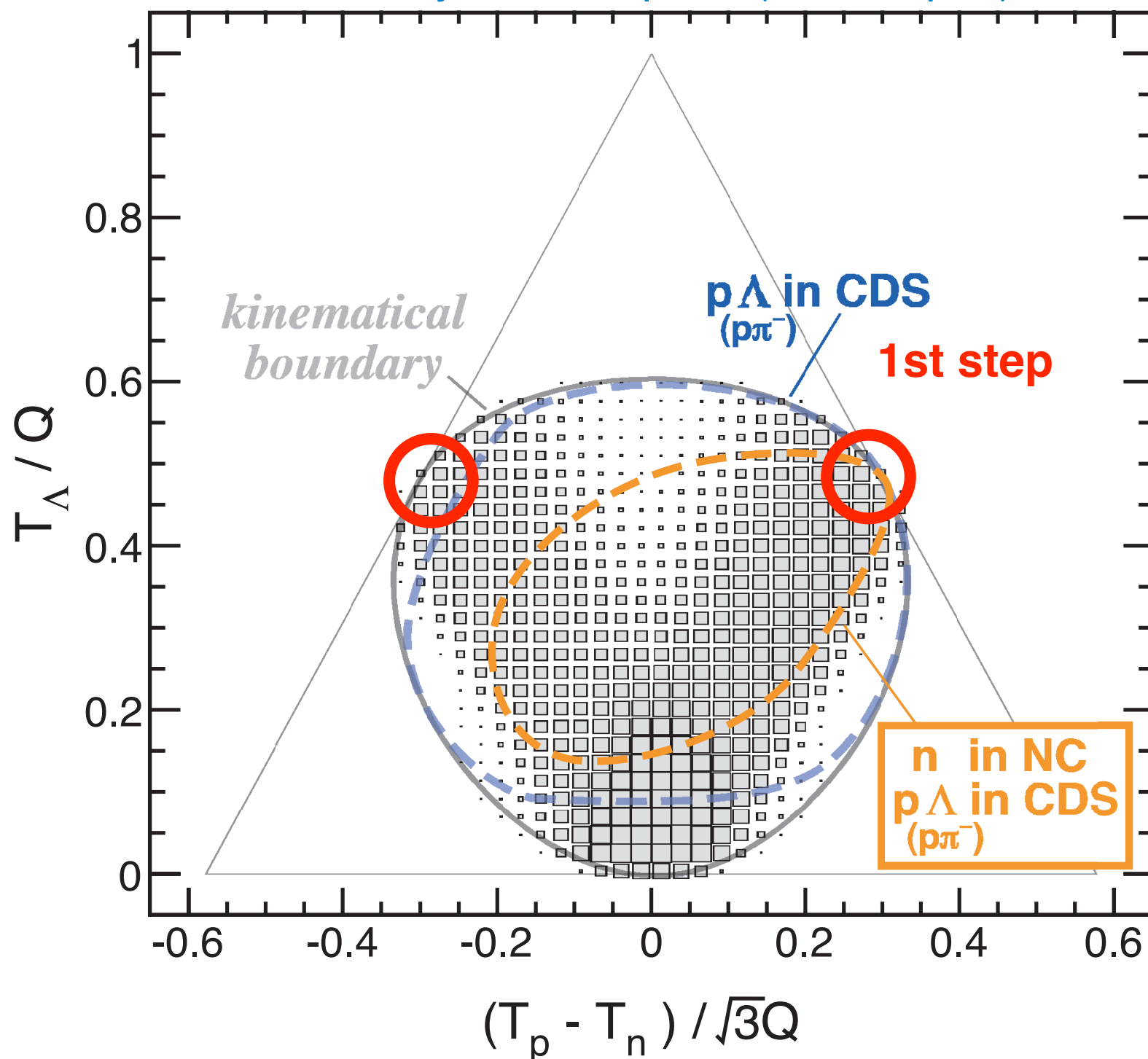
simulated by T. Hiraiwa



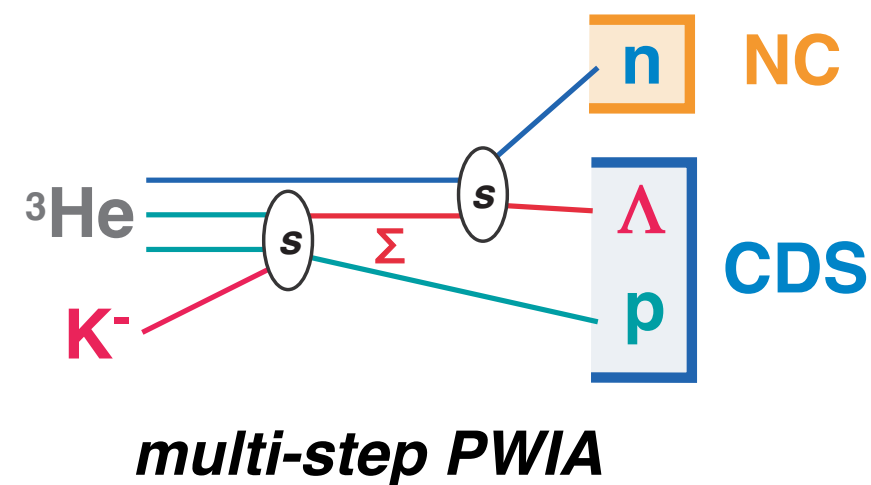
Background?

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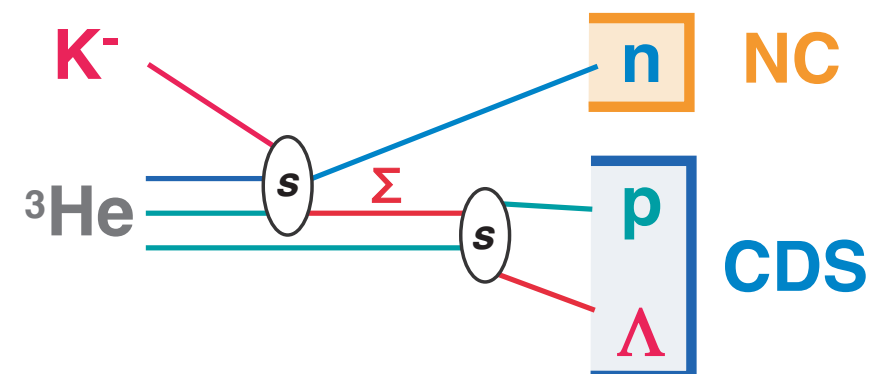
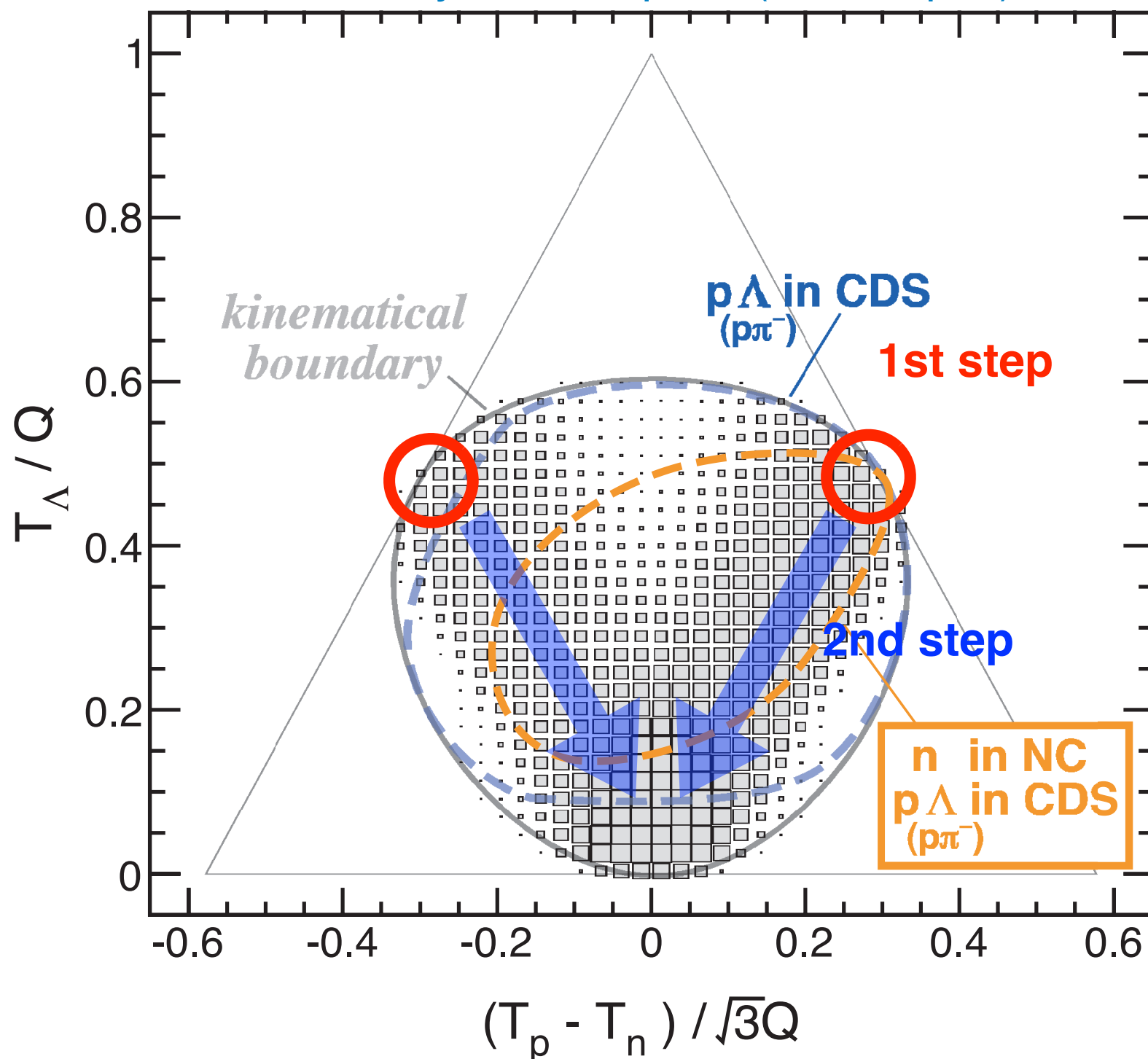
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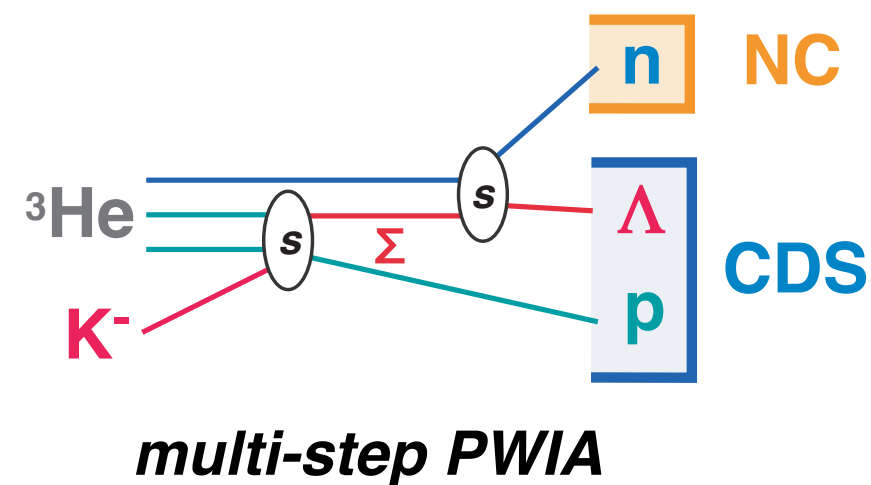
Background?

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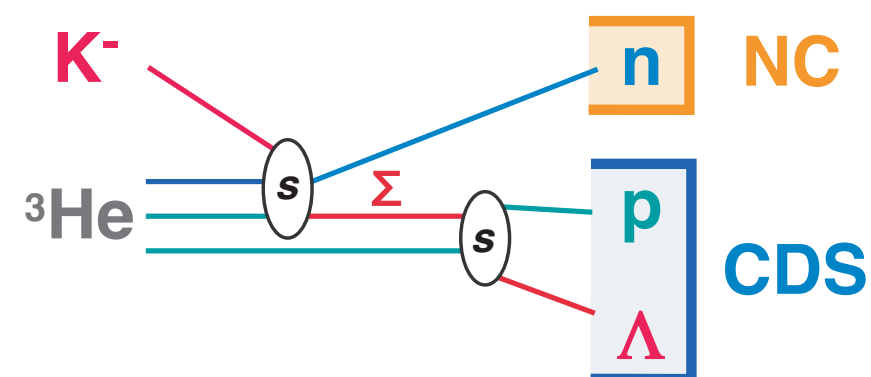
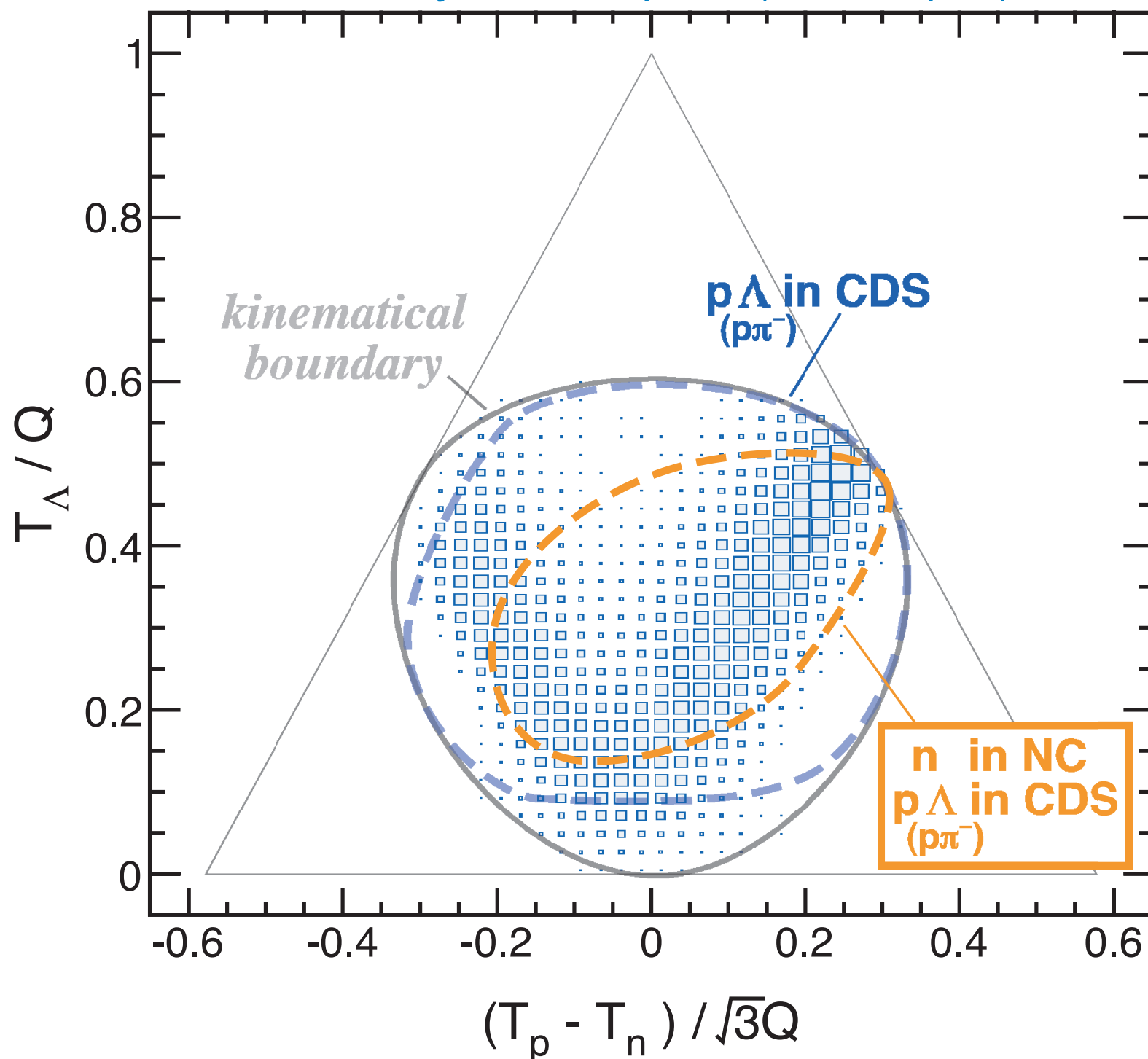
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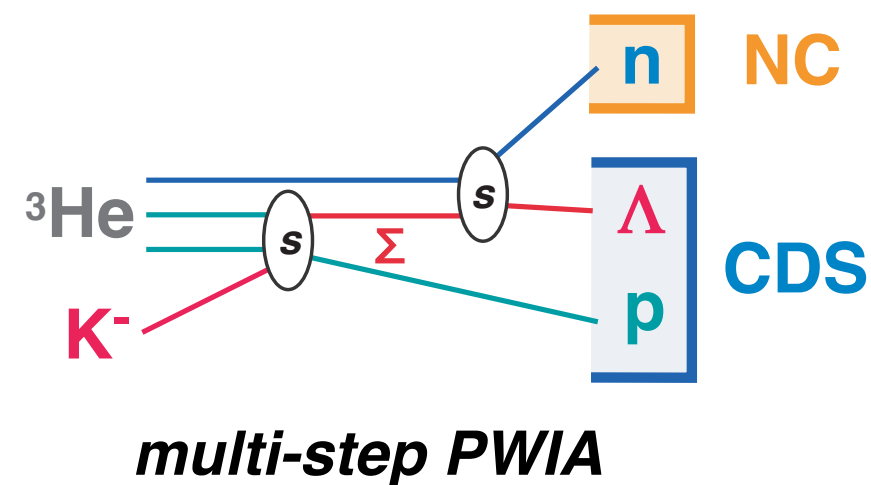
Background?

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or



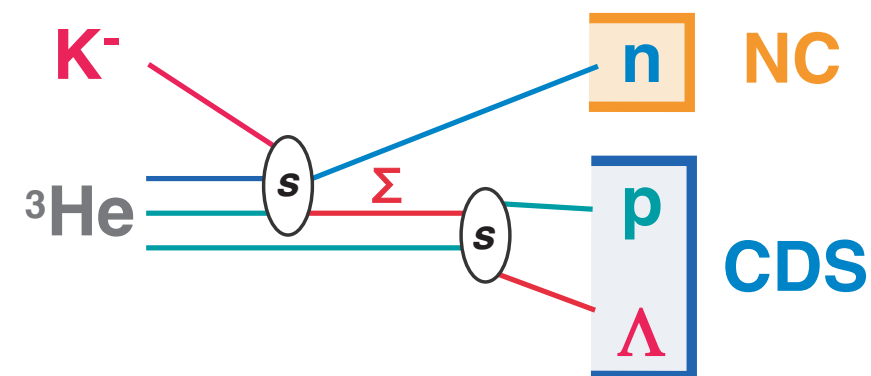
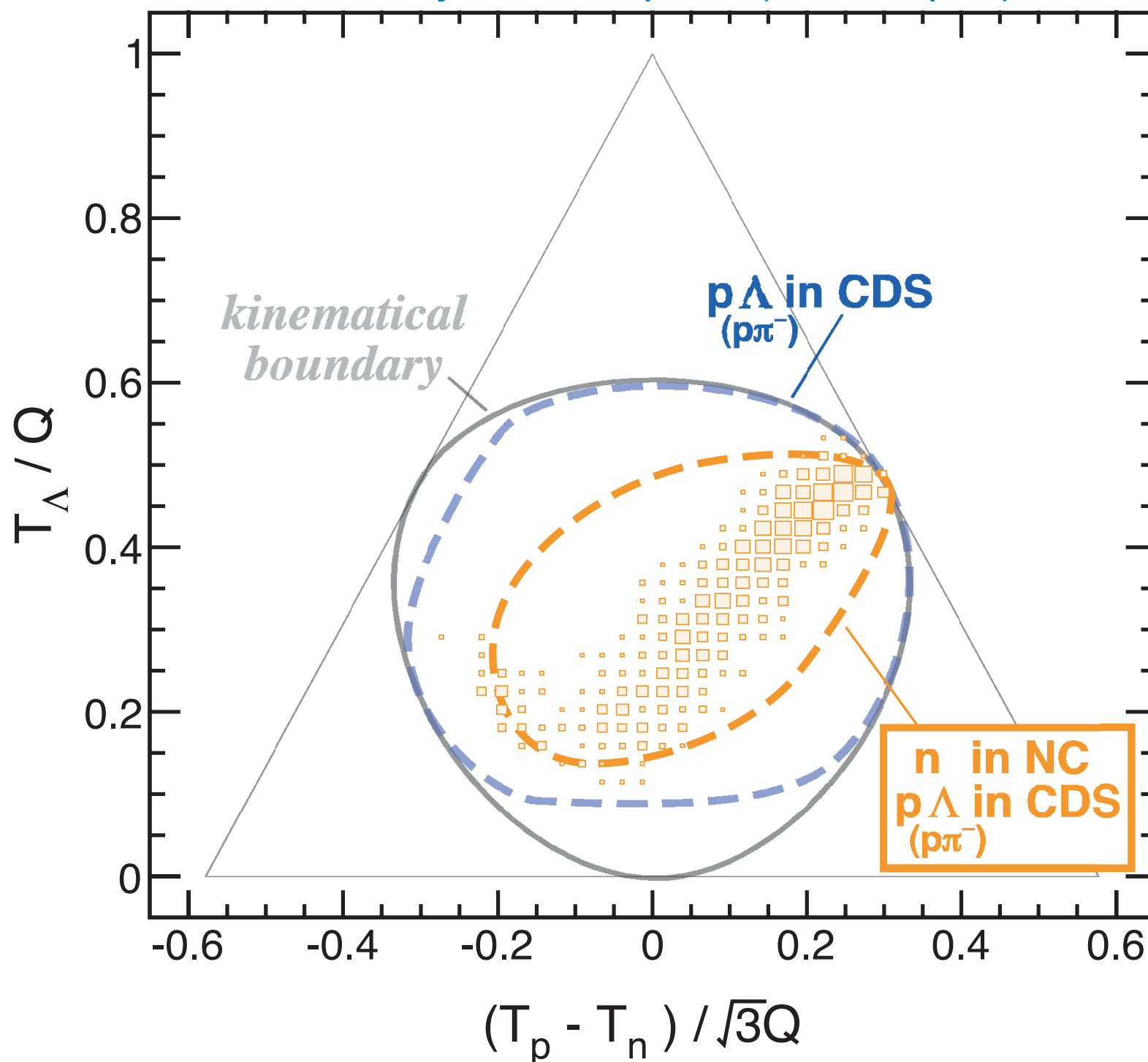
simulated by T. Hiraiwa



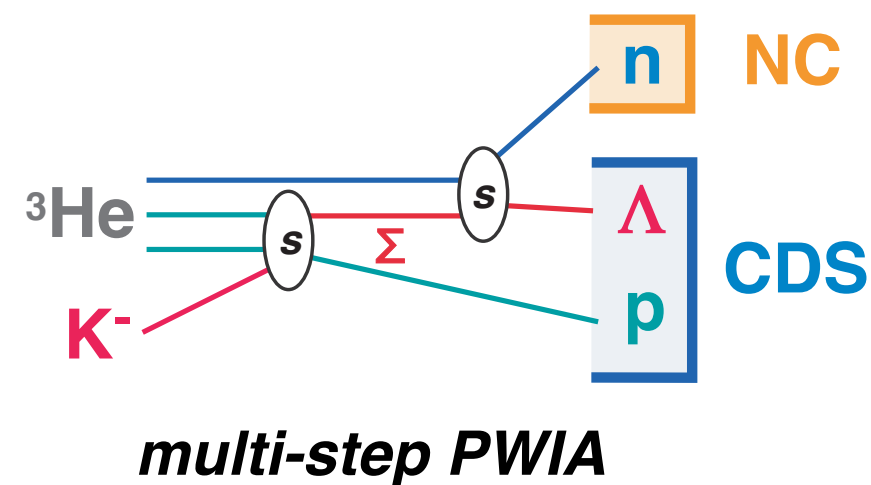
Background?

Two Nucleon Reaction and FSI (Σ - Λ conversion)

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or



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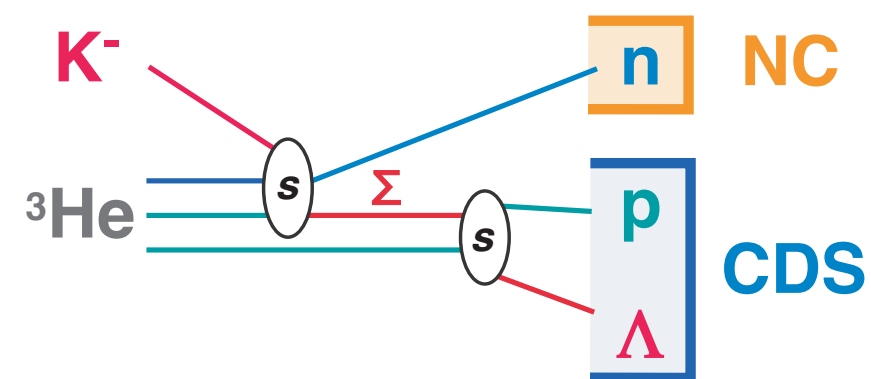
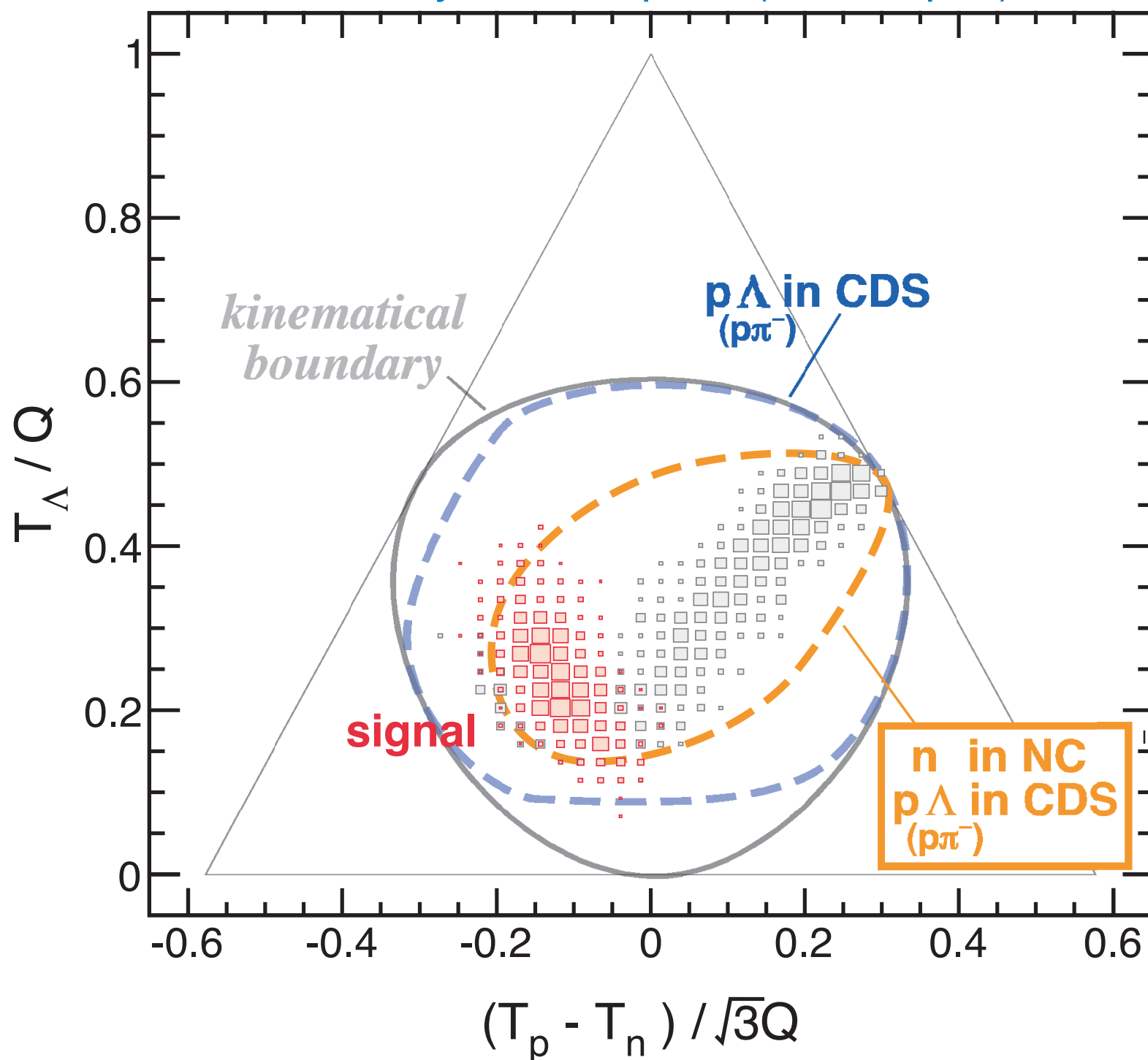


Background?

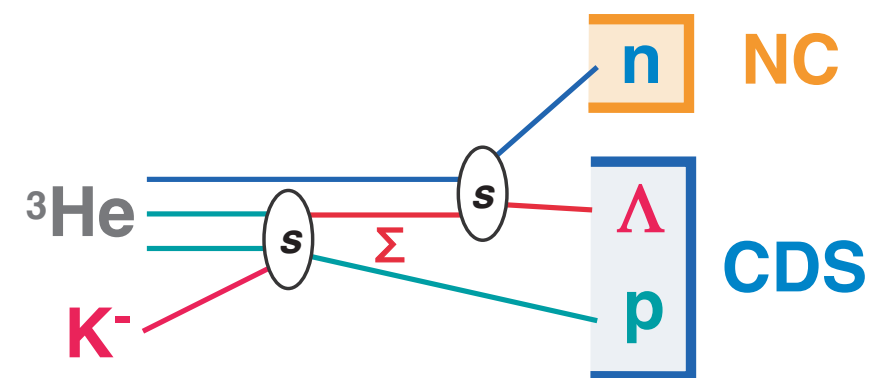
vs **signal** (*ratio arbitrary*)

Two Nucleon Reaction and FSI (Σ - Λ conversion)

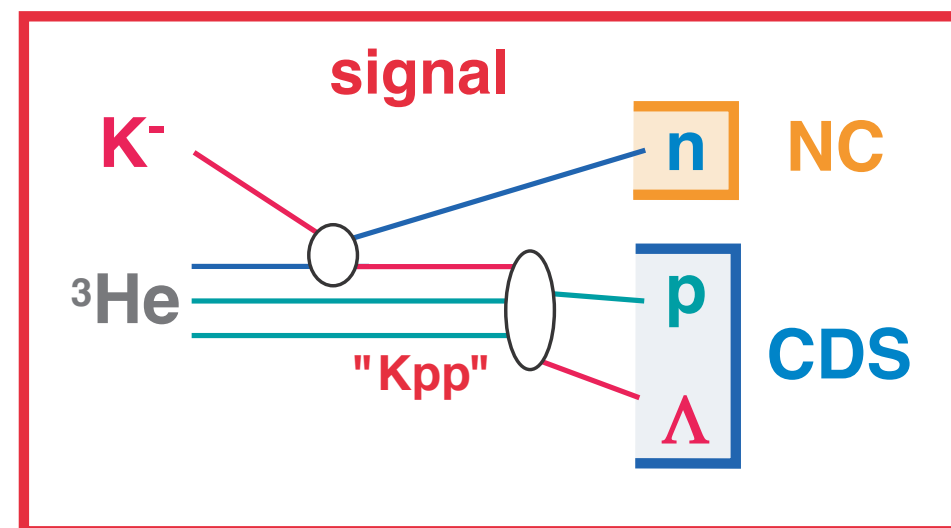
2NR and Σ - Λ conversion
on 3-body Phase Space (Dalitz's plot) at CM



or



multi-step PWIA



simulated by T. Hiraiwa



Estimated yield by **one proton missing**

- $\text{Yield} = N_{\text{kaon}} \times t \times d\sigma/d\Omega_{(\theta=0)} \times r \times R \times A \times e \times \varepsilon$

- N_{kaon} : kaon per spill $\rightarrow$ **300k/spill** (30 kW operation)

- t : target $\rightarrow 0.08 \text{ [g/cm}^3\text{]} / 3 \text{ [g/mol]} \times 6.02 \times 10^{23} \text{ [mol}^{-1}\text{]} \times 9.3 \text{ [cm]} \sim$ **$1.4 \times 10^{23} \text{ [cm}^{-2}\text{]}$**

- $d\sigma/d\Omega$ (@ $\theta = 0$) $\rightarrow$ **3 [mb/sr]**

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PR C 80,055208(2009)

- r : branching ratio ($\Lambda \rightarrow \pi^- p$) $\rightarrow$ **0.63**

- R : “Kpp” decay branch $\rightarrow$ **$\text{Br}(\Lambda p) + \text{Br}(\Sigma^0 p) \sim 1$**

- A : NC acceptance $\rightarrow$ **12 [msr]**

- e : NC efficiency $\rightarrow$ **0.3**

- ε : overall efficiency (trigger, detector, ana., etc) $\rightarrow$ **0.7**

- **2.1×10^4 signals on missing mass spectrum (by 1 week run)**
(**Λp** + **$\Sigma^0 p$** branch)