Strangeness production in the NA61/SHINE experiment at the CERN SPS energy range

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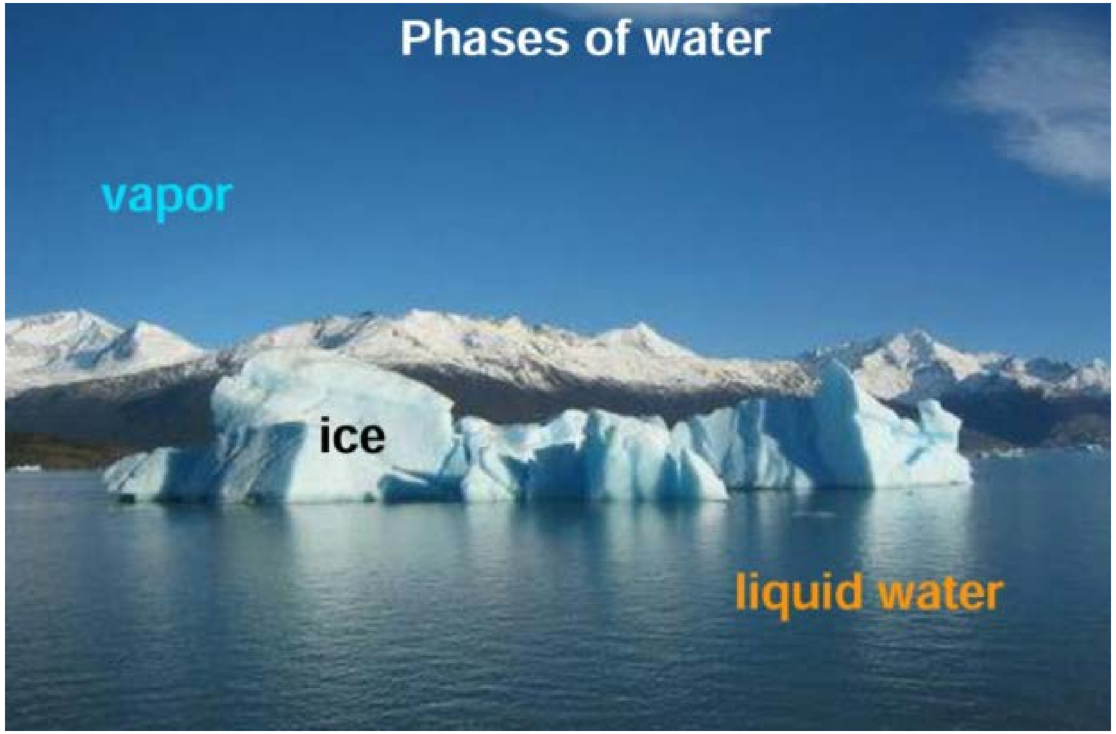
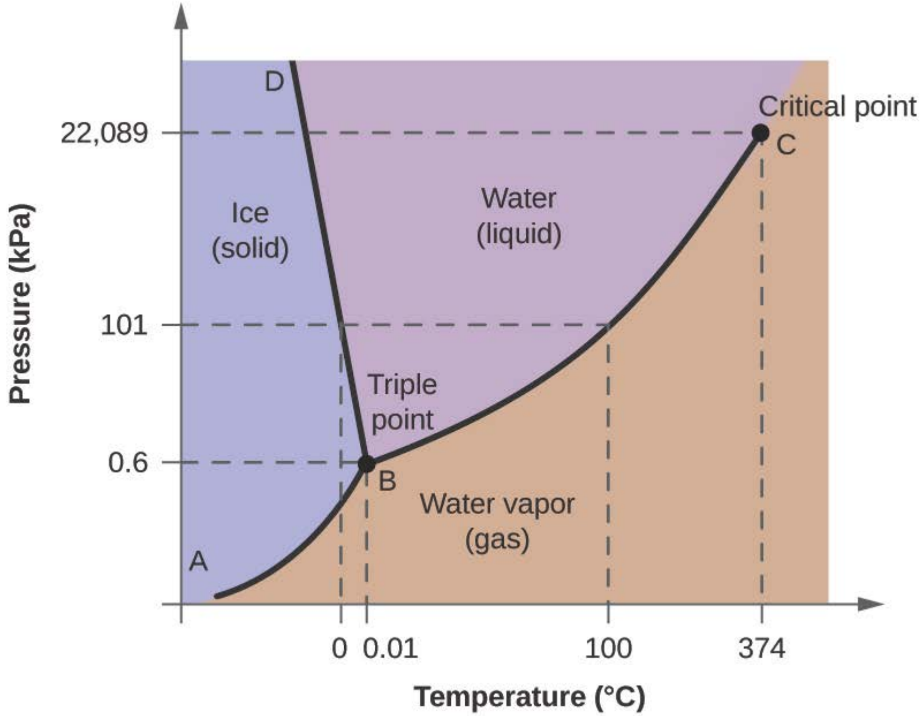
Well-known example – phase diagram of water

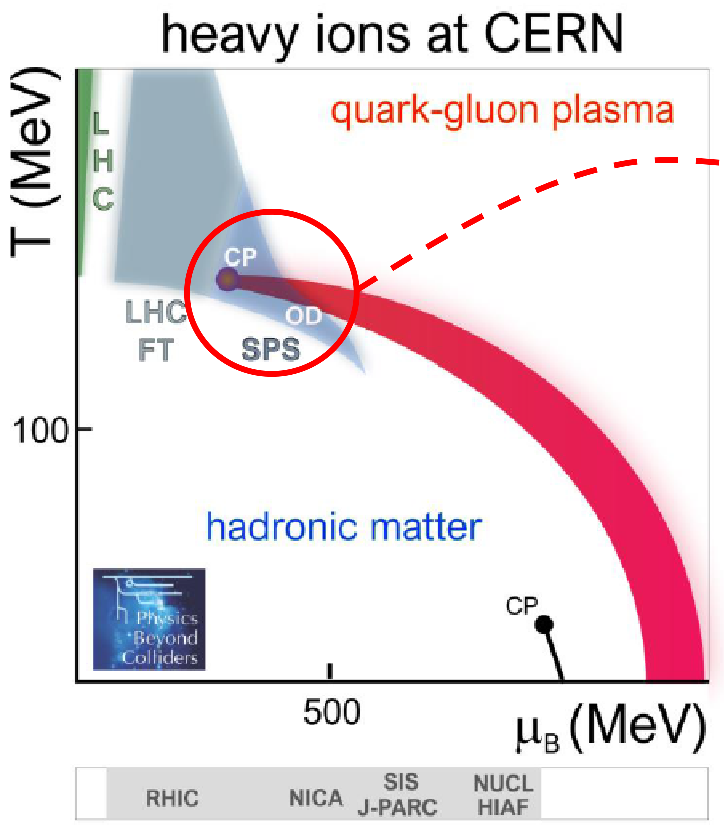
Phase diagram is a plot, which contains information about conditions at which thermodynamically distinct phases occur and coexist at equilibrium.

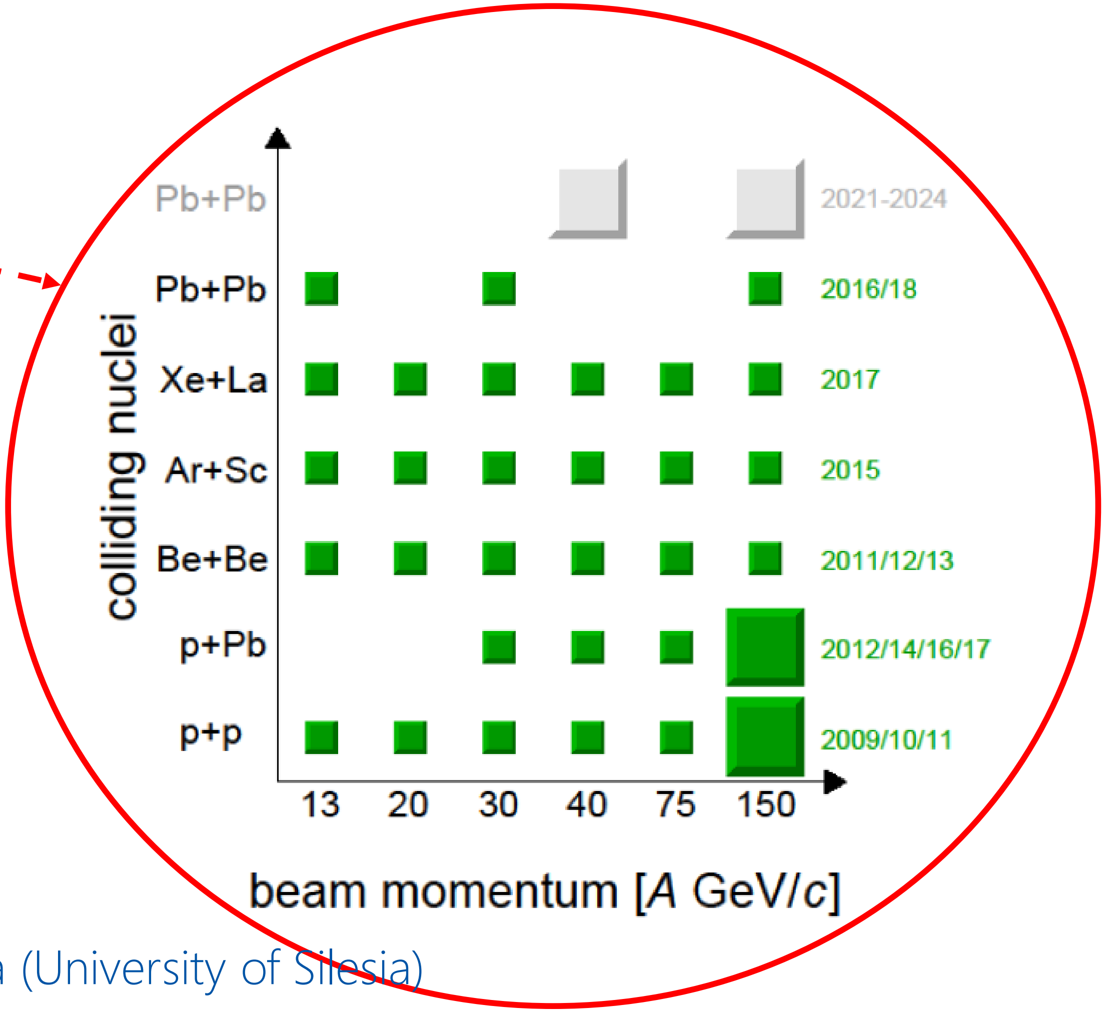




NA61/SHINE two-dimensional scan

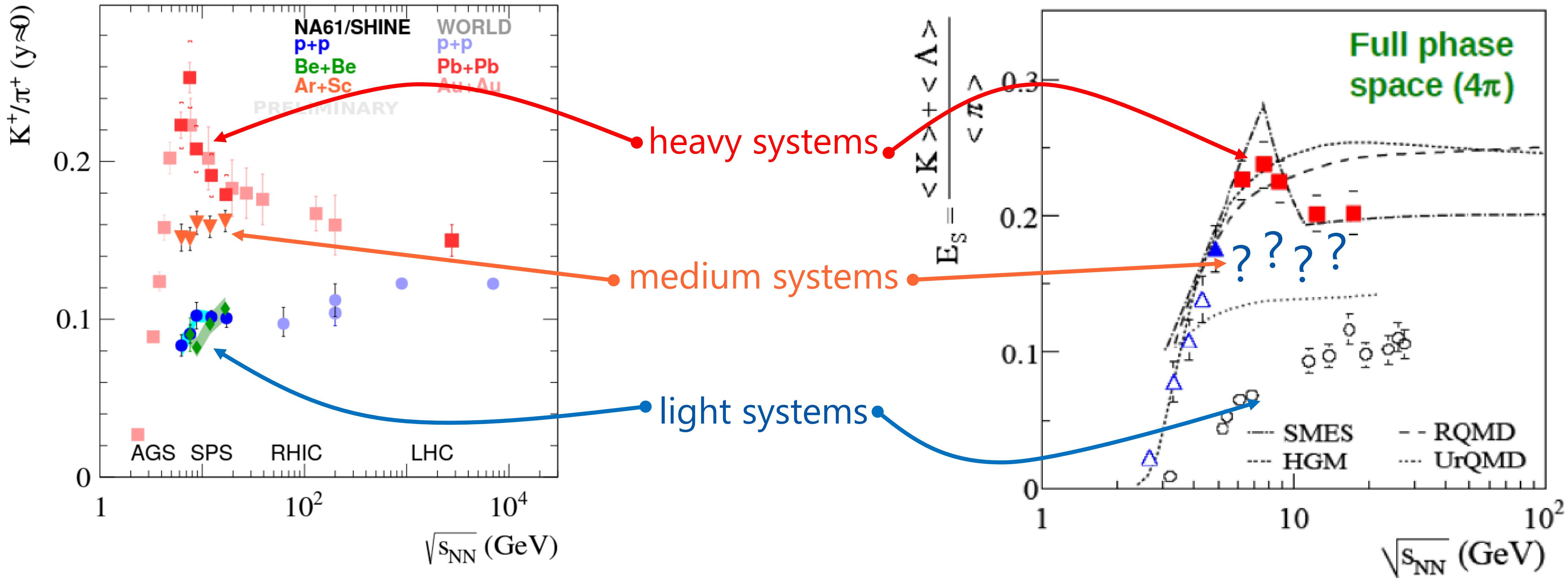
NA61/SHINE performed the 2D scan in **collision energy and system size** to study the phase diagram of strongly interacting matter.





Onset of deconfinement: horn

Rapid changes in strangeness production E_s („horn") were observed in **Pb+Pb** collisions at SPS energies, which was predicted by SMES as a signature of onset of deconfinement. On the contrary, plateau-like structure is visible in **p+p** and **Be+Be**.

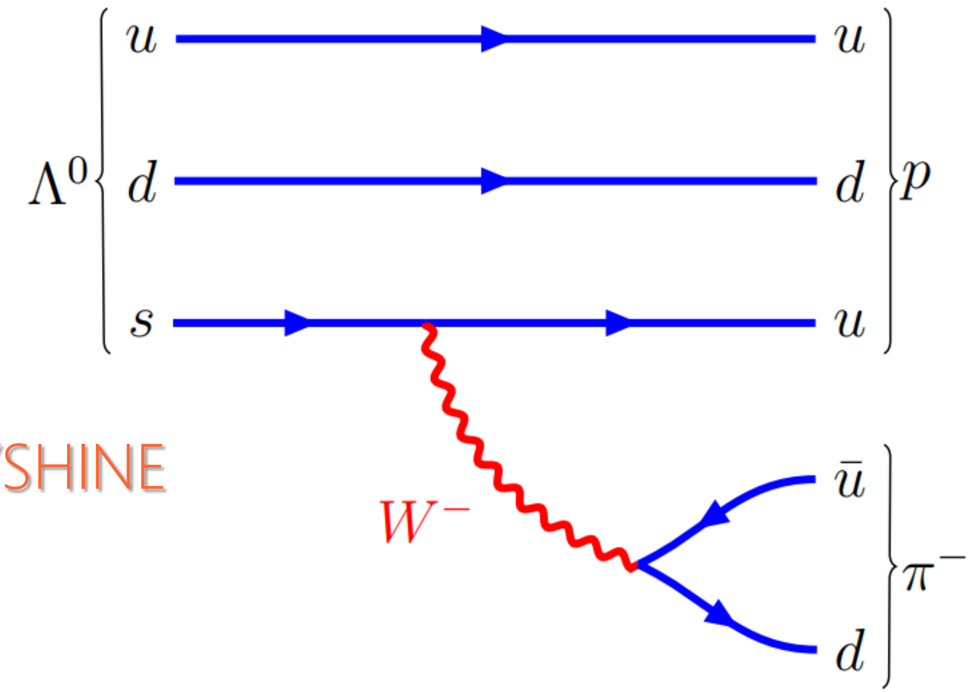


General research plan

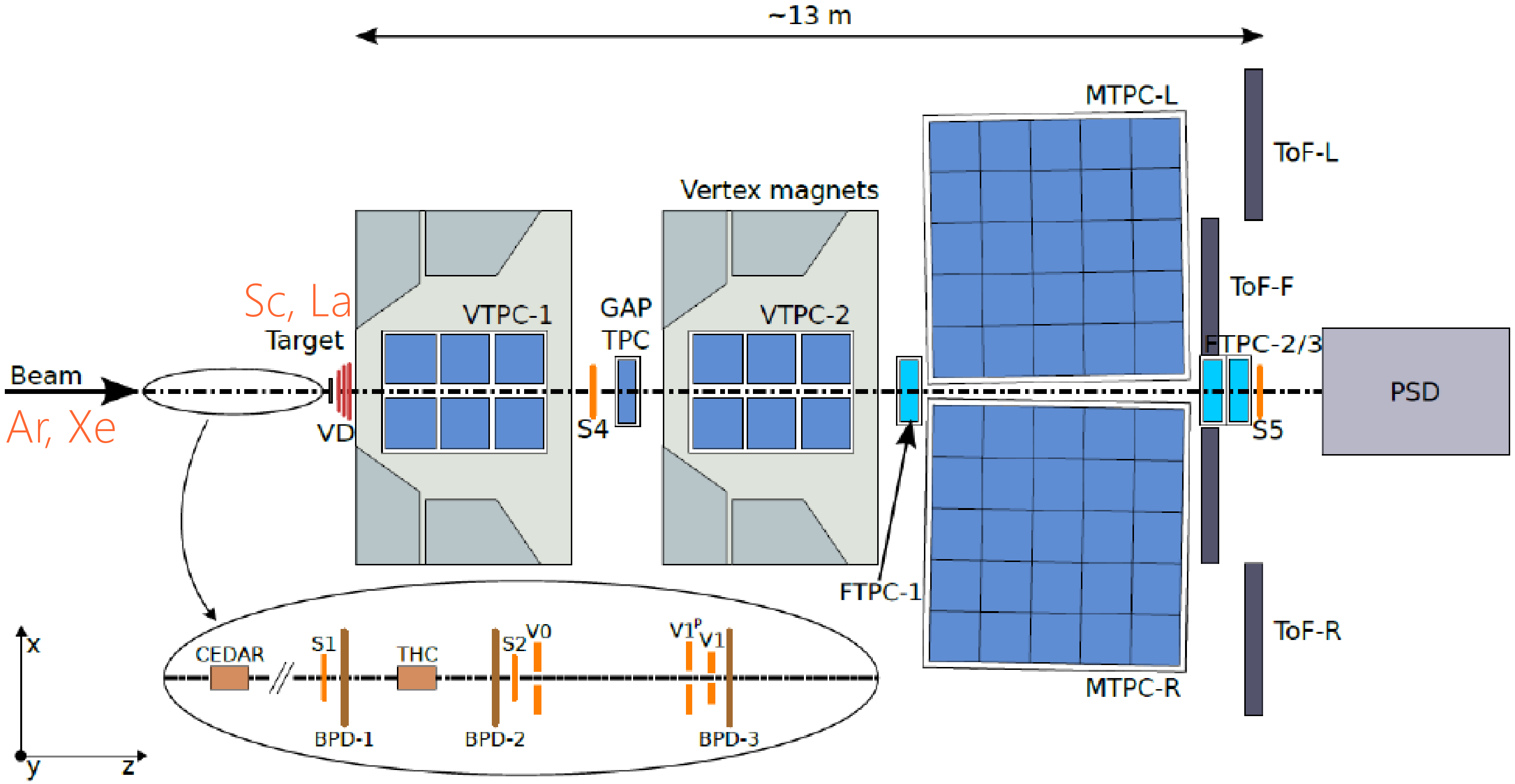
The main goal of the proposed project is to measure Λ^0 (1115) and $\bar{\Lambda}^0$ produced in Ar+Sc and Xe+La interactions at SPS energy range.

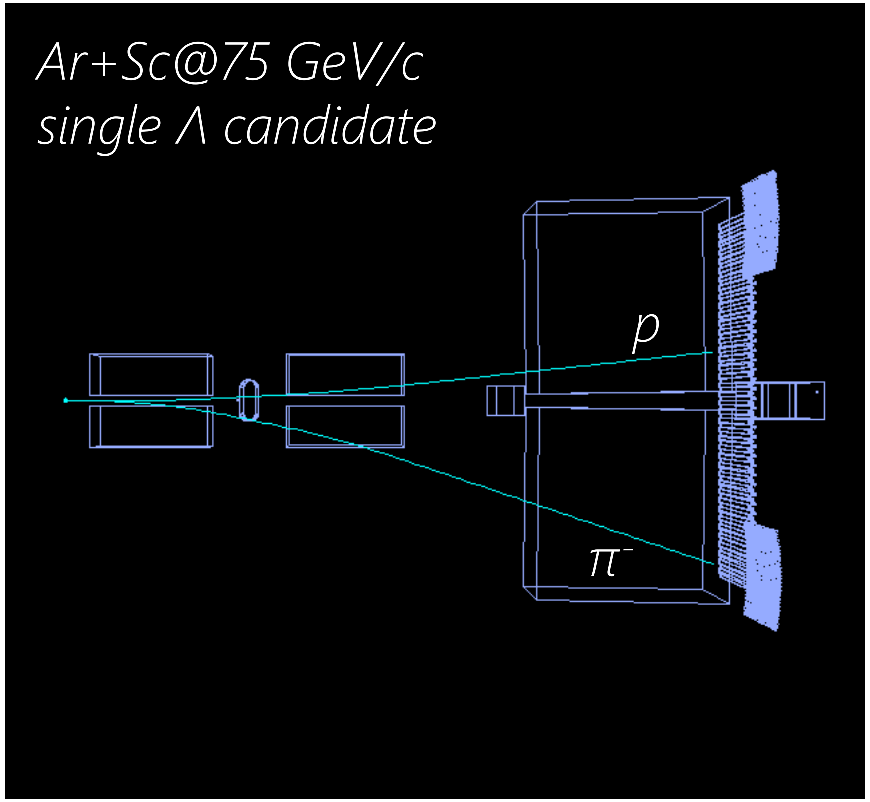
Properties of Lambda baryon [PDG]:

- rest mass $m = 1115.683 \pm 0.006\ MeV$
- mean lifetime $\tau = (2.632 \pm 0.020) \times 10^{-10}\ s$
  - $c\tau = 7.89\ cm$
- decay modes
  - $p\pi^-$ $\Gamma_i/\Gamma = (63.9 \pm 0.5)$ % - used in NA61/SHINE
  - $n\pi^0$ $\Gamma_i/\Gamma = (35.8 \pm 0.5)$ %



Schematic layout of the NA61/SHINE experiment





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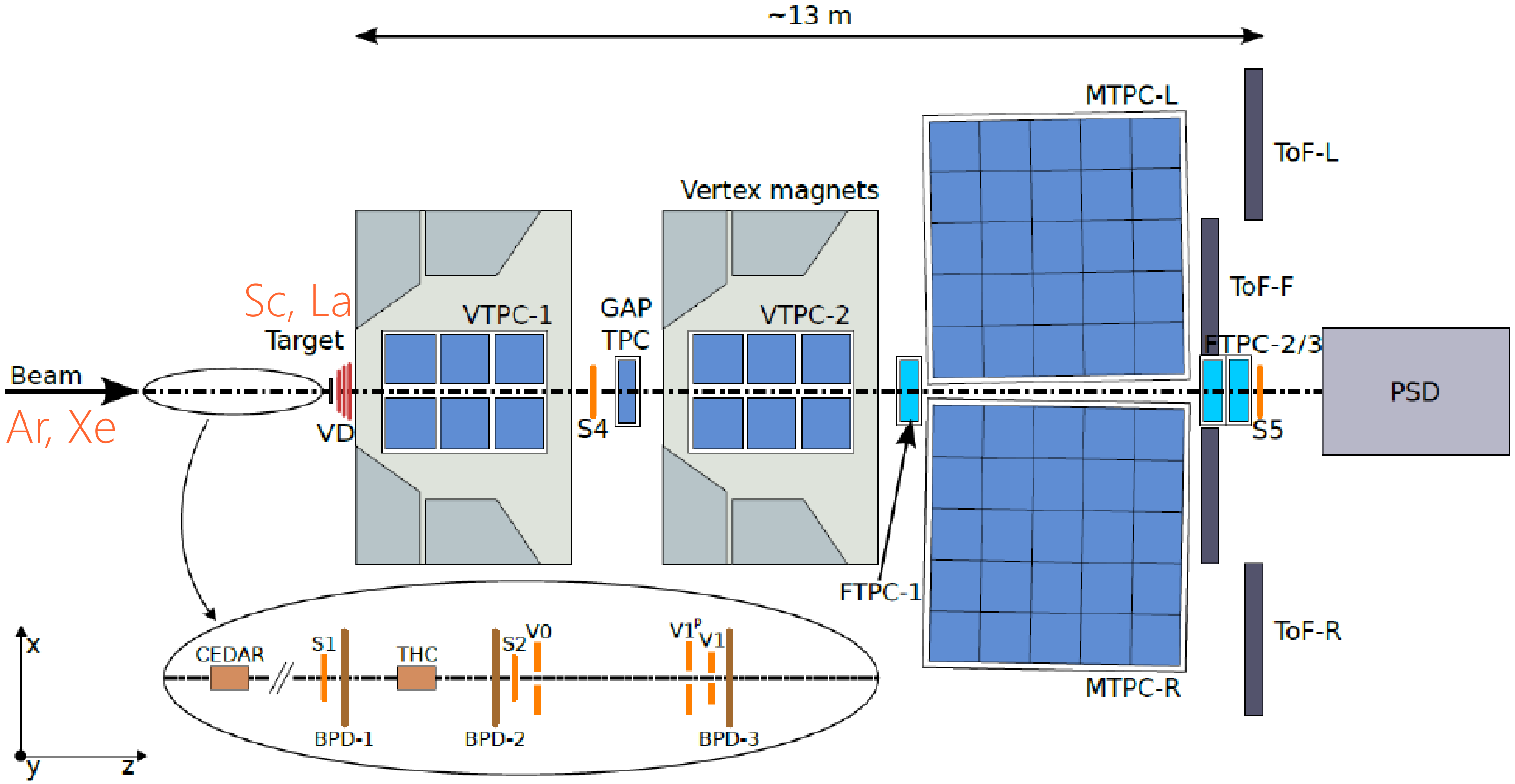
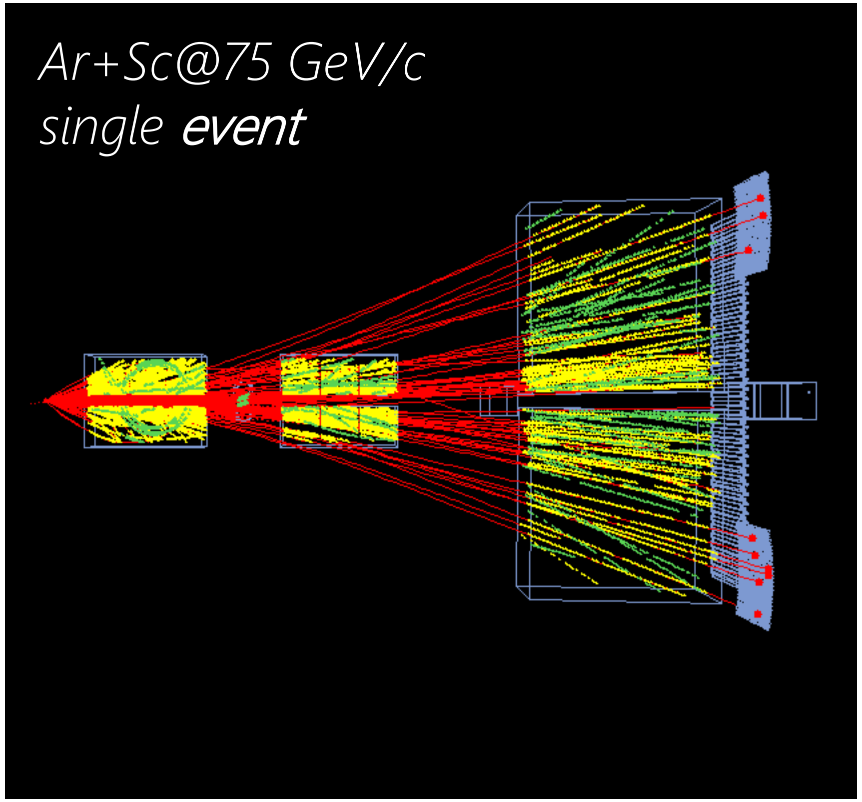
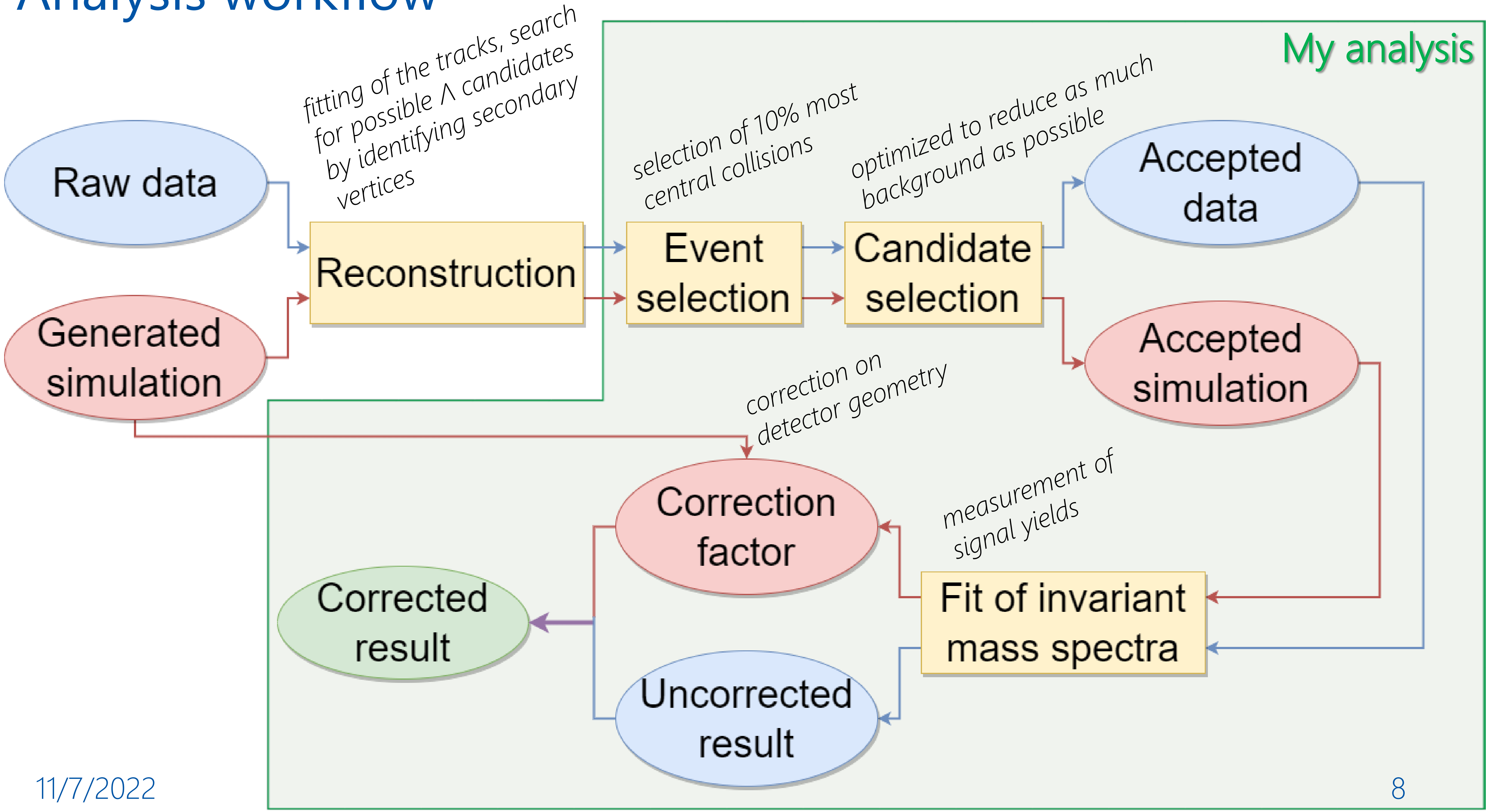


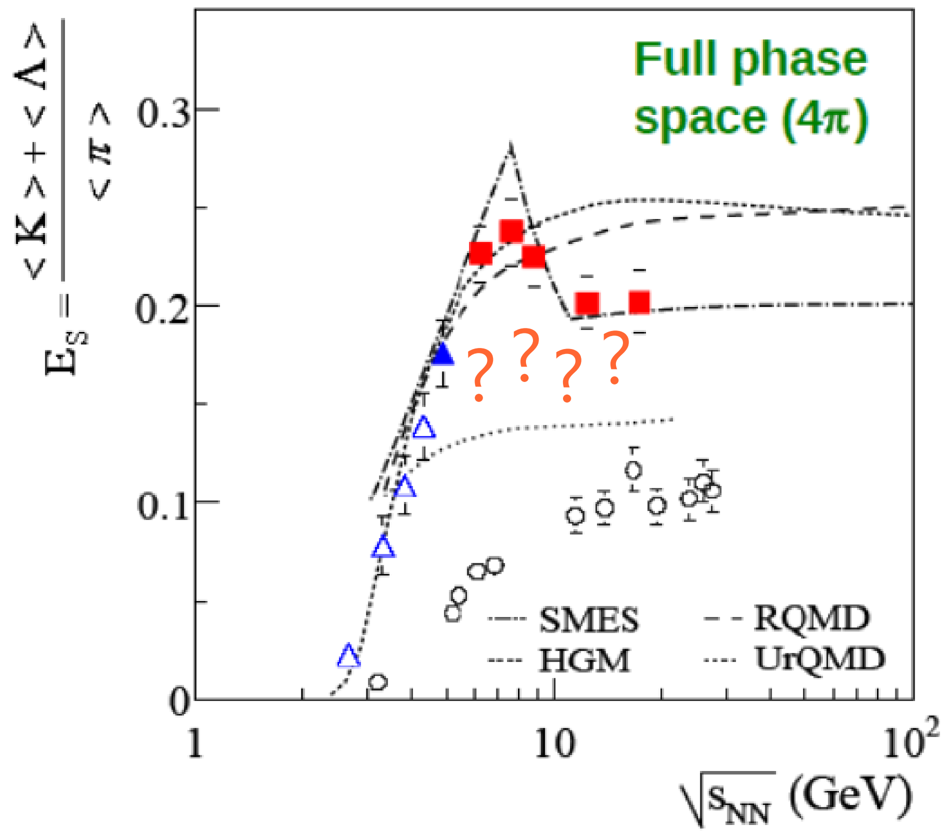


Analysis workflow



Analysis outcome

- two-dimensional spectra in rapidity-transverse momentum phase space
- one-dimensional transverse momentum spectra
  - fitted with exponential function to obtain inverse slope parameter *T*
- one-dimensional rapidity spectra
  - fitted with sum of Gaussians to obtain total mean multiplicity $\langle\Lambda\rangle$
- fill in "horn" plot with data from intermediate systems



Summary

- ✓ analysis procedure tested for Ar+Sc at 40 GeV/c and 75 GeV/c
  - ✓ event selection
  - ✓ candidate selection
  - ✓ optimization of selection criteria
  - ✓ fitting procedure
  - ✓ correction procedure
- ✓ statistical and systematic uncertainty
- ✓ comparison with the world data and particle production models
- ✓ improvement of reconstruction tools for search of Λ candidates

Thank you for your attention!

All comments and questions are very welcome:
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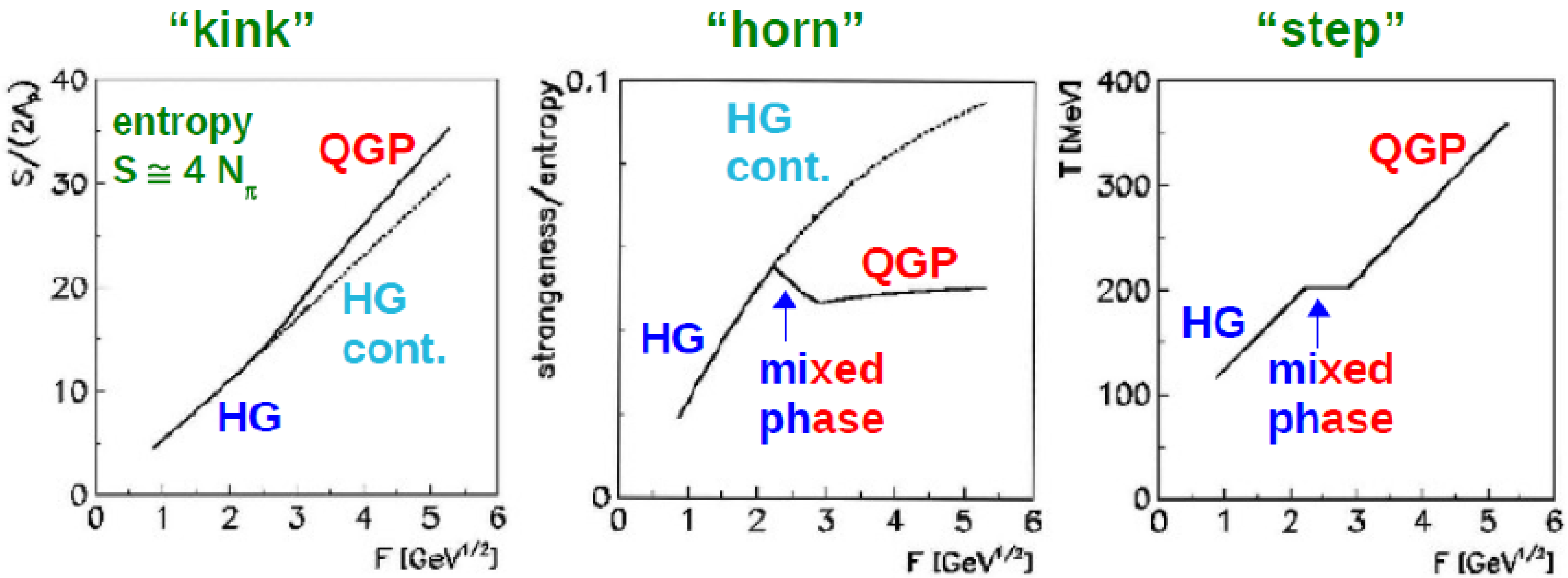
Backup

Motivation: Statistical Model of the Early Stage (SMES)

Gaździcki, Gorenstein, Acta Phys. Polon. B30, 2705 (1999)



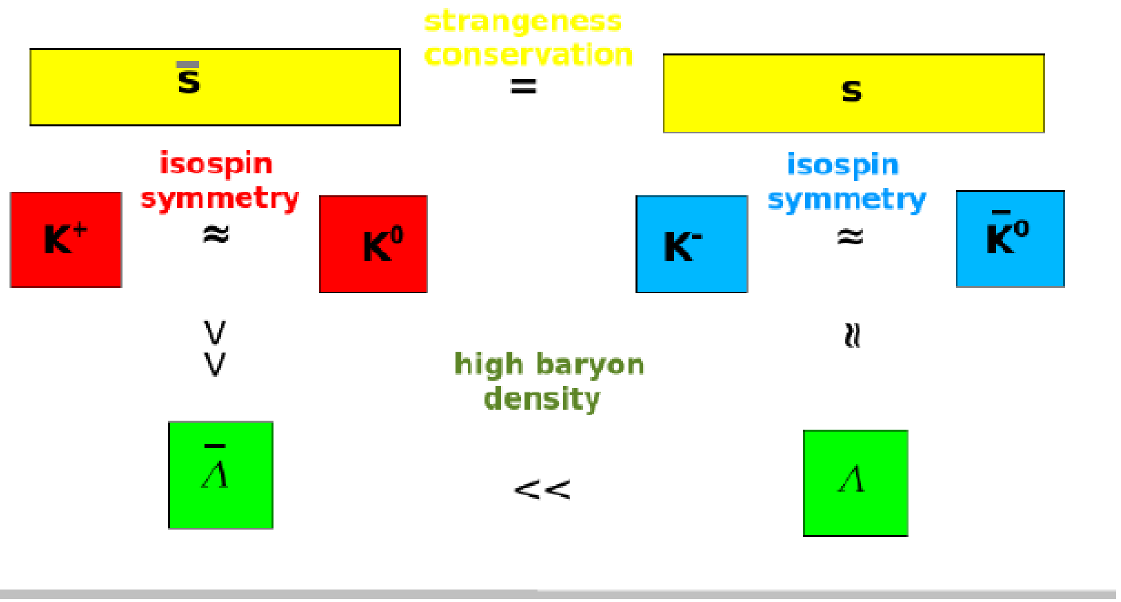
Fermi variable

$$F \equiv \left[\frac{(\sqrt{s_{NN}} - 2m_N)^3}{\sqrt{s_{NN}}} \right]^{1/4}$$

$$F \simeq \sqrt{\sqrt{s_{NN}}}$$

- 1^{st} order phase transition to QGP between top AGS and top SPS energies $\sqrt{s_{NN}} \approx 7$ GeV
- number of internal degrees of freedom (*ndf*) increases HG → QGP (activation of partonic degrees of freedom)
- total entropy and total strangeness are the same before and after hadronization (cannot decrease QGP → HG)
- mass of strangeness carriers decreases HG → QGP ($m_{\Lambda, K, \ldots} > m_s$)
- constant temperature and pressure in mixed phase

main strangeness carriers

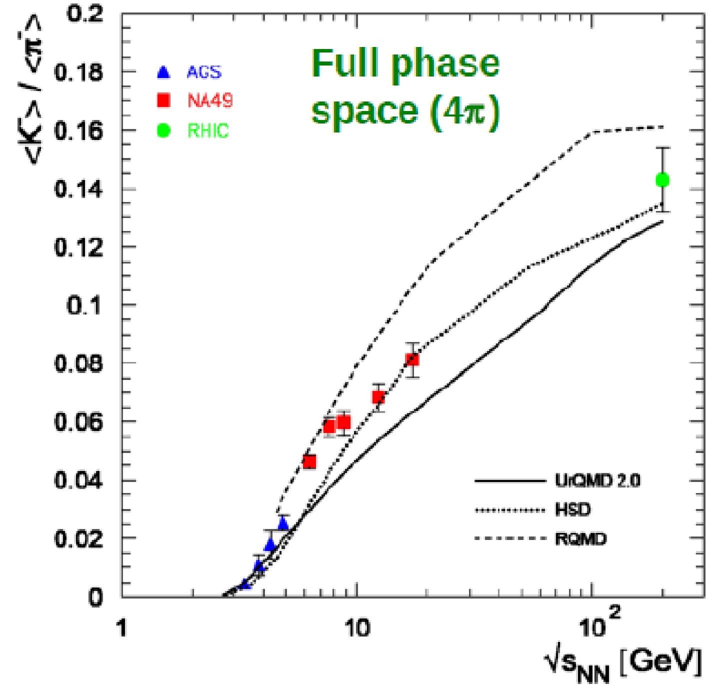


sensitive to strangeness content only

sensitive to strangeness content and baryon density

Difference in ⟨K^+⟩ and ⟨K^-⟩ production due to different sensitivity to baryon density. At SPS energies lambdas have significant influence on total strangeness production (anti-lambdas not)

Λ (uds)
K^+ (u **anty-s**)
K^- (anty-u **s**)
K^0 (d **anty-s**)
anty-K^0 (anty-d **s**)



$\bar{s} \rightarrow K^+, K^0$

$s \rightarrow K^-, \bar{K}^0, \Lambda$

⟨K^+⟩/⟨π^+⟩ proportional to strangeness/entropy

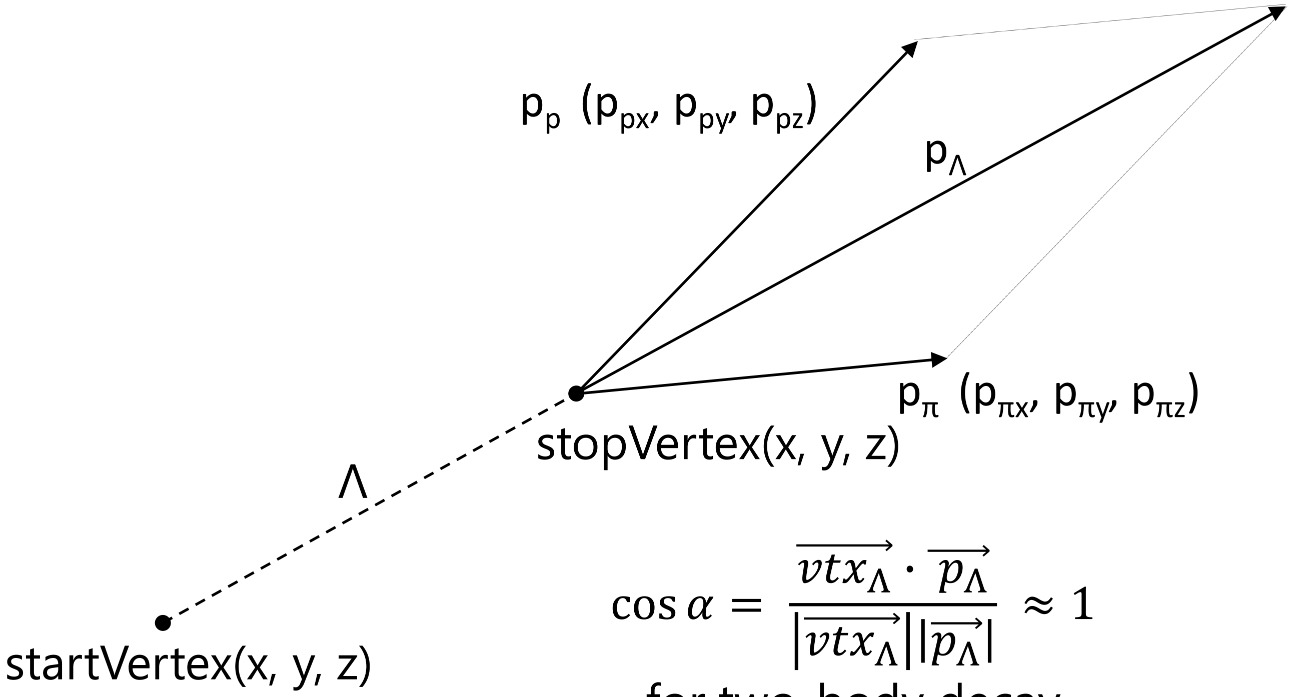
⟨K^-⟩/⟨π^-⟩ additionally sensitive to baryon density

Kinematic variables

- rapidity $y = \frac{1}{2}\ln\frac{E+p_z}{E-p_z}$ - additive under the Lorentz boosts, difference in rapidity does not change from system to system
- transverse momentum $p_T = \sqrt{p_x^2 + p_y^2}$ - invariant under the Lorentz boosts

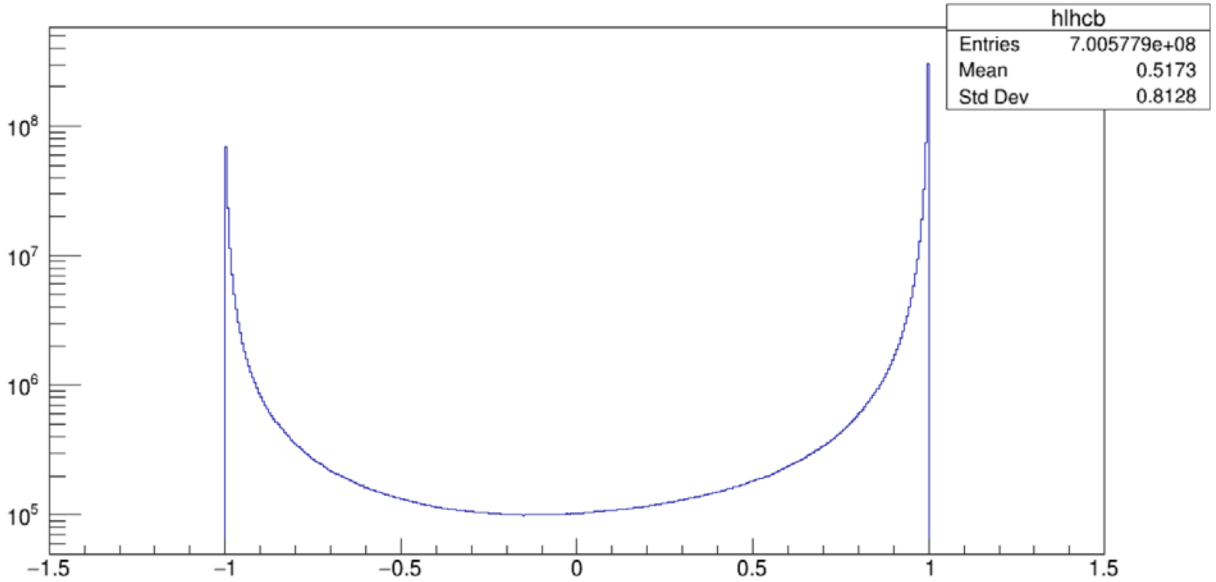
DirA (directional angle) cut for V0 candidates

//adapted from LHCb

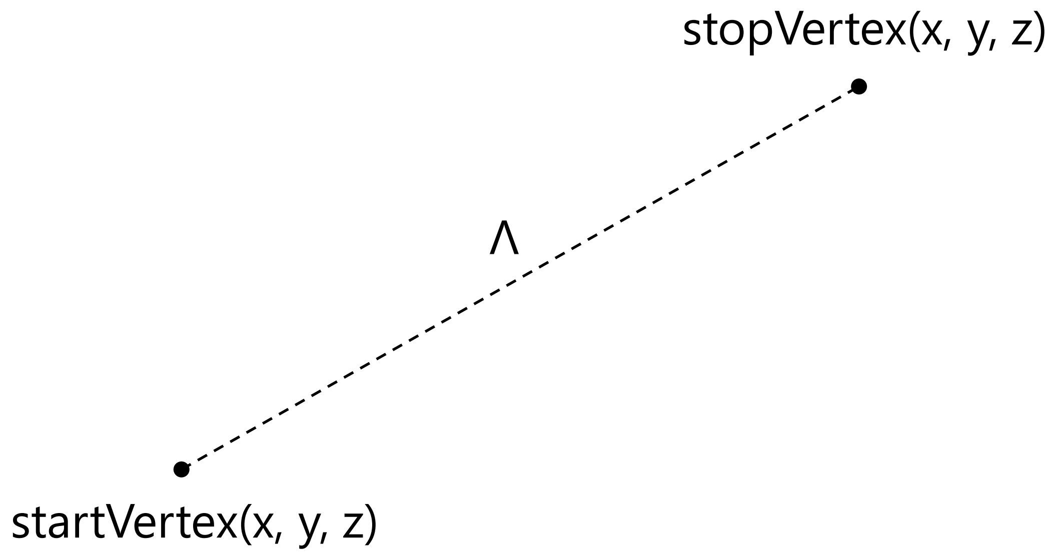


$$\cos\alpha = \frac{\overrightarrow{vtx_\Lambda} \cdot \overrightarrow{p_\Lambda}}{|\overrightarrow{vtx_\Lambda}||\overrightarrow{p_\Lambda}|} \approx 1$$

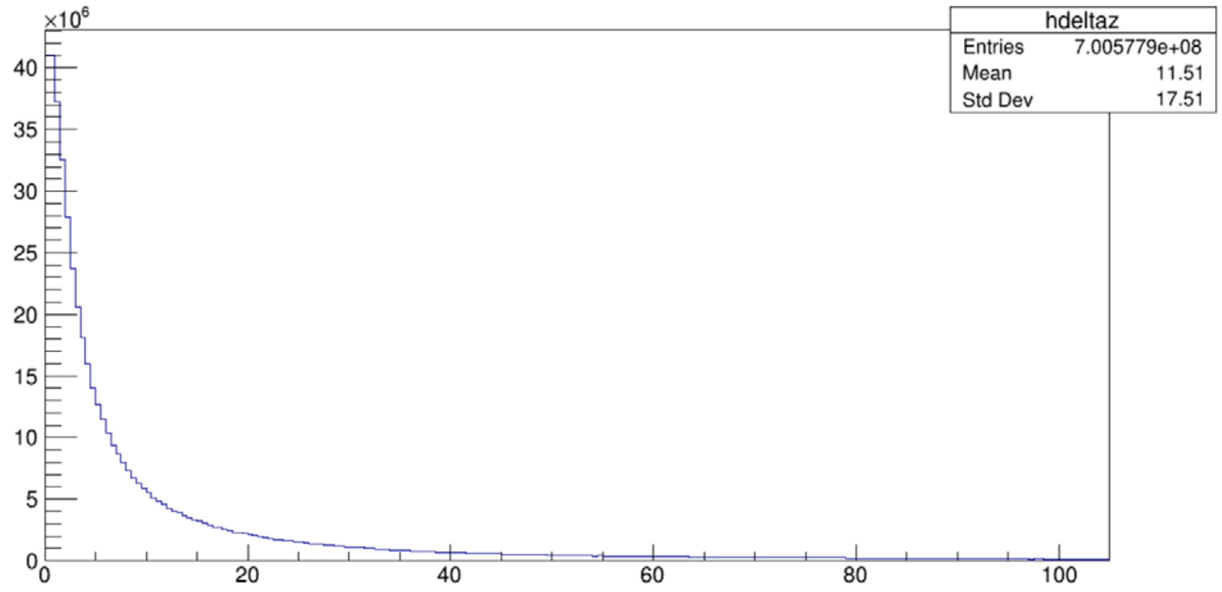
for two-body decay



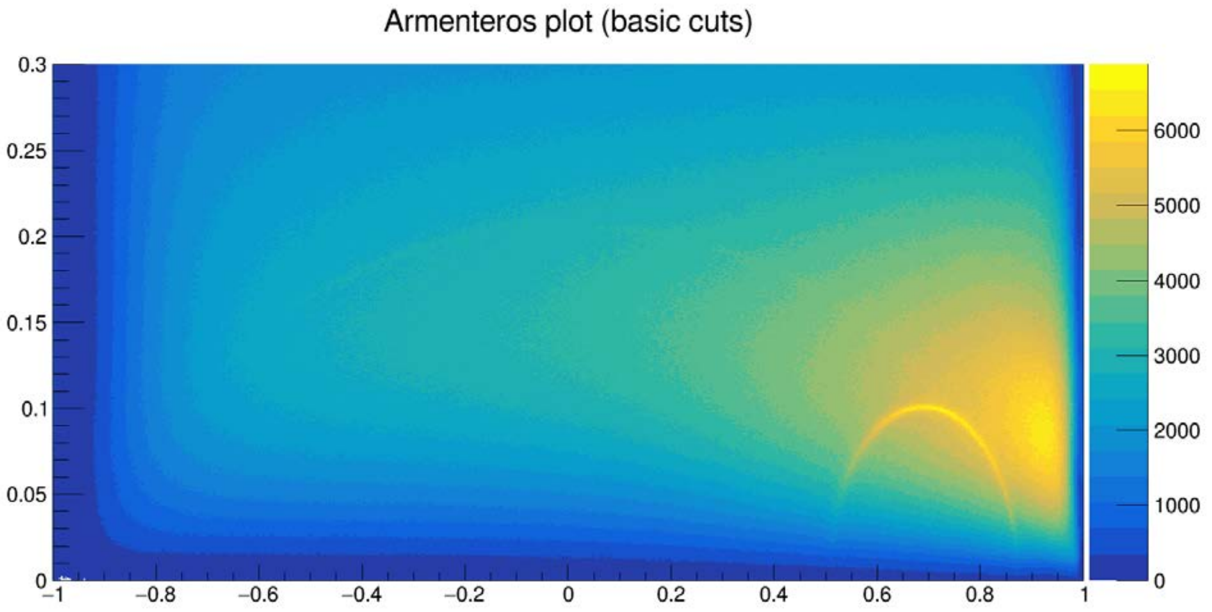
ΔL cut for V0 candidates

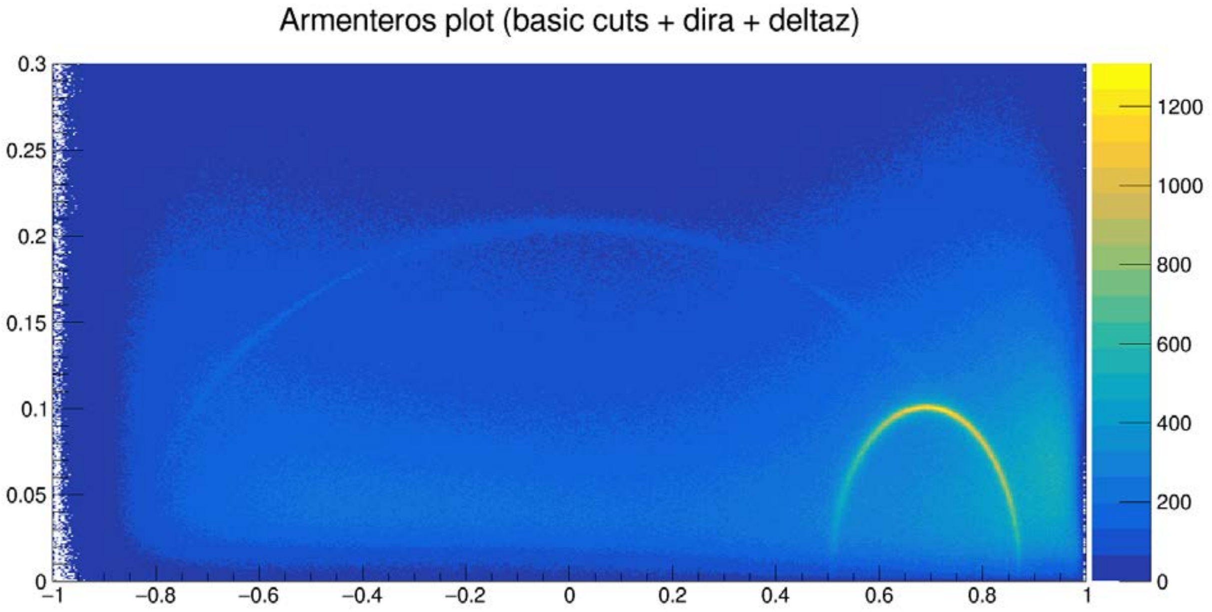


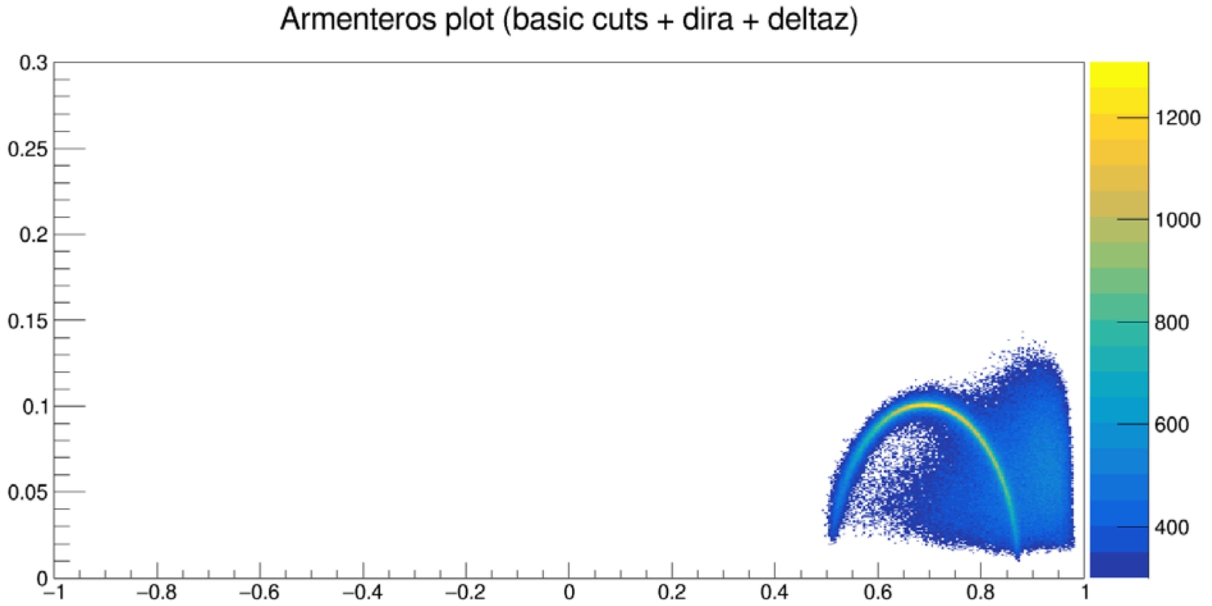
$$\Delta \boldsymbol{L} = |\bar{\boldsymbol{L}}| = \sqrt{\sum_{i=x,y,z} (startVertex_i - stopVertex_i)^2}$$



Armenteros-Podolanski plots







$$\alpha_{Arm} = \frac{p_L^+ - p_L^-}{p_L^+ + p_L^-}$$

$$p_{T\ Arm} = \sqrt{(p^+)^2 - (p_L^+)^2}$$