Strangeness Production in Heavy-Ion Collisions and Antiproton-Annihilation

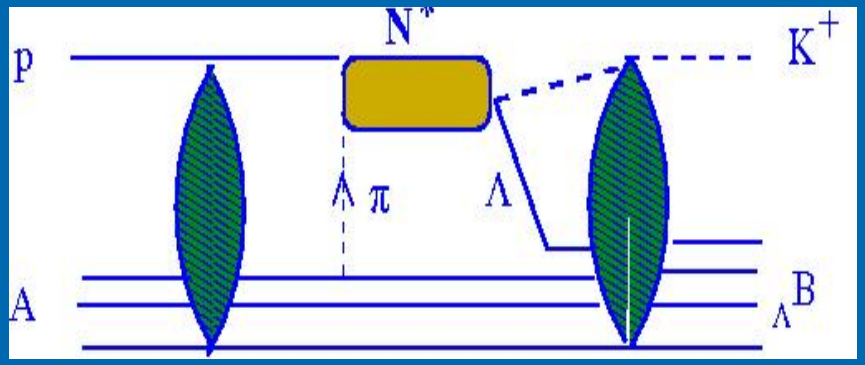
H. Lenske

Agenda:

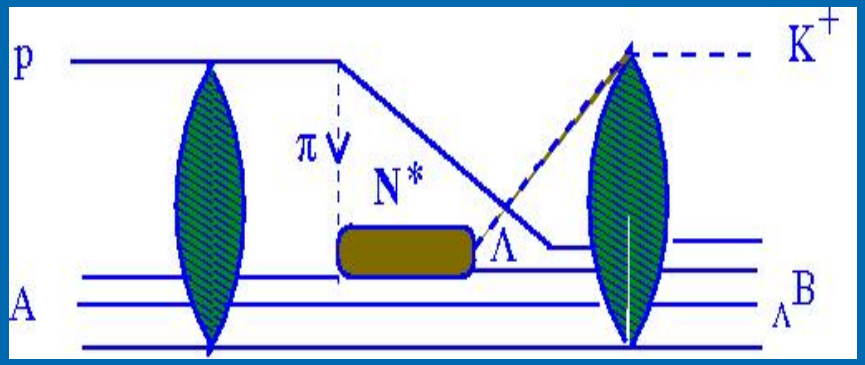
- Strangeness Production by Resonance Excitation
- S=-1 Strangeness Production in Heavy Ion Collisions
- S=-2,-3 Multi-Strangeness Production by Antiproton Annihilation on Nuclei

Strangeness Production by Resonance Excitation in Nuclear Matter

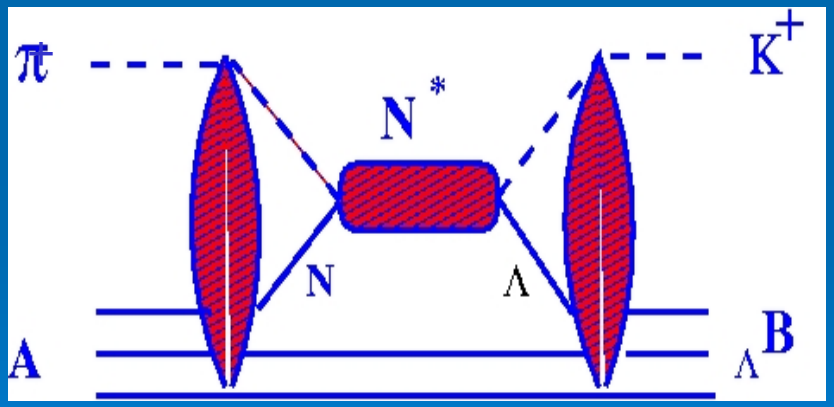
Strangeness Production at “GSI”-Energies : The Giessen Resonance Model



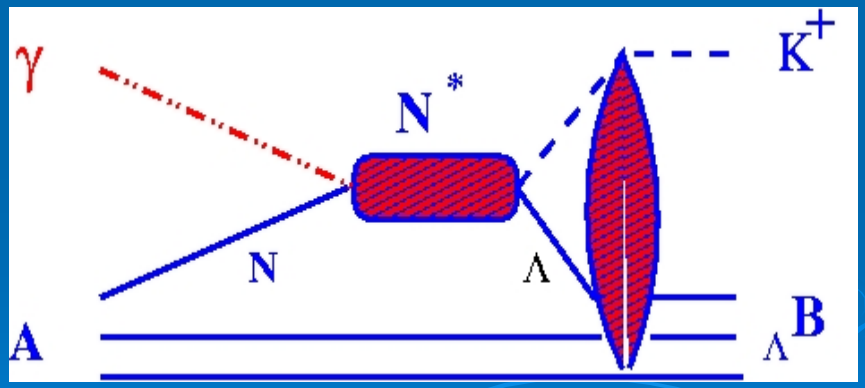
Target emission $A\,(p,K^+)_\Lambda B$



Projectile emission $A\,(p,K^+)_\Lambda B$



$A\,(\pi^+,K^+)_\Lambda B^*$



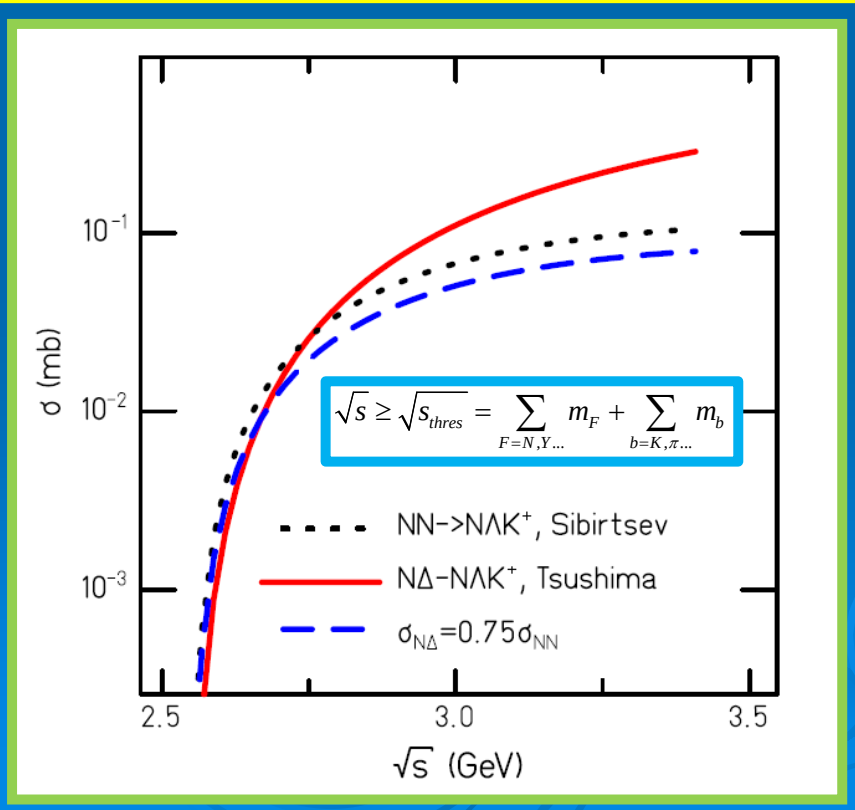
$A\,(\gamma,K^+)_\Lambda B'$

R. Shyam, H.L., PRC77 (2008) 052201; NPA839 (2010) 51; PRC81 (2010) 015204; PRD90 (2014) 1, 014017; PRD (2016) in print.

Strangeness Production in Baryonic Matter

$$e.g.\ \ N + N \rightarrow N^{*} + N \rightarrow Y + N + K$$

$NN \rightarrow N\Lambda K^{+}$	$NN \rightarrow N\Sigma K^{+}$	$NN \rightarrow \Delta\Lambda K^{+}$	$NN \rightarrow \Delta\Sigma K^{+}$
$N\Delta \rightarrow N\Lambda K^{+}$	$N\Delta \rightarrow N\Sigma K^{+}$	$N\Delta \rightarrow \Delta\Lambda K^{+}$	$N\Delta \rightarrow \Delta\Sigma K^{+}$
$\Delta\Delta \rightarrow N\Lambda K^{+}$	$\Delta\Delta \rightarrow N\Sigma K^{+}$	$\Delta\Delta \rightarrow \Delta\Lambda K^{+}$	$\Delta\Delta \rightarrow \Delta\Sigma K^{+}$
$\pi N \rightarrow \Lambda K^{+}$	$\pi N \rightarrow \Sigma K^{+}$	$\pi\Delta \rightarrow \Lambda K^{+}$	$\pi\Delta \rightarrow \Sigma K^{+}$
$NN \rightarrow NNK^{+}K^{-}$	$N\Delta \rightarrow NNK^{+}K^{-}$	$N\Delta \rightarrow N\Delta K^{+}K^{-}$	$\Delta\Delta \rightarrow NNK^{+}K^{-}$
$\Delta\Delta \rightarrow \Delta\Delta K^{+}K^{-}$	$\pi N \rightarrow NK^{+}K^{-}$	$\pi\Delta \rightarrow NK^{+}K^{-}$	

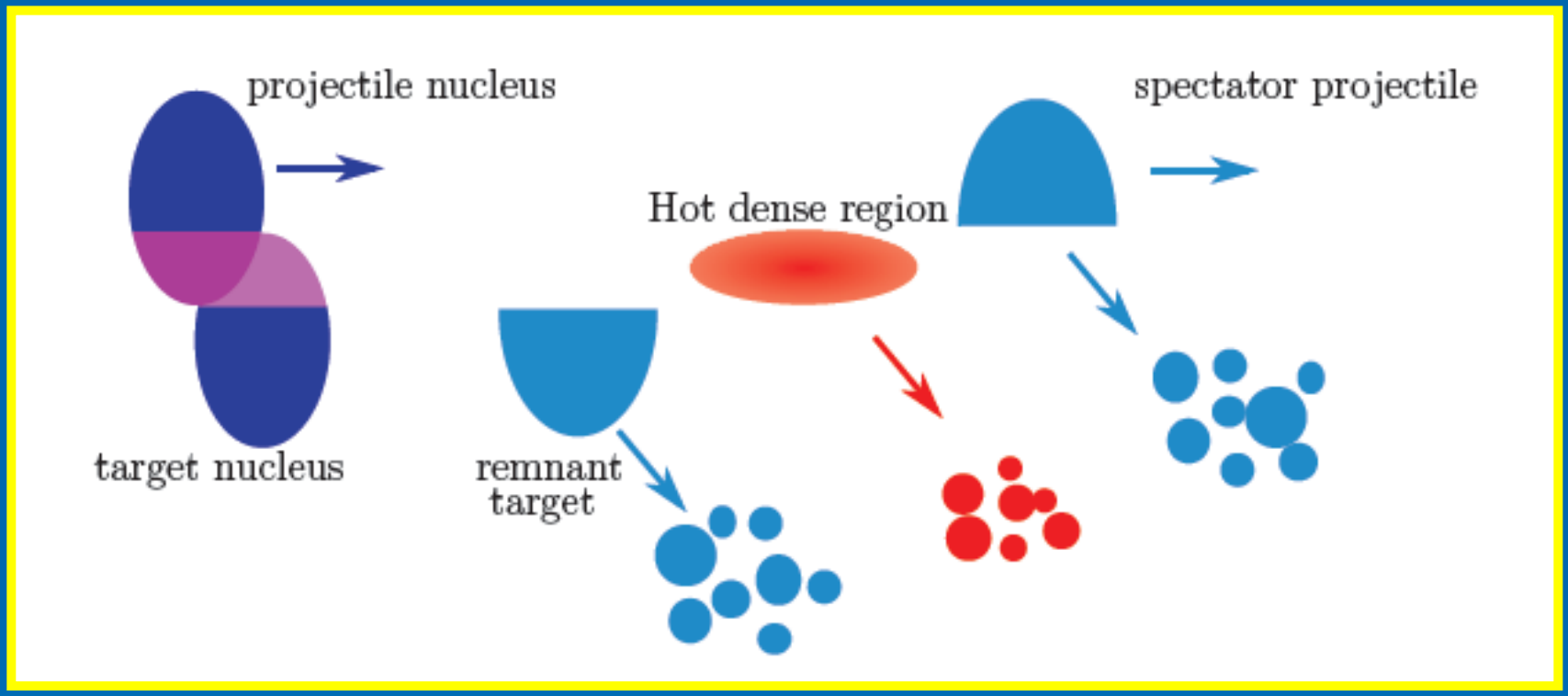


…see also:

Christoph Hartnack *et al.*
Physics Reports 510 (2012) 119-

Fragmentation Reactions

Scenario of a fragmentation reaction (T_{lab}>2AGeV)



GiBUU Transport Theory & SMM Grand Canonical Fragment Production

Gaitanos, Lenske, Phys. Lett. B 675, 297 (2009); Phys. Lett. B 663, 197 (2008)

GiBUU: Phys. Rept. 512 (2012) 1, O. Buss, Th. Gaitanos, et al.

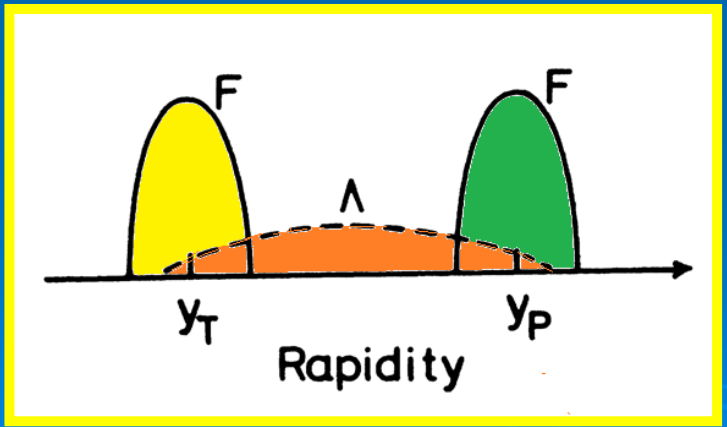
Formation of a Hypernucleus by capture of a Λ by a pre-formed fragment F:

$$\frac{\gamma}{\sigma_r}\frac{d^3\sigma^{(\Lambda F)}}{dk_c^2} = \left[\frac{m_\Lambda + m_F}{m_\Lambda m_F}\right]^3 S_{\Lambda F} \left[\frac{\gamma}{\sigma_r}\frac{d^3\sigma^{(\Lambda)}}{dk_c^3}\right]\left[\frac{\gamma}{\sigma_r}\frac{d^3\sigma^{(F)}}{dk_c^3}\right]$$

Structure

GiBUU

SMM

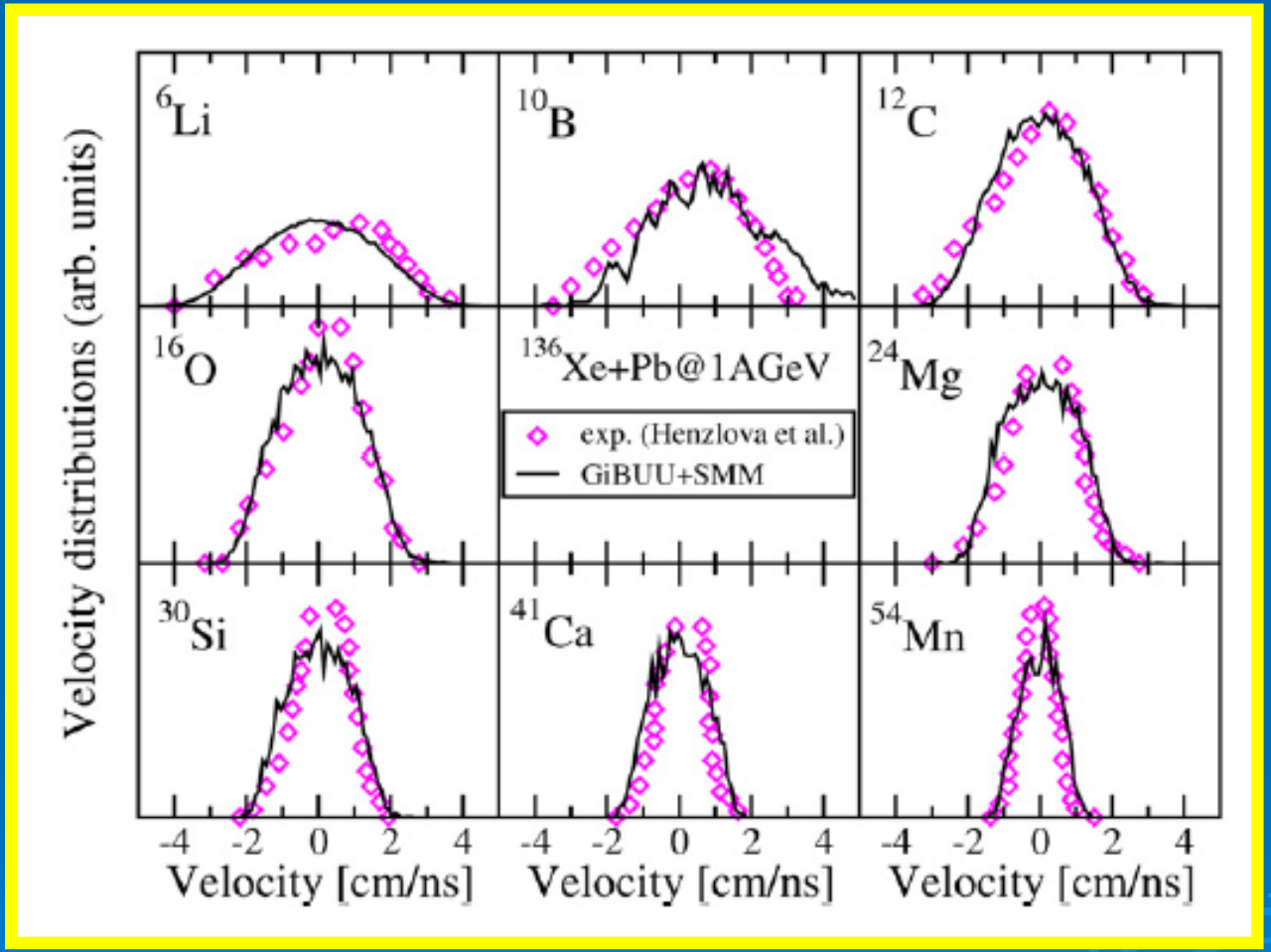


Λ Production X-section

Fragment Production X-section

M. Wakai, H. Bando, M. Sano, Phys. Rev. C 38 (1988) 748.

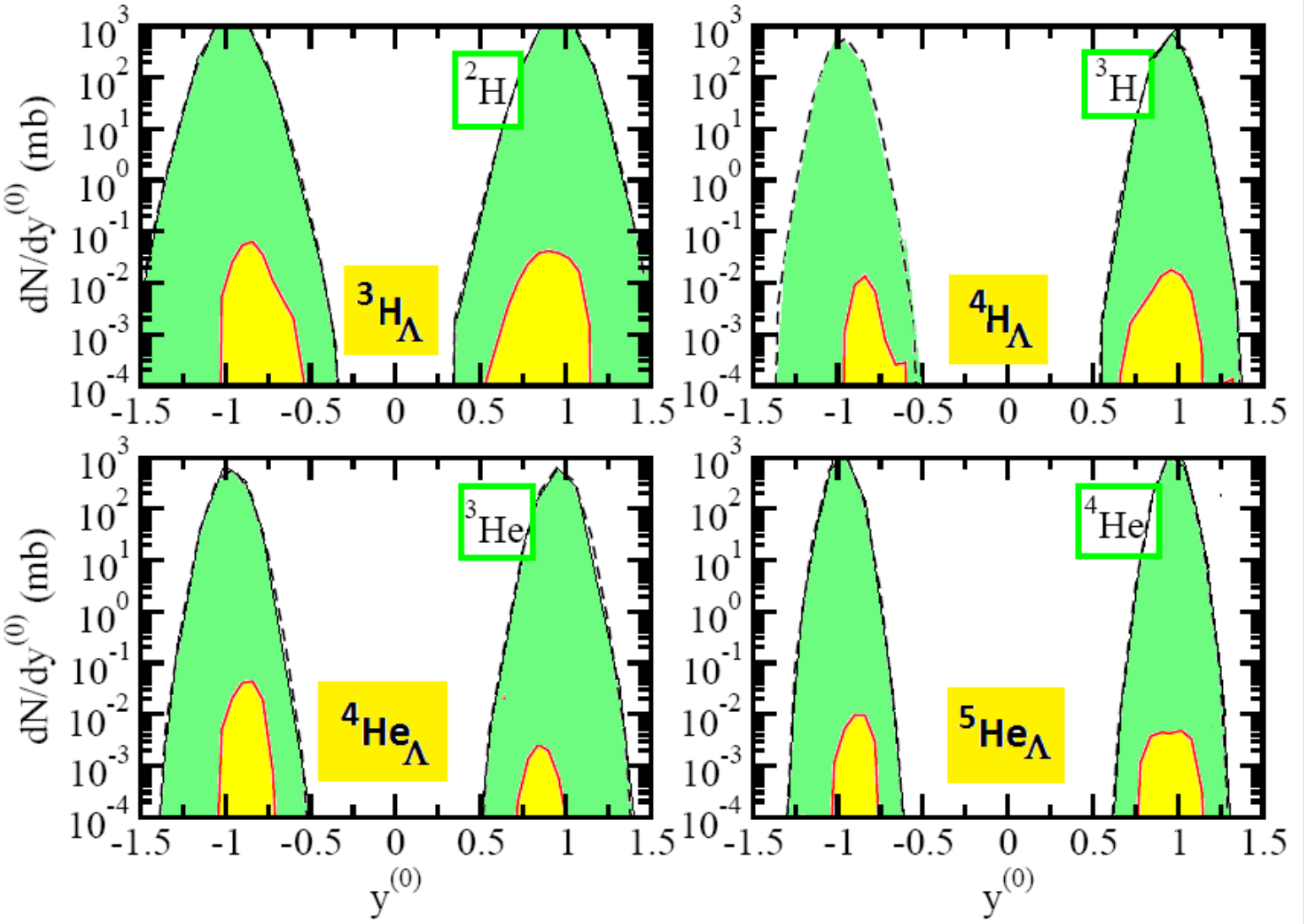
Production of Light Nuclei from ^{136}Xe+Pb by GiBUU+SMM (FOPI data)



Longitudinal velocity distributions in the projectile frame

Th. Gaitanos et al.: PL B663, 197 (2008) & PL B675 (2009) 297

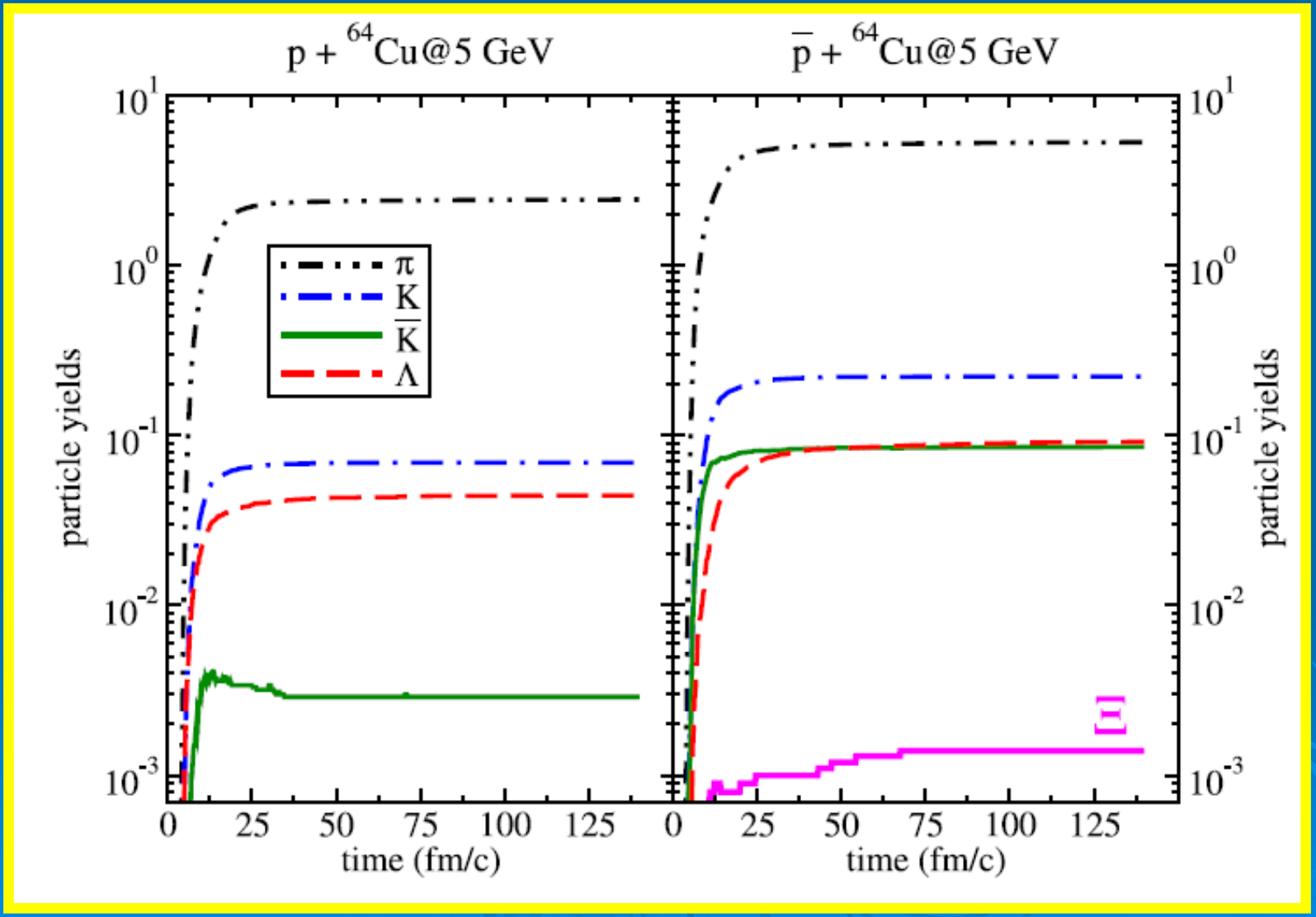
Production of Hypernuclei in $^{12}C+^{12}C$@2AGeV: HypHI@(S)FRS



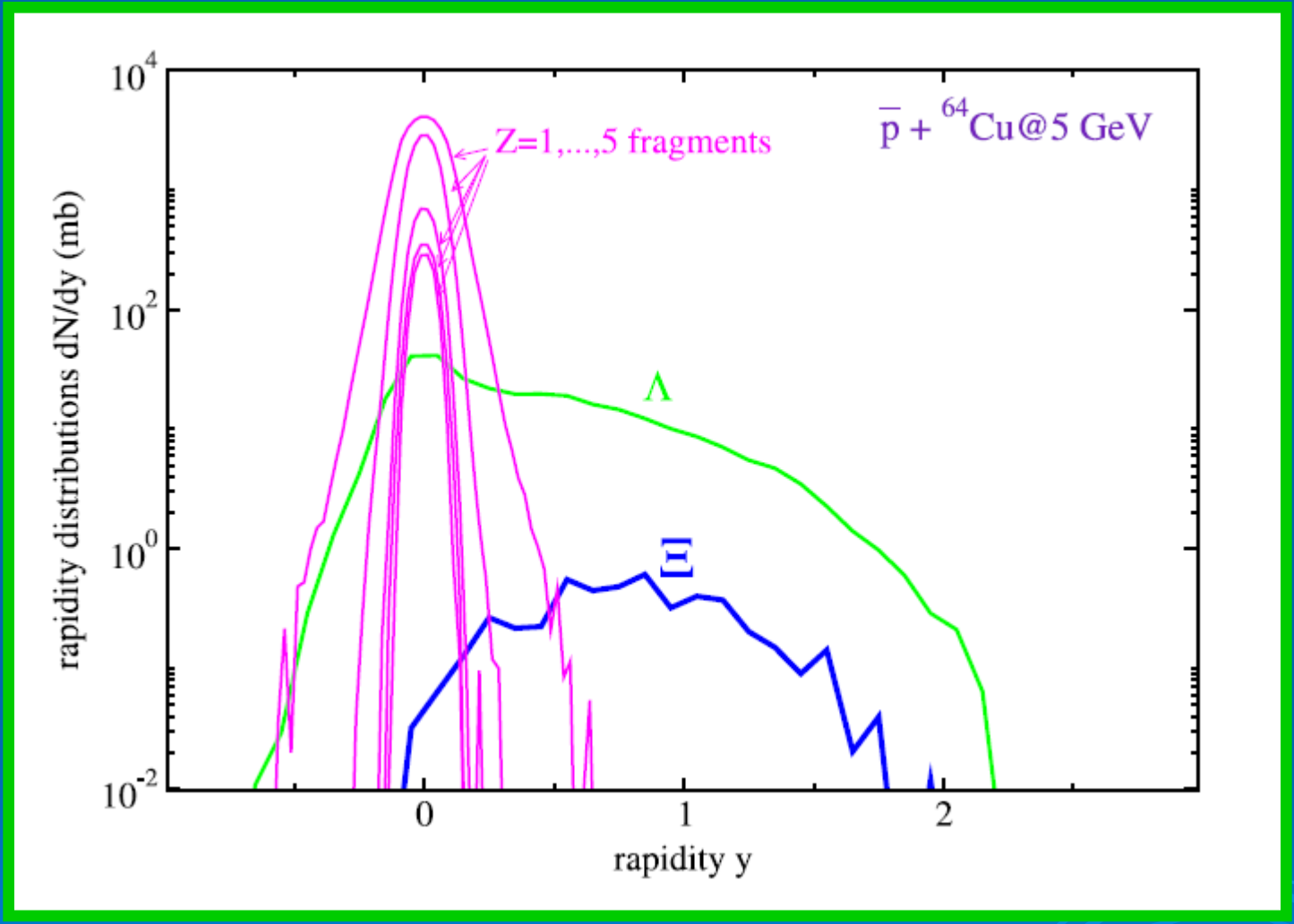
Th. Gaitanos, HL et al., Phys. Lett. B 675, 297 (2009), NPA 914 (2013) 405

S=-2 Hypernuclear Formation by Antiproton-Annihilation

Hadro-Production in Proton and Antiproton Collisions on Nuclei as a Function of Reaction Time

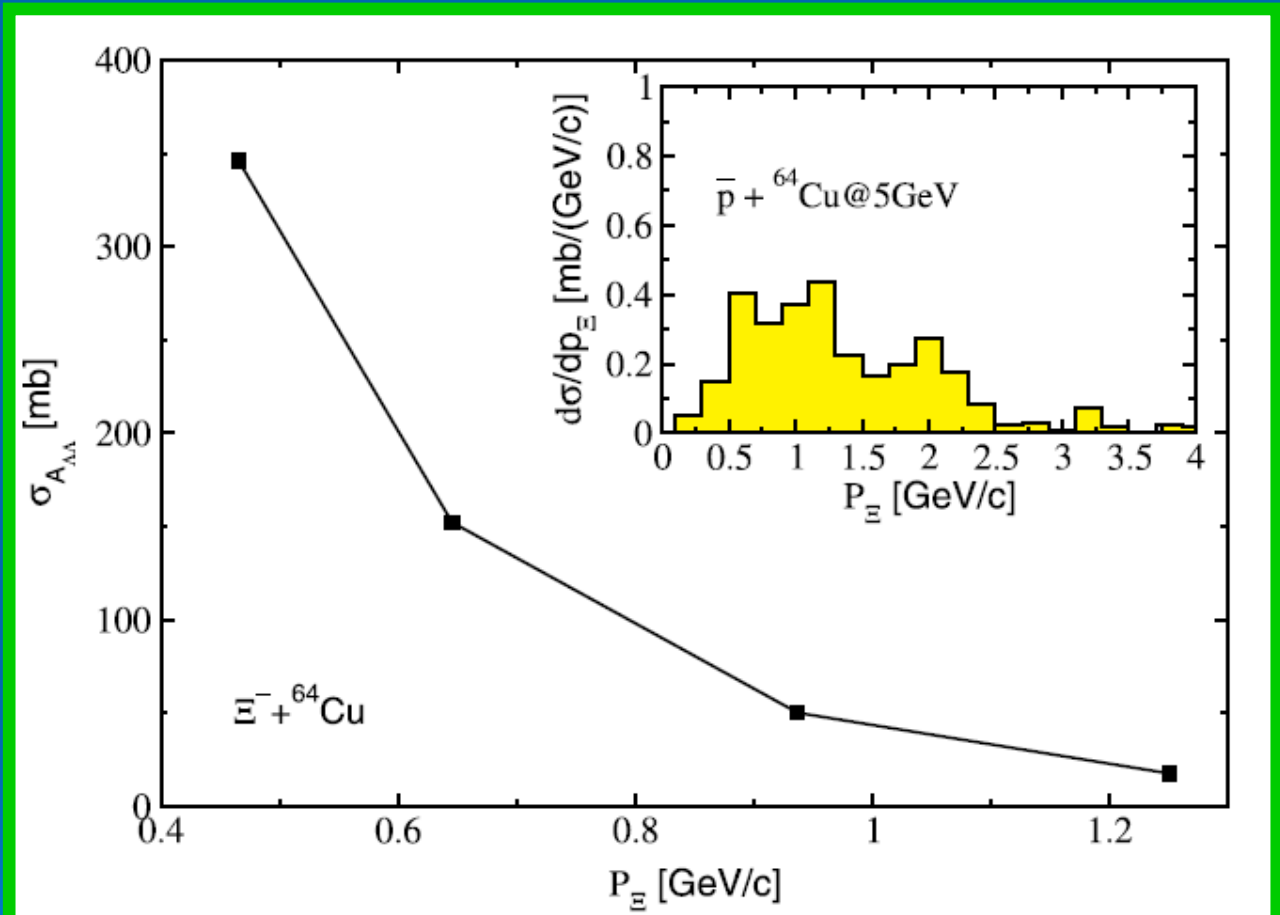


Rapidity Distribution of Fragments



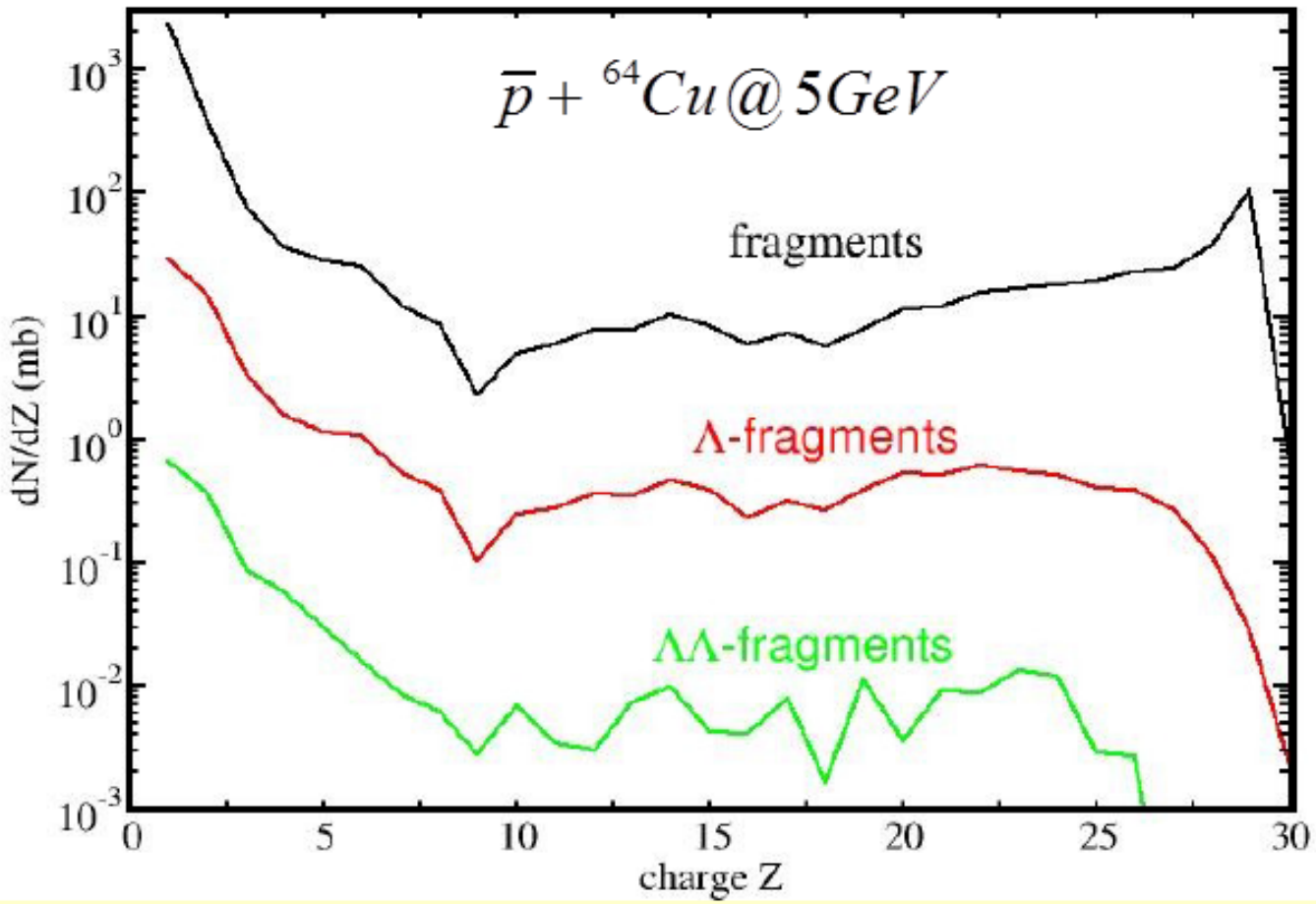
GiBUU + SMM calculations for the rapidity distributions of fragments with charge $Z = 1, \ldots, 5$ and hyperons with strangeness $S = -1$ (Λ) and $S = -2$ (Ξ), as indicated, for inclusive $\bar{p}$ + Cu@5 GeV reactions.

Hypernuclei@PANDA
ΛΛ Nucleus Formation by Ξ secondary beams

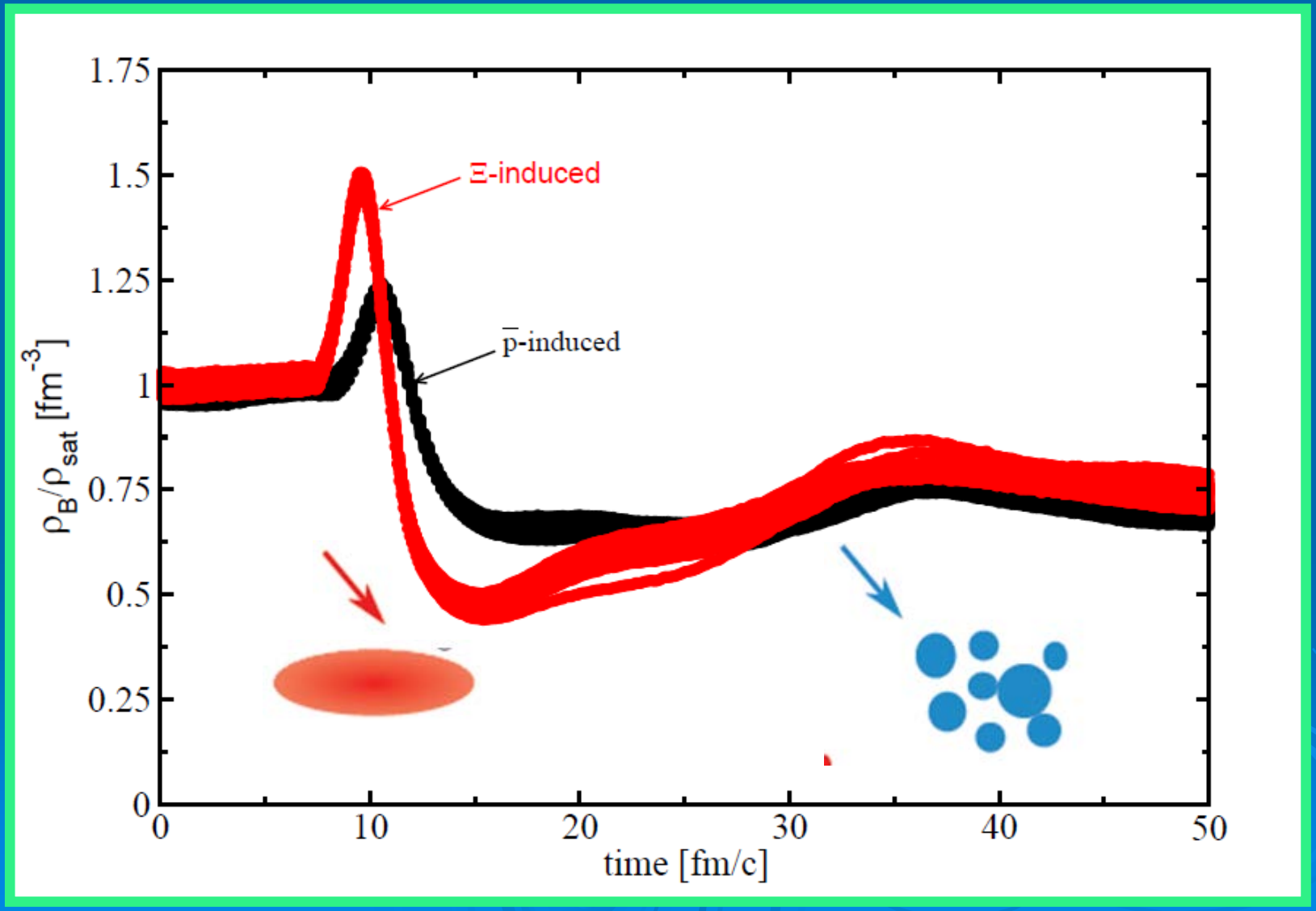


The insert panel shows the Ξ-production cross section from $\bar{p}$-collisions on the first target, as indicated.

Hypernuclei@PANDA
S=-1 and S=-2 Hypernuclear Yields in Antiproton Annihilation on a Nucleus

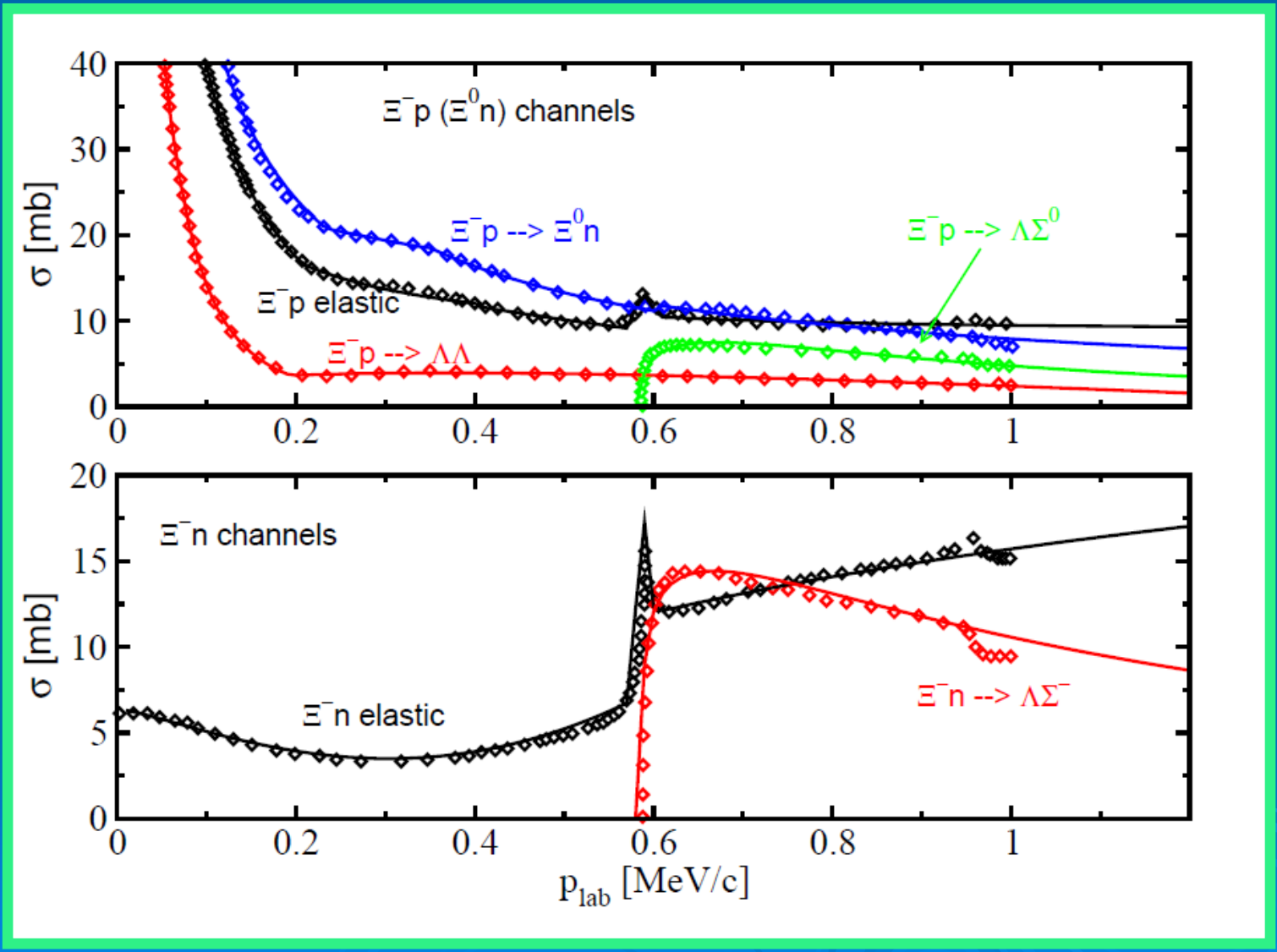


Density Evolution in Antiproton- and Cascade-Nucleus Collisions



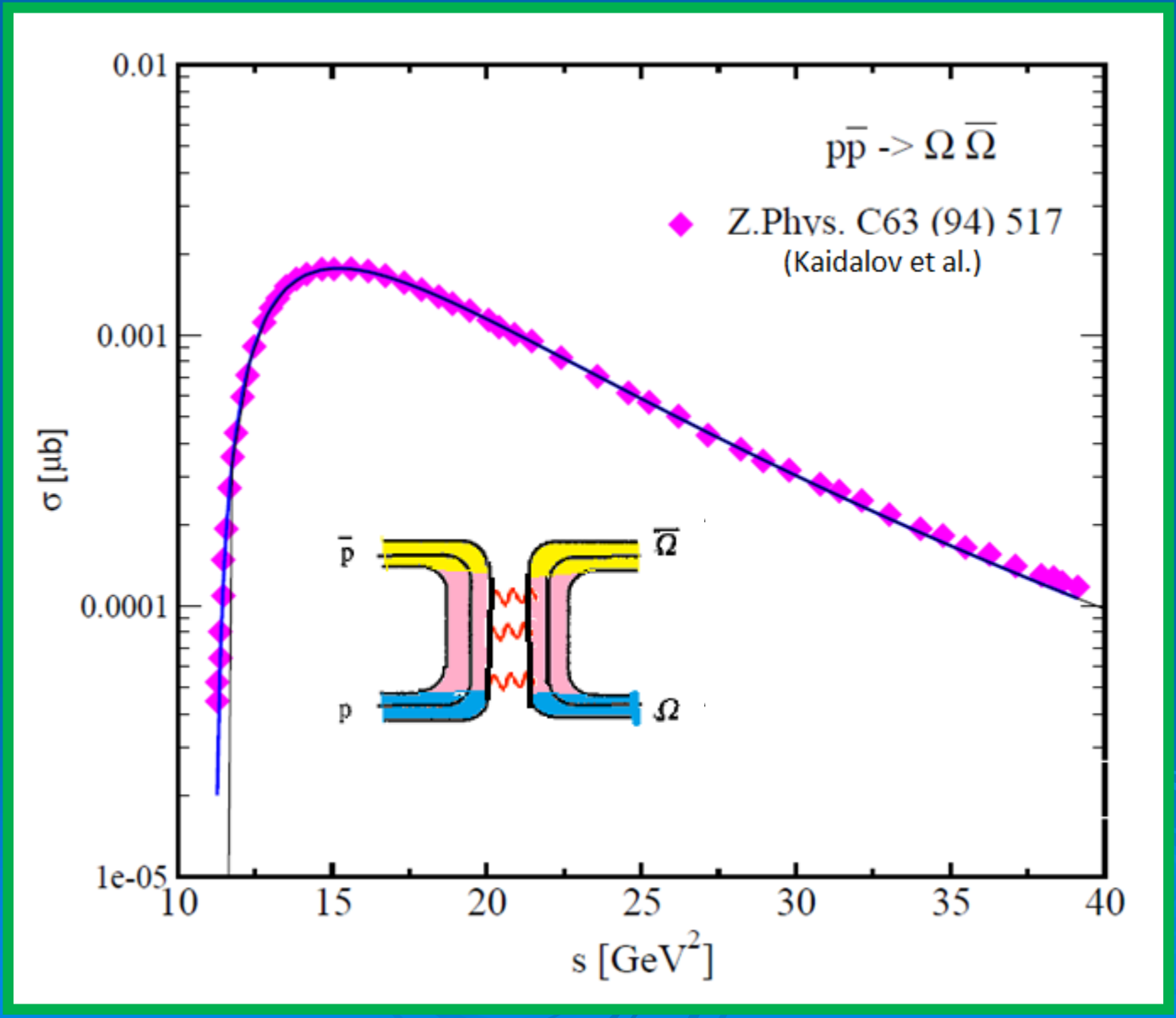
S=-3 Multi-Strangeness Production

Elementary S=-2 Interaction Channels in Free Space



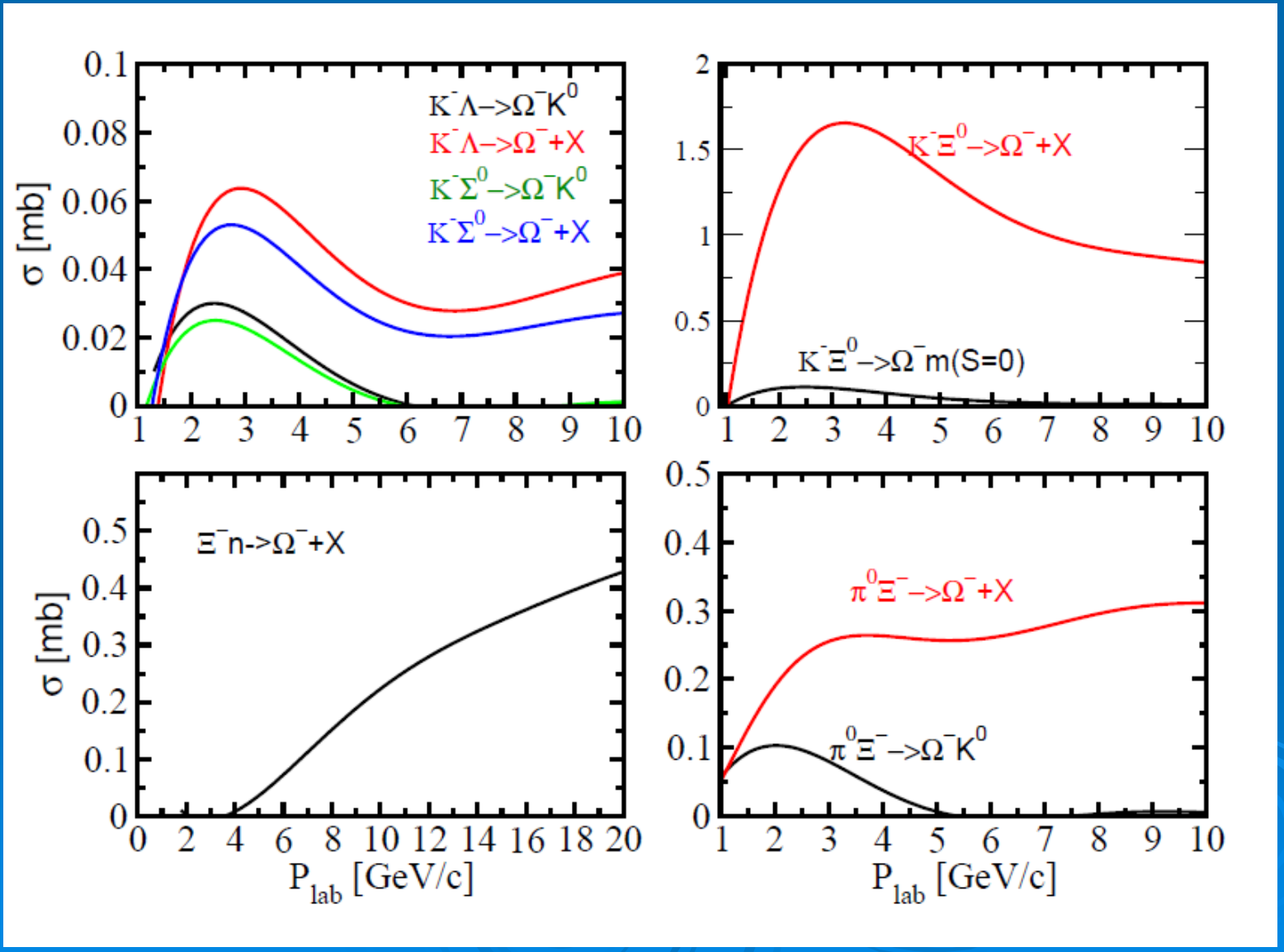
Th. Gaitanos, H.L. Phys. Lett. B 737 (2014) 256

Elementary Ω-Production by Antiproton-Proton Annihilation

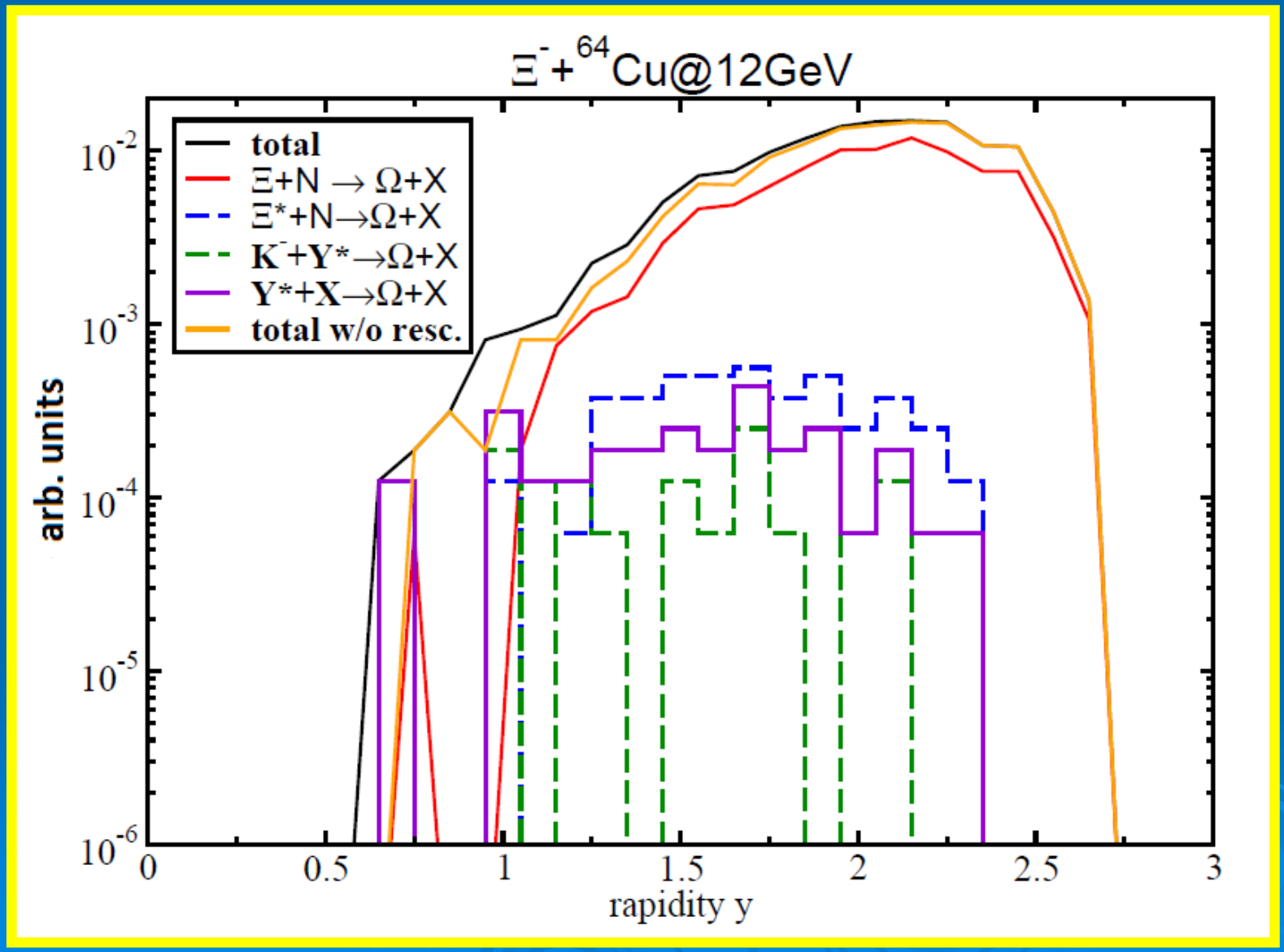


Secondary and *Ternary* Routes to Ω^- - Production

Dominant: $K^- / K^{-*} + Y/Y^* (S=-1) \rightarrow \Omega^- + K^+$



Ω^--Production by Secondary Ξ-Beams



Summary and Outlook

- **Strangeness production through baryon resonances**
- **Heavy Ion collisions and hypernuclear fragmentation**
- **Multi-Strangeness production in antiproton annihilation**
- **Dominance of hadronic strangeness accumulation scenarios**
- **SU(3) anti-octet physics: anti-baryons in nuclear matter**
- **Charmed mesons and hyperons (→ PRD (2015), PRD (2016))**

…together with:

Madhumita Dhar, Theo Gaitanos, Alexei Larionov, Radhey Shyam

Supported by BMBF, DFG, GSI, and HIC for FAIR