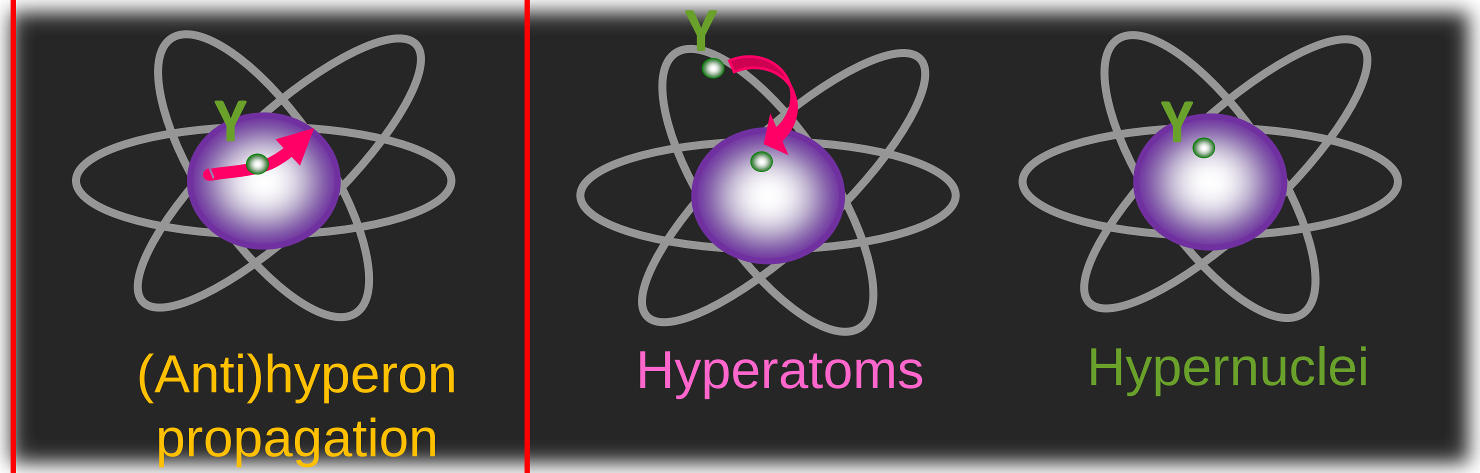
Antihyperons in nuclear matter at PANDA Phase One

Falk Schupp

Helmholtz Institute Mainz

SMuK 2021

Strangeness nuclear physics at PANDA



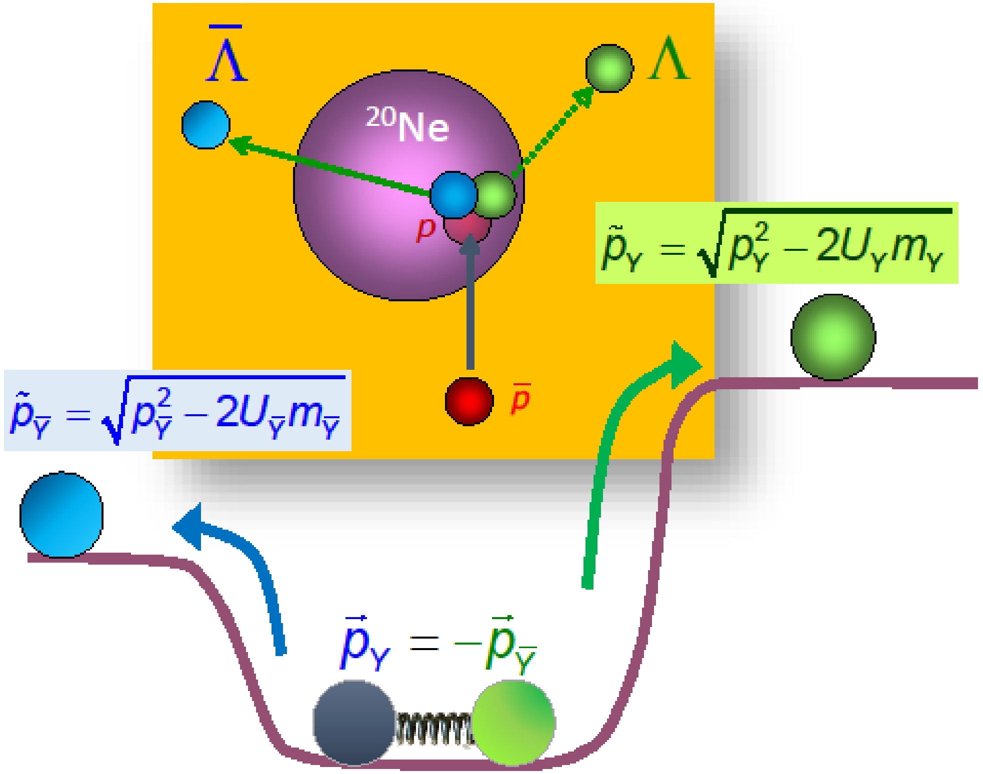
Physics Topic

Antihyperon potential in cold baryonic matter	Ξ^- potential in neutron-rich baryonic matter	Structure of $\Lambda\Lambda$ hypernuclei

Sanchez Lorente et al.
Physics Letters B 749 (2015)

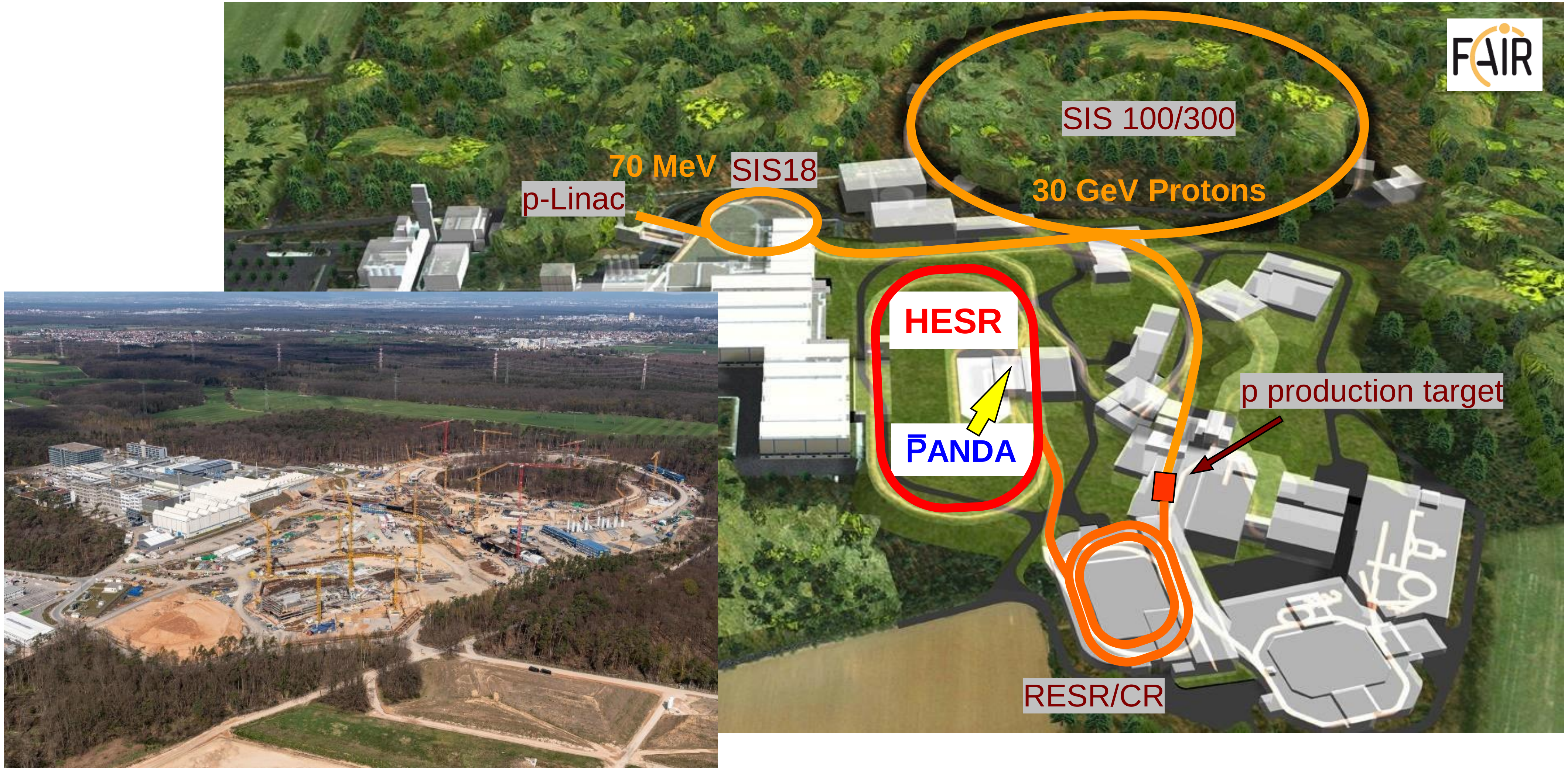
Pochodzalla et al.
Nuclear Physics A 954 (2016)

(anti-)hyperon potential in cold baryonic matter



- Hyperon pair production in nuclei
- Observed hyperon momenta depend on nuclear potential
  - seperate potential for hyperon and antihyperon
    - ➢ Different observable momenta
- p, p̄ nuclear potential is known to be different

PANDA@FAIR and current construction work

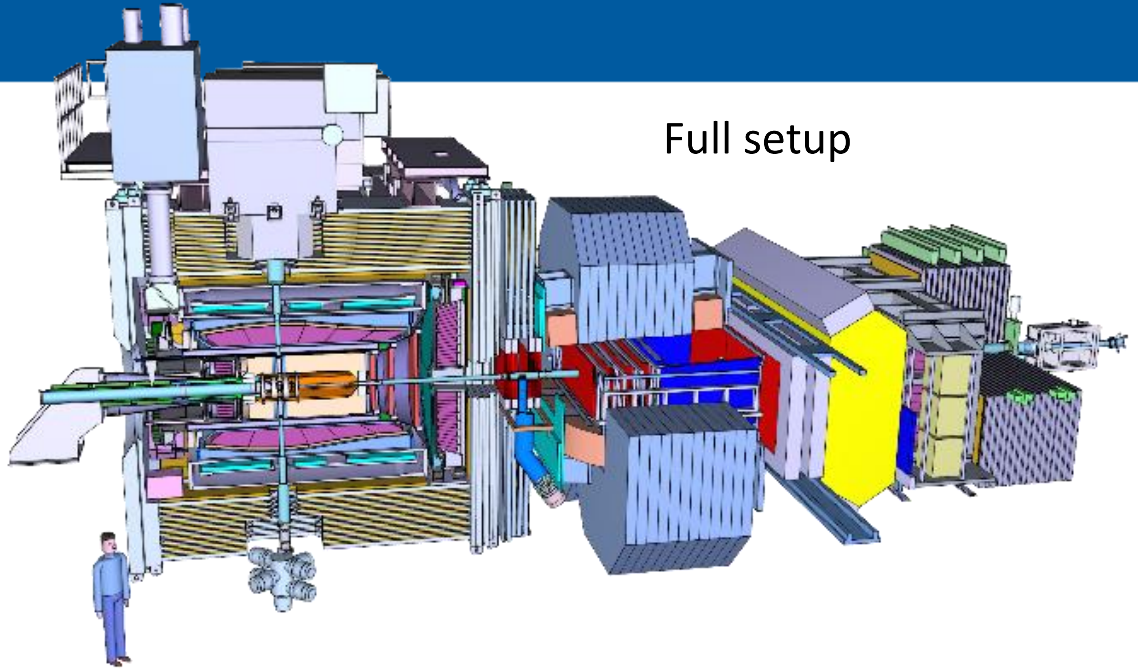


https://www.gsi.de/forschungbeschleuniger/fair/bau_von_fair/bilder_und_videos.htm

PANDA Phase One

- Start of antiproton production
- HESR with limited luminosity

Full setup



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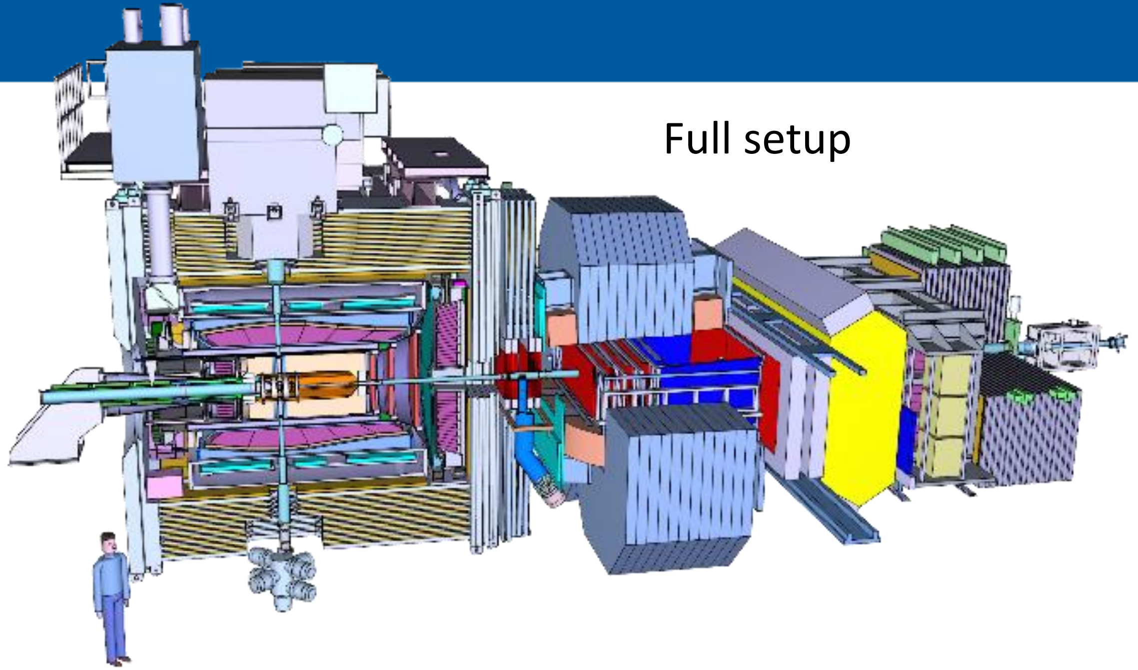
PANDA Phase One

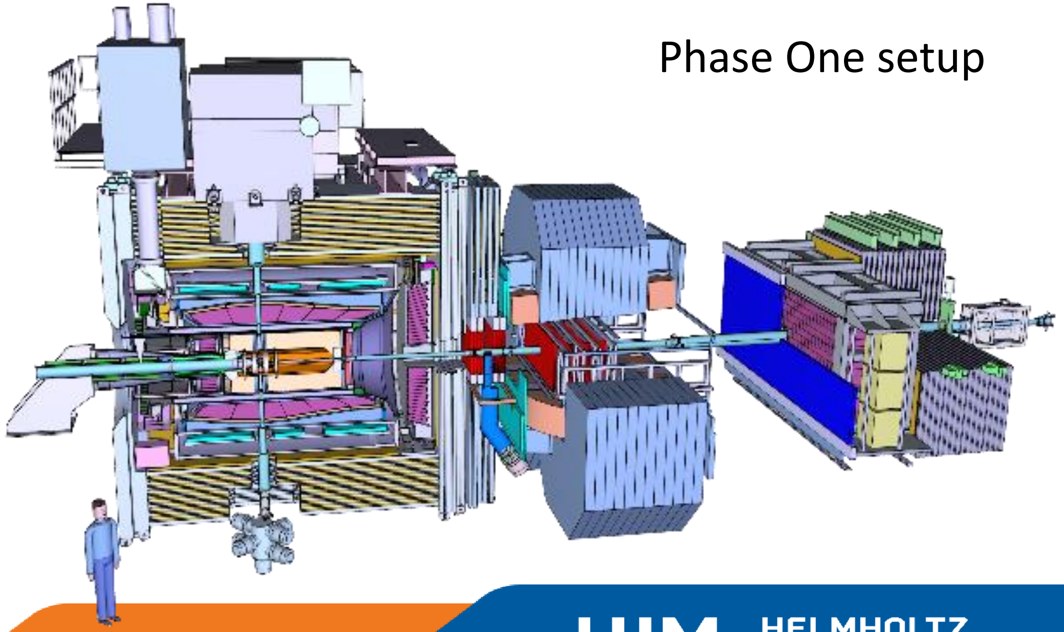
- Start of antiproton production
- HESR with limited luminosity

- Reduced PANDA detector setup

Full setup



Phase One setup



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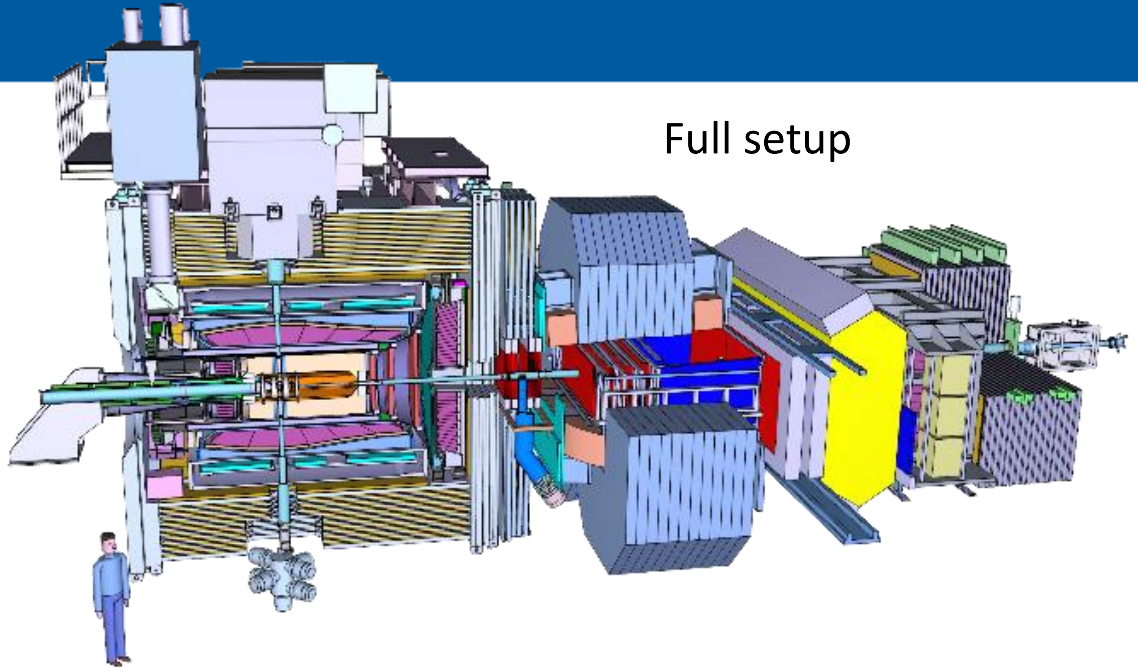
PANDA Phase One

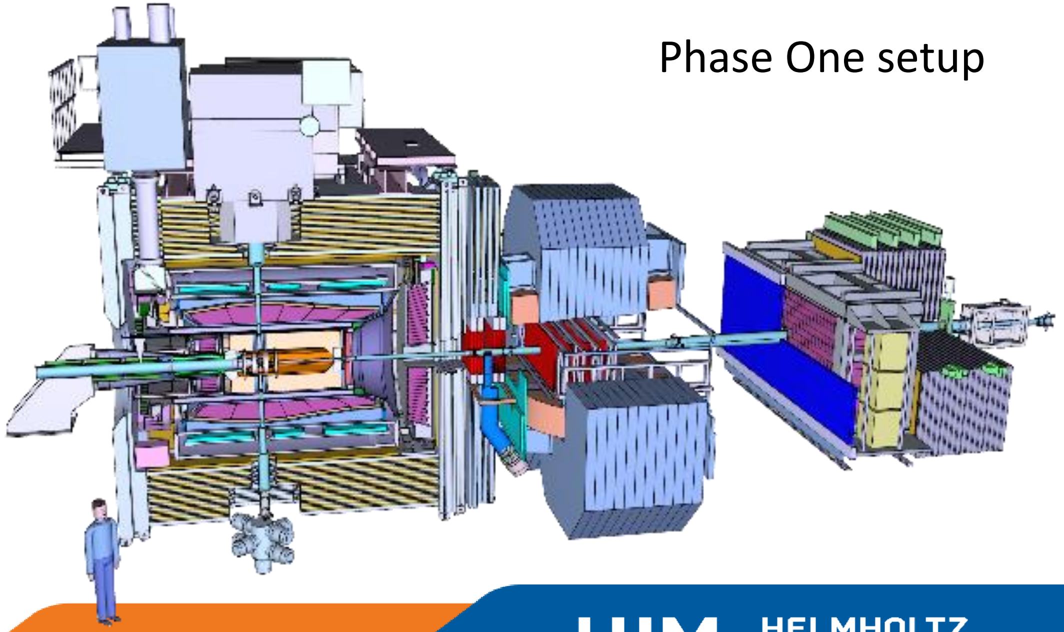
- Start of antiproton production
- HESR with limited luminosity

- Reduced PANDA detector setup

- Focus on reactions with:
    - large expected cross sections
    - good signal-to-background ratios
    - Small final state multiplicities



Full setup



Phase One setup

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PANDA Phase One

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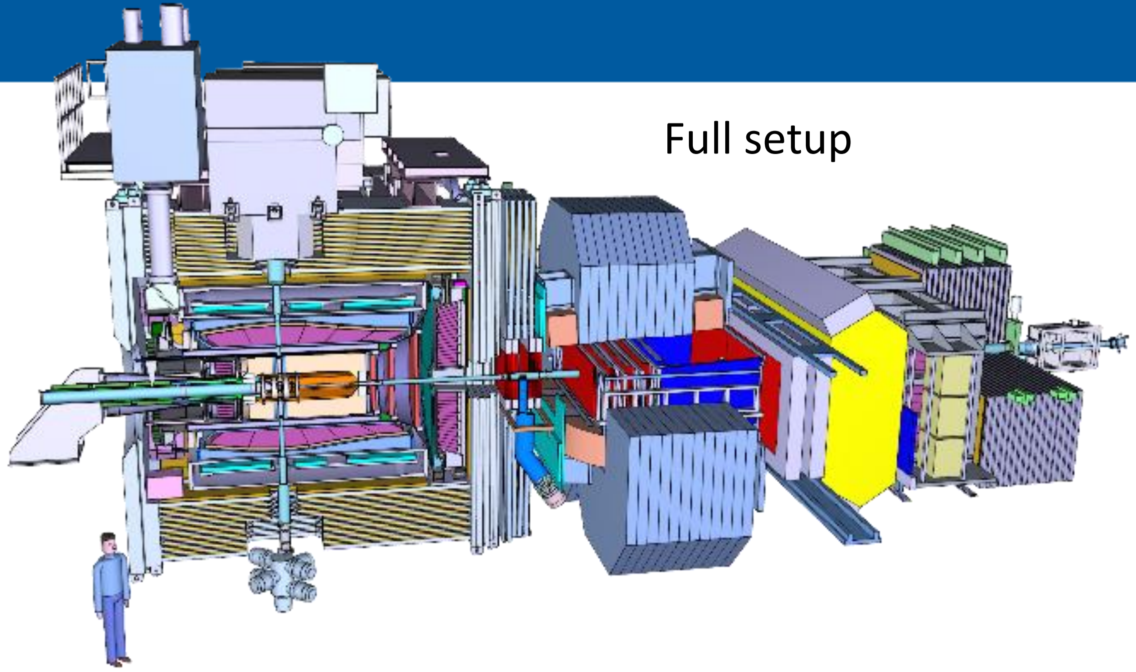
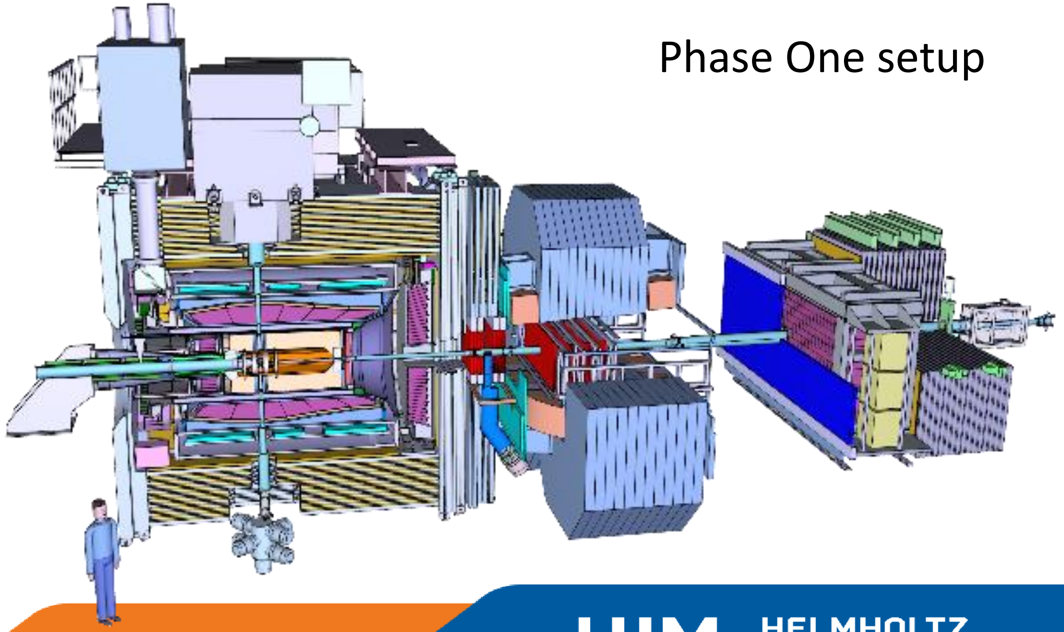
➢ $\bar{p}A \rightarrow \Lambda\bar{\Lambda} + X$



Full setup



Phase One setup

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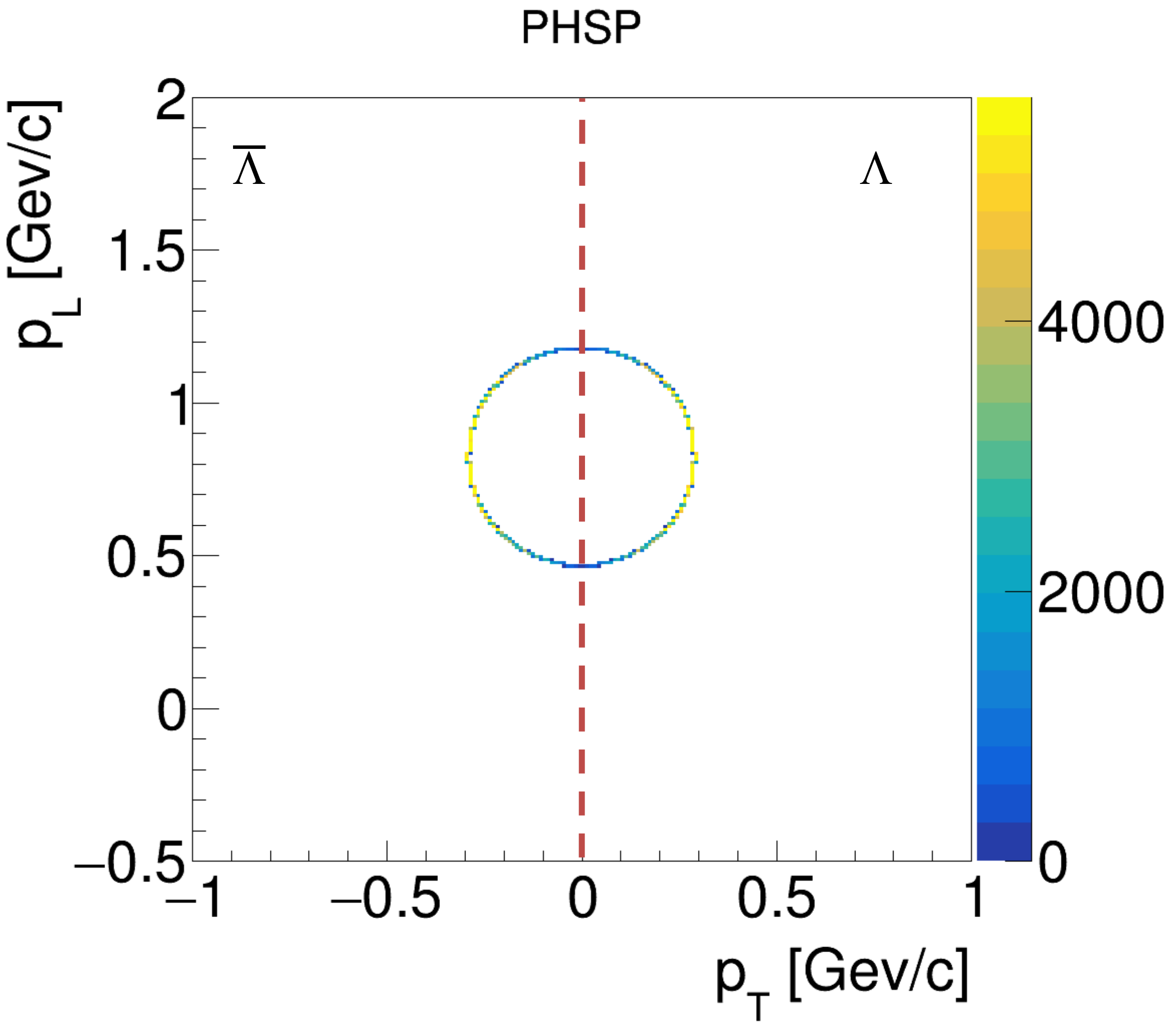
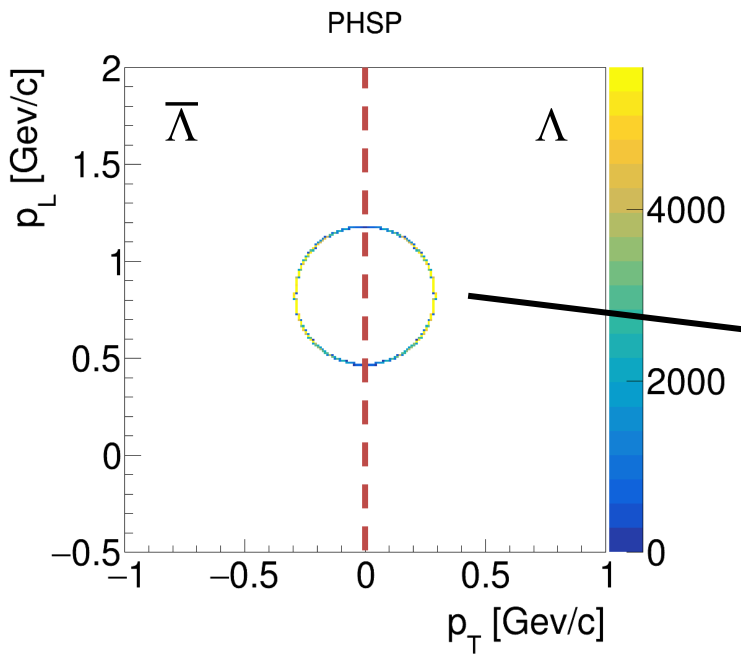
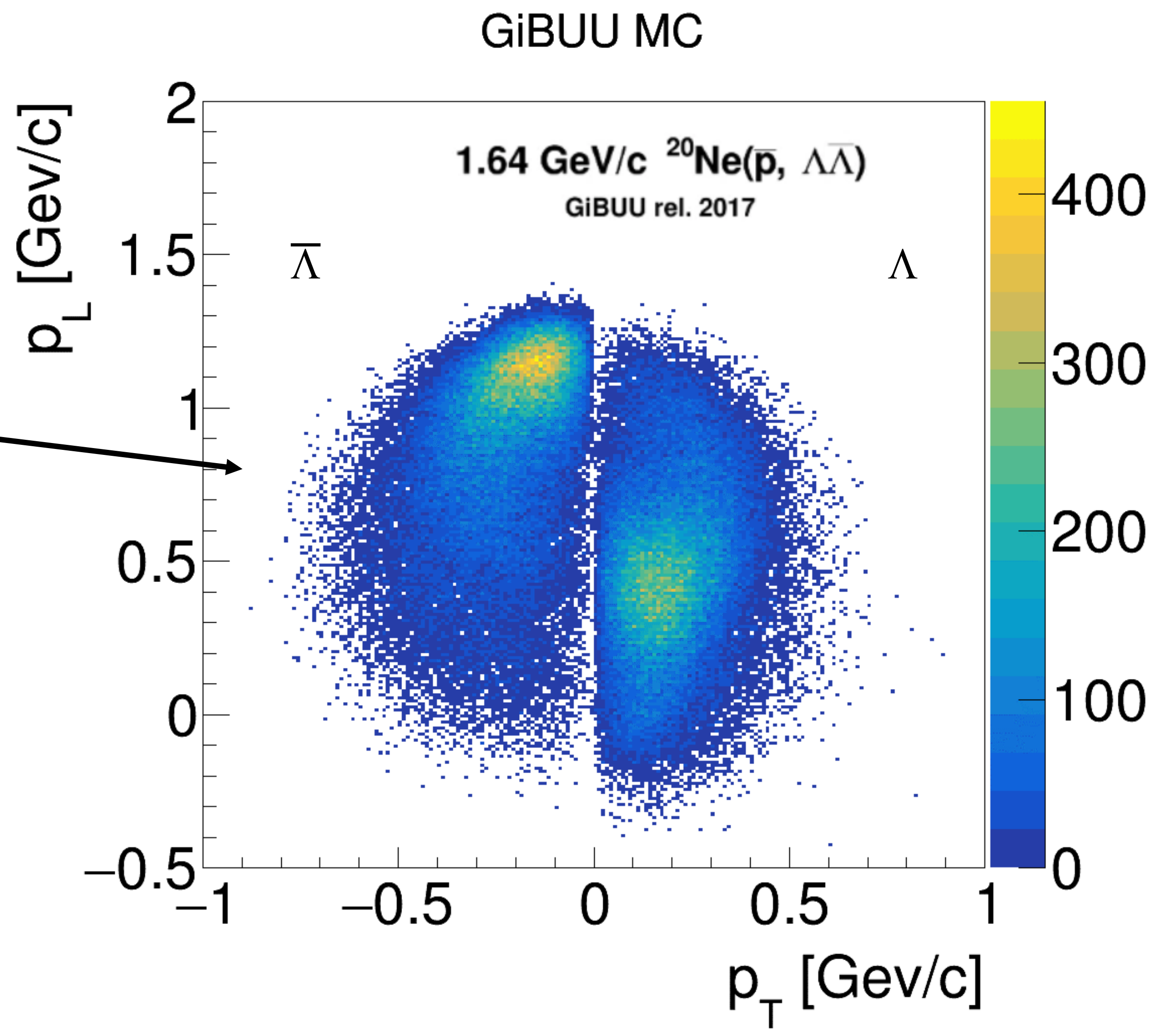
$p\bar{p}$ vs $\bar{p}A$ collisions - GiBUU

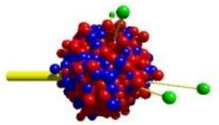


- Two-body interaction $p\bar{p}$ -> $\Lambda\bar{\Lambda}$
  - Transverse momenta trivial
  - $P_{T,\Lambda} = -P_{T,\bar{\Lambda}}$
- $\bar{p}A$ system more complex
  - Fermi motion
  - Many body interactions

$p\bar{p}$ vs $\bar{p}A$ collisions - GiBUU







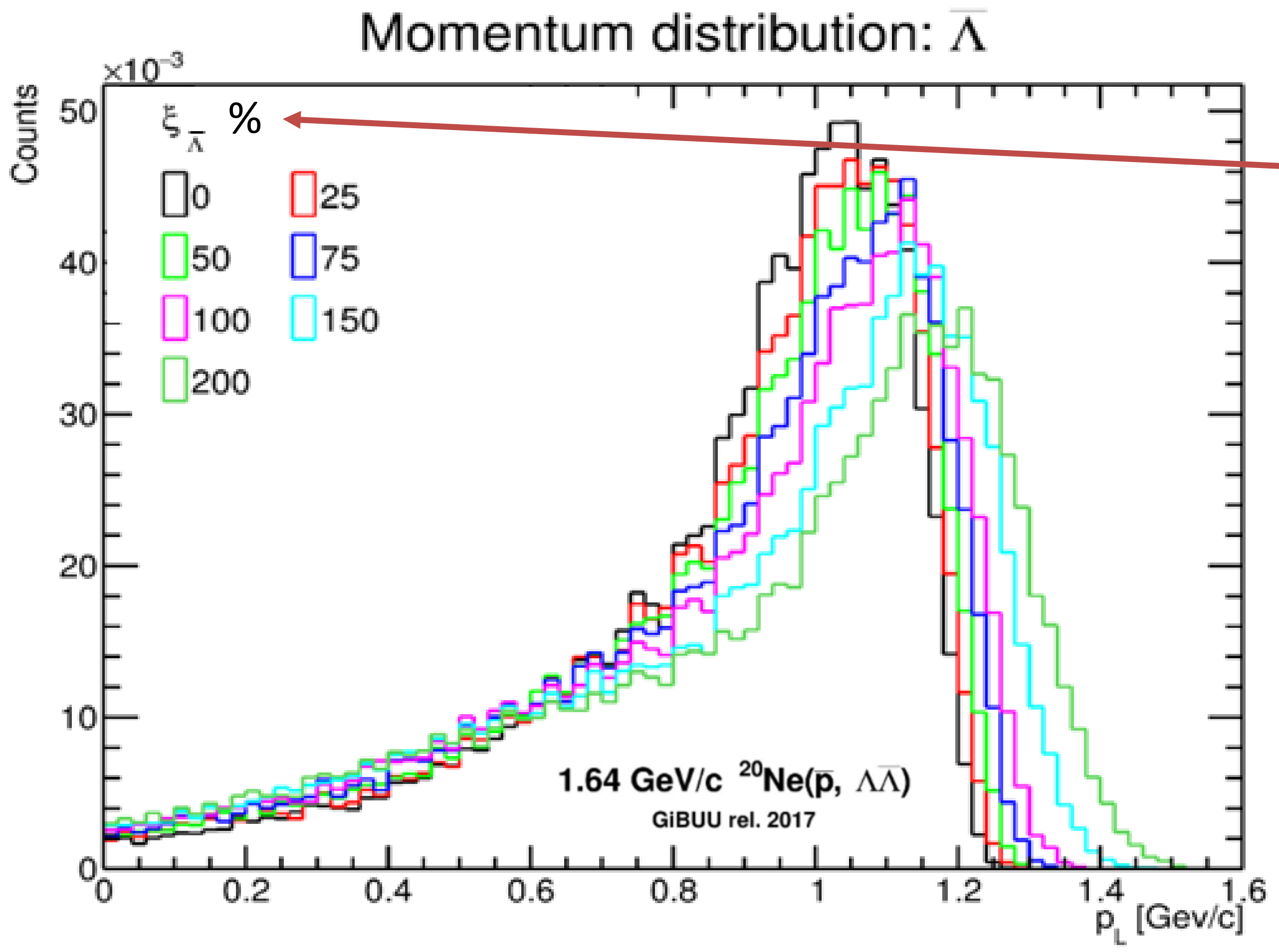
GiBUU
The Giessen Boltzmann-Uehling-Uhlenbeck Project

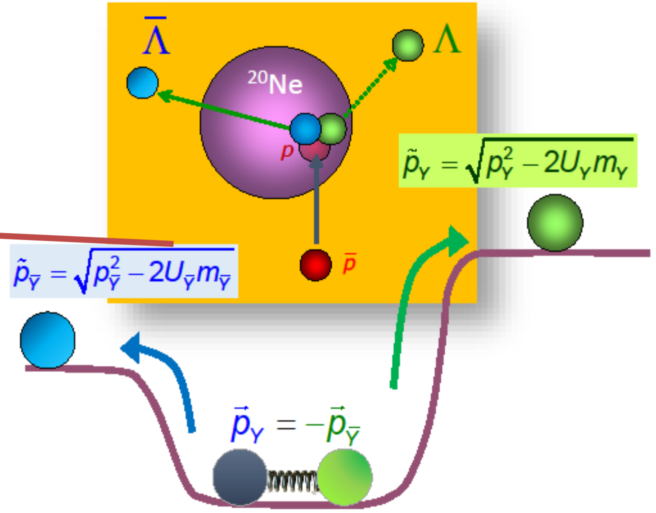
The **GiBUU project** provides a unified theory and transport framework in the MeV and GeV energy regimes for

- **elementary reactions on nuclei**, as e.g.
  - **electron** + A,
  - **photon** + A,
  - **neutrino** + A ,
  - **hadron** + A (especially **pion** + A and **proton** + A)
- and for A + A **heavy-ion collisions**,

https://gibuu.hepforge.org/trac/wiki

Antihyperon potential dependence





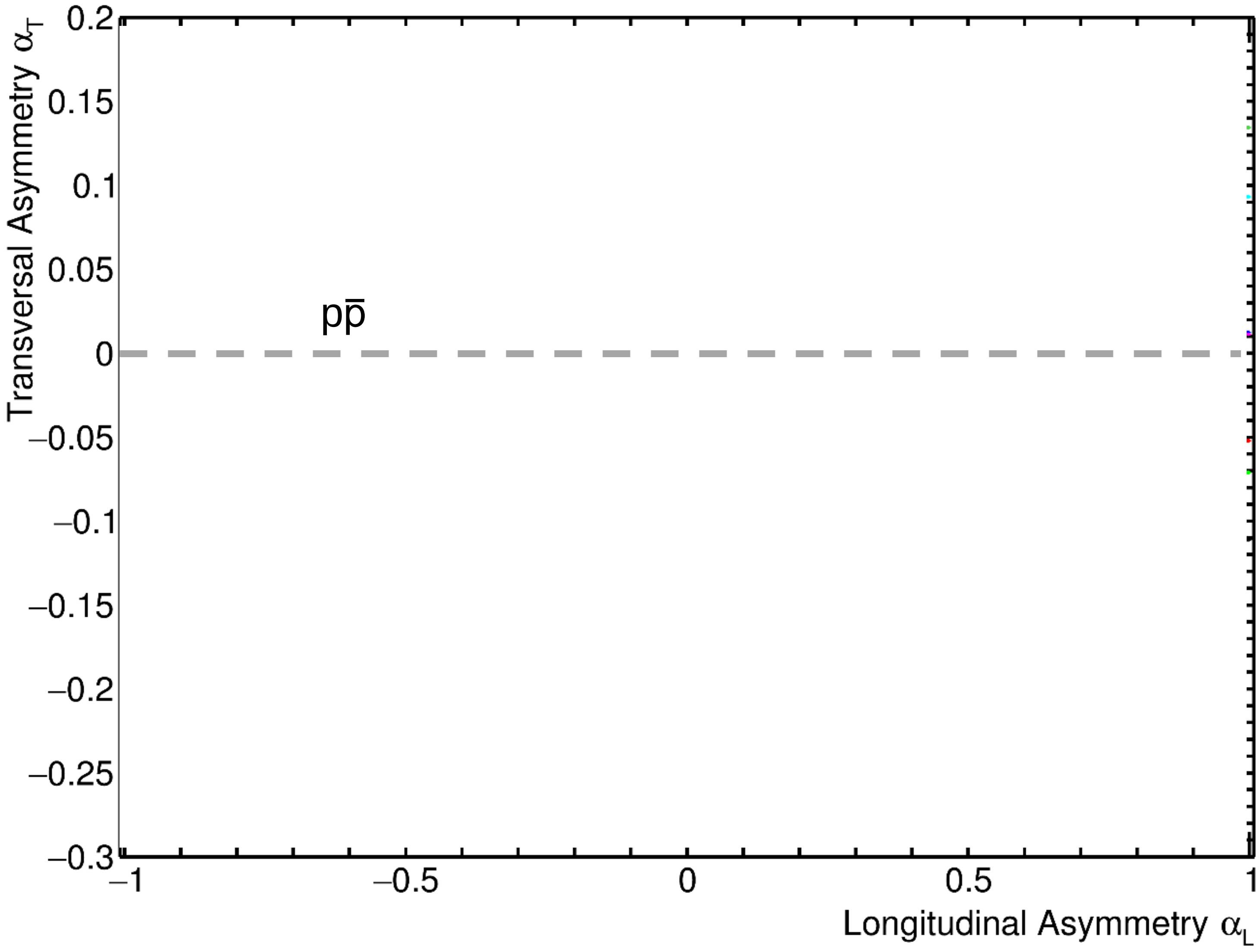
- GiBUU simulation with varying antihyperon potential
  - Modifying default GiBUU potential with factor
- $\bar{\Lambda}$ longitudinal momentum distribution

Potential depended momentum asymmetry

$$\alpha_T = \frac{p_T(Y) - p_T(\overline{Y})}{p_T(Y) + p_T(\overline{Y})}$$

$$\alpha_L = \frac{p_L(Y) - p_L(\overline{Y})}{p_L(Y) + p_L(\overline{Y})}$$

- $p\bar{p}$ -> $\Lambda\overline{\Lambda}$ => no asymmetry



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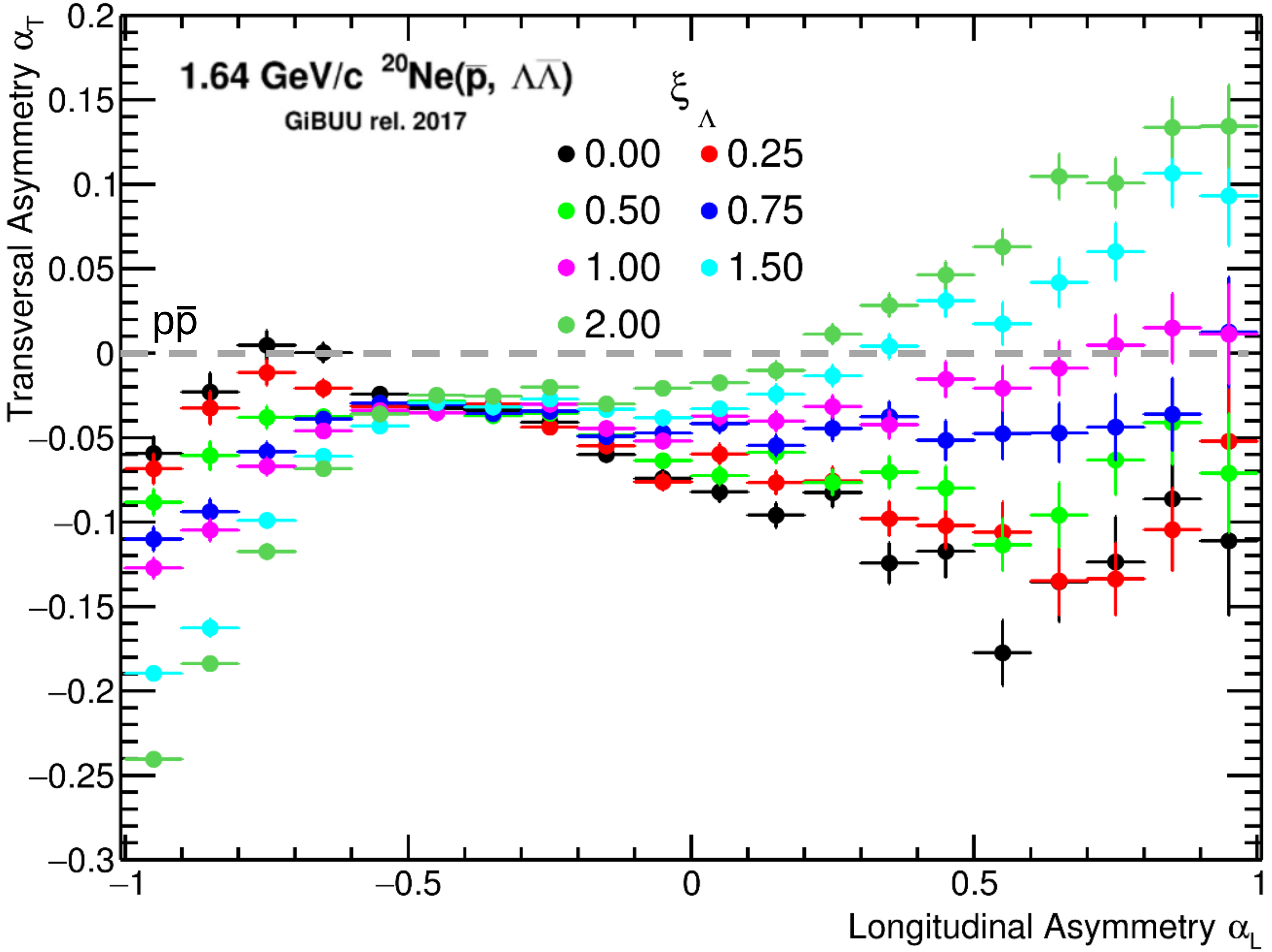
- $p\bar{p} \to \Lambda\bar{\Lambda}$ => no asymmetry
- $\Lambda\bar{\Lambda}$ pair momentum assymmetry calculated per event



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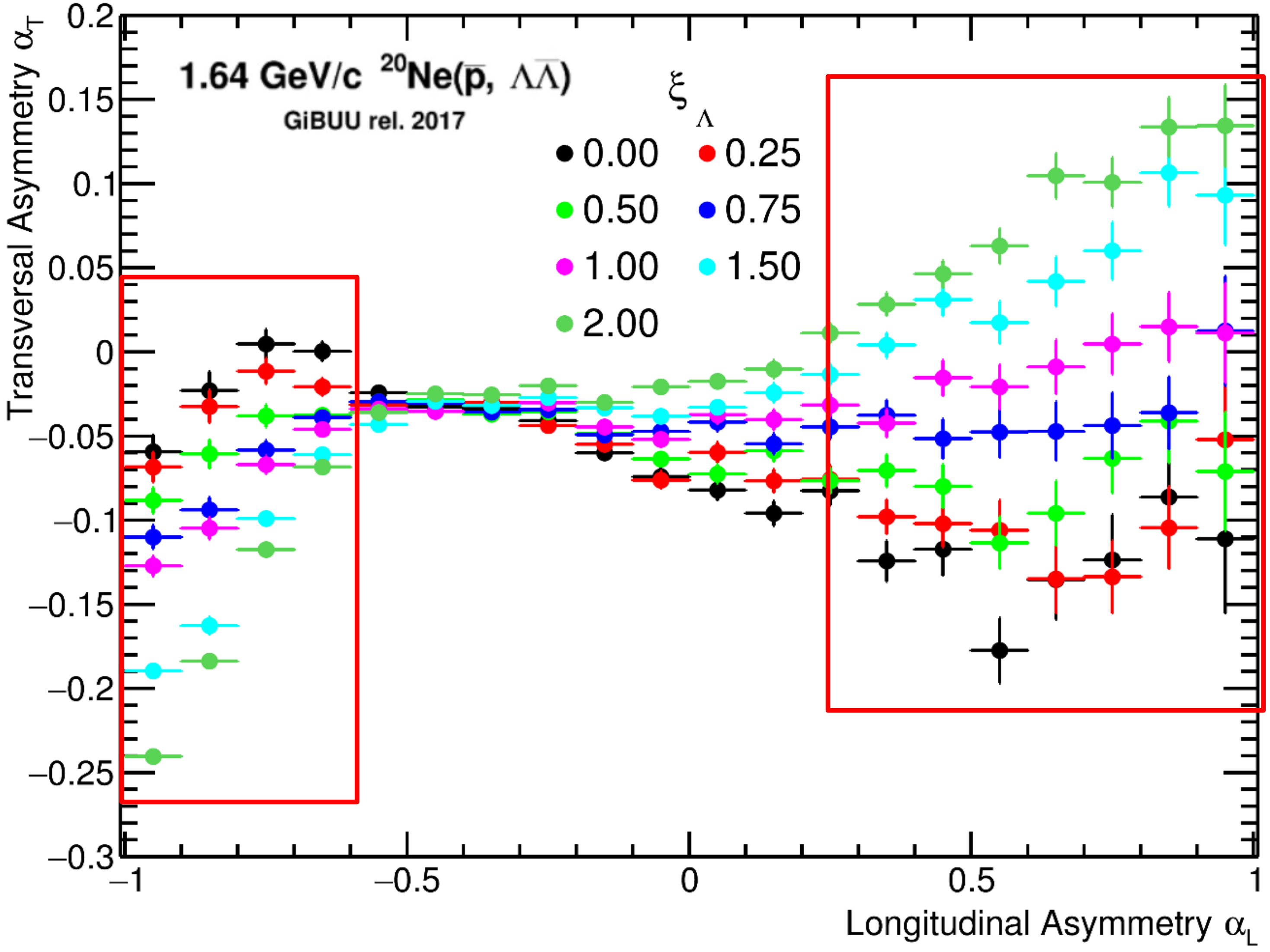
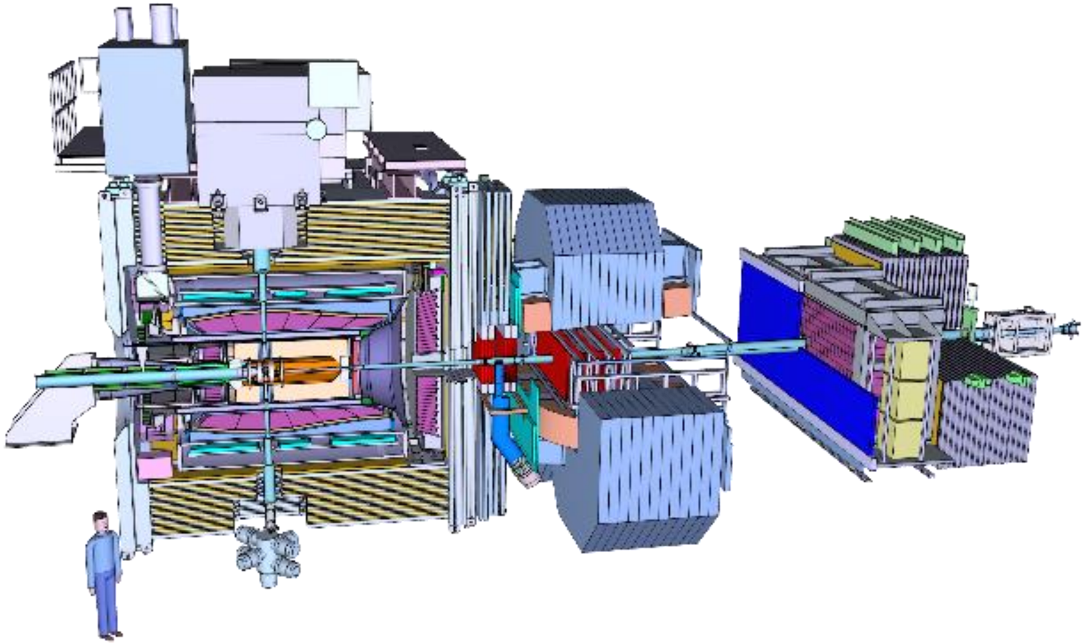


- $\Lambda\bar{\Lambda}$ pair momentum assymmetry calculated per event
- p$\bar{\text{p}}$ -> $\Lambda\bar{\Lambda}$ => no asymmetry
- **GiBUU data sensitiv to**
  - **momentum assymmetry**
    - **nuclear potential**

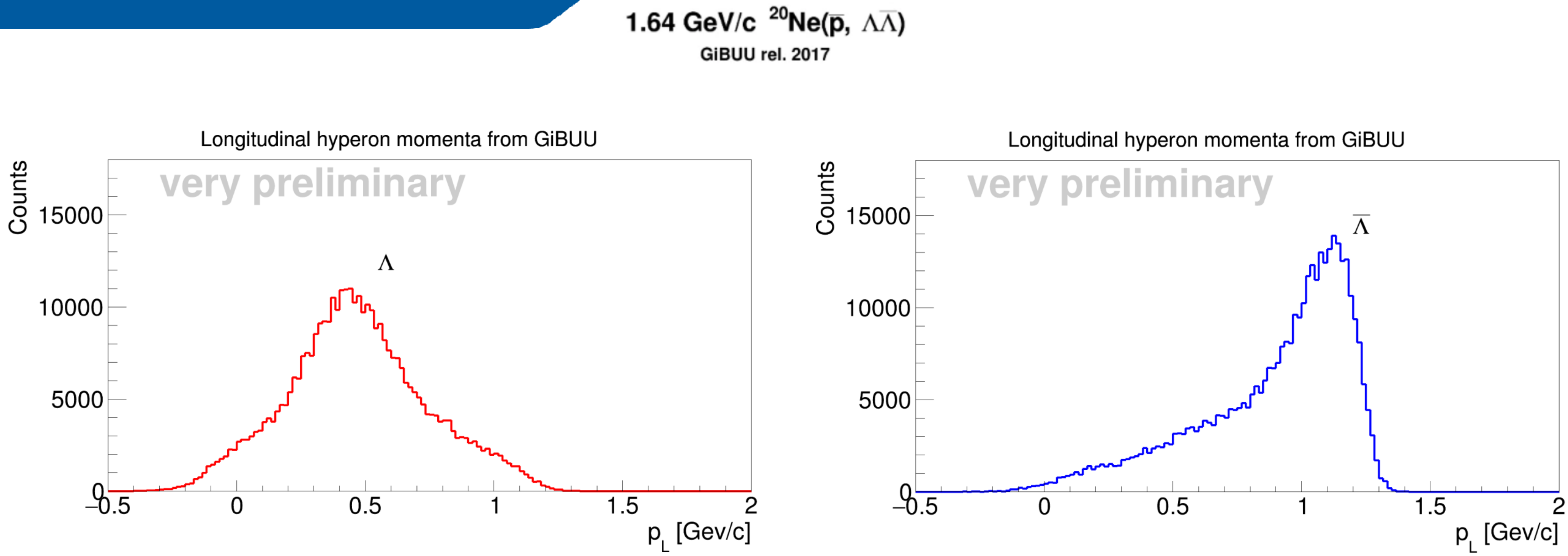
Potential depended momentum asymmetry

- Recently started with analysis of PANDA detector performance
- Using PandaRoot for simulations

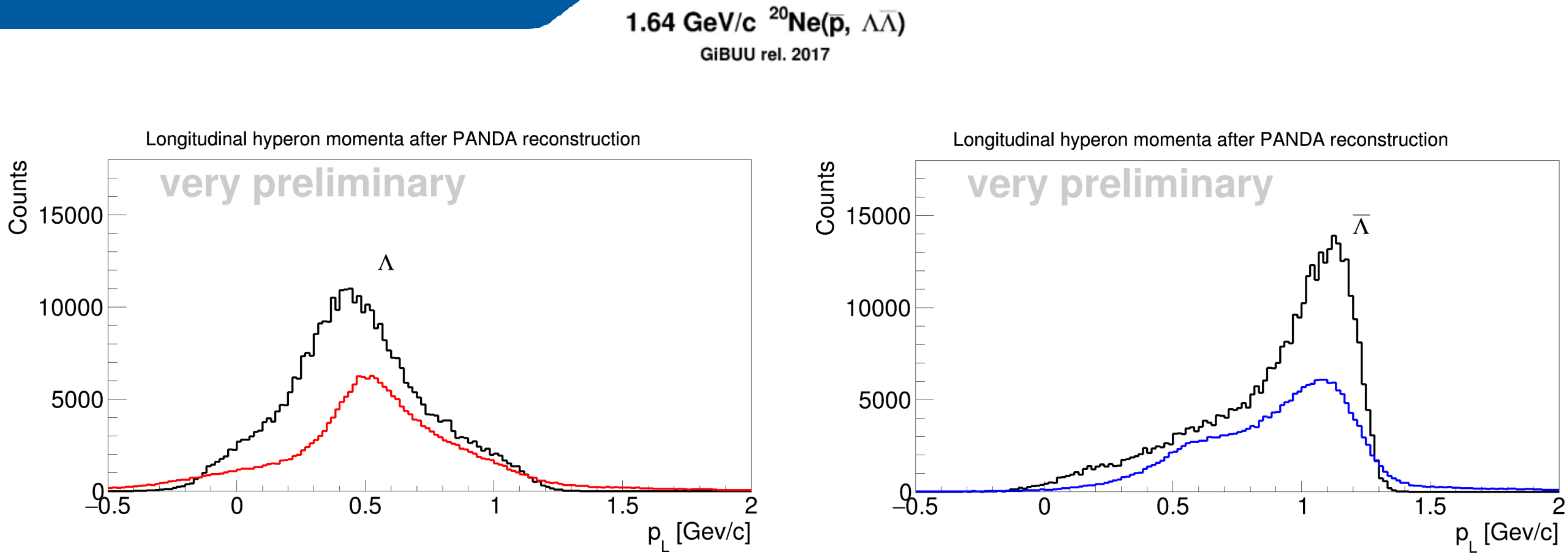


- PANDA Phase One setup
- GiBUU as event generator for MC studies

PandaRoot reconstruction for potential 1.0



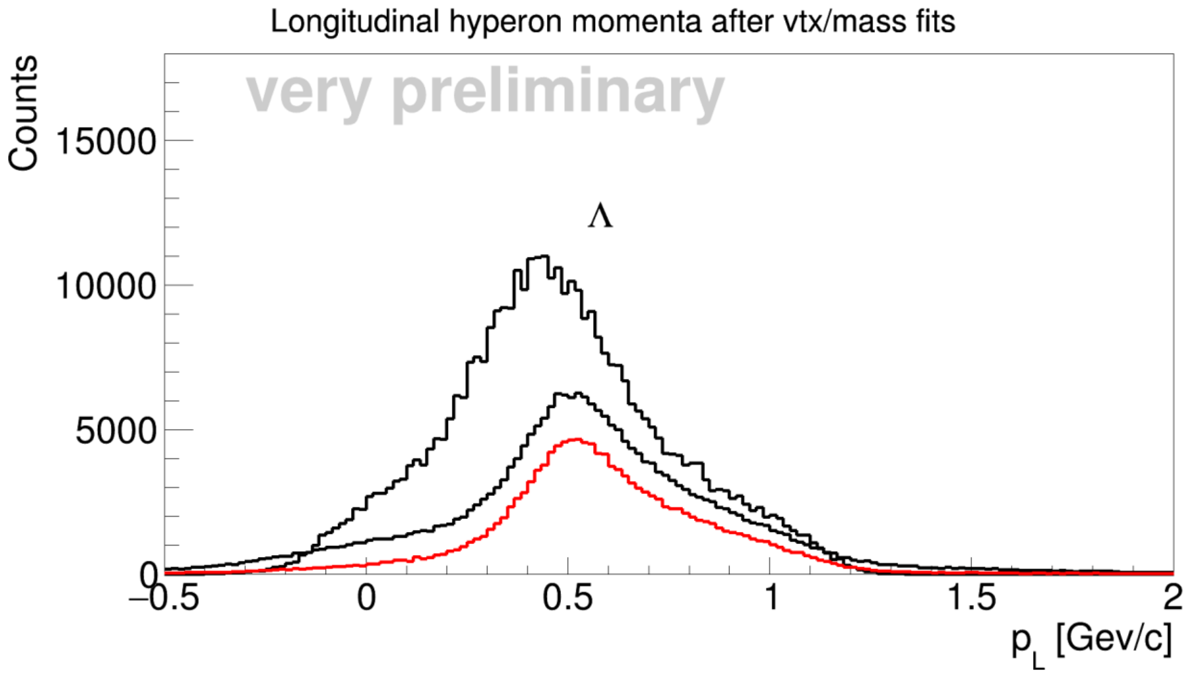
PandaRoot reconstruction for potential 1.0

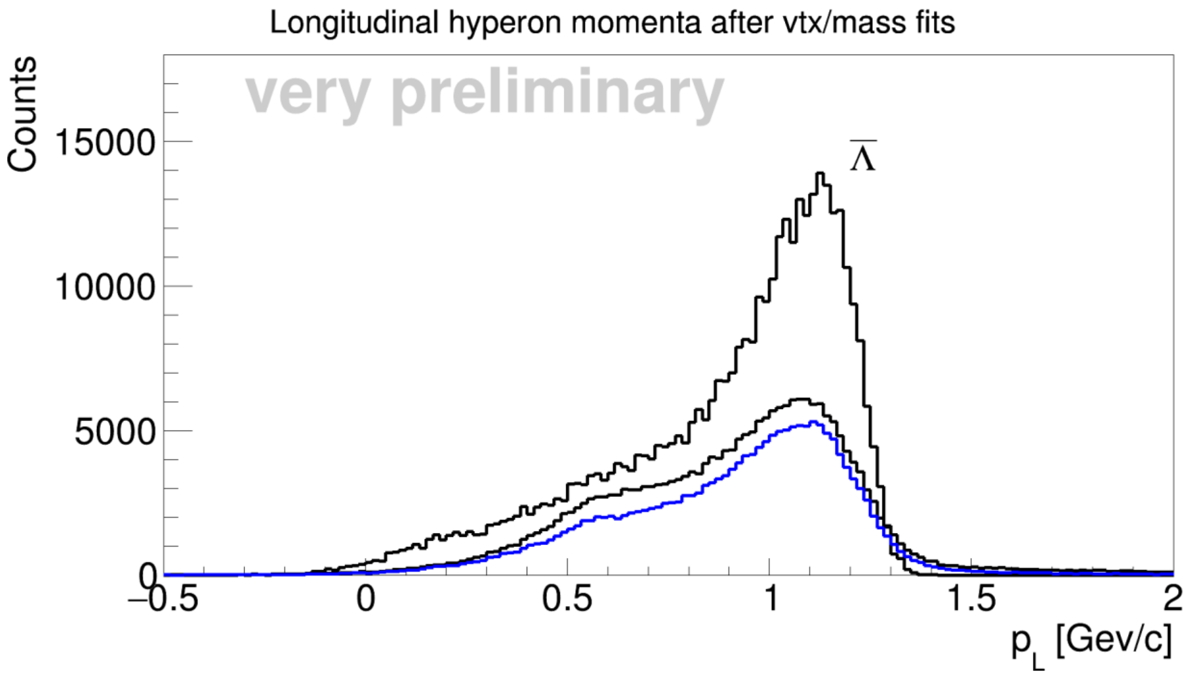


PandaRoot reconstruction for potential 1.0

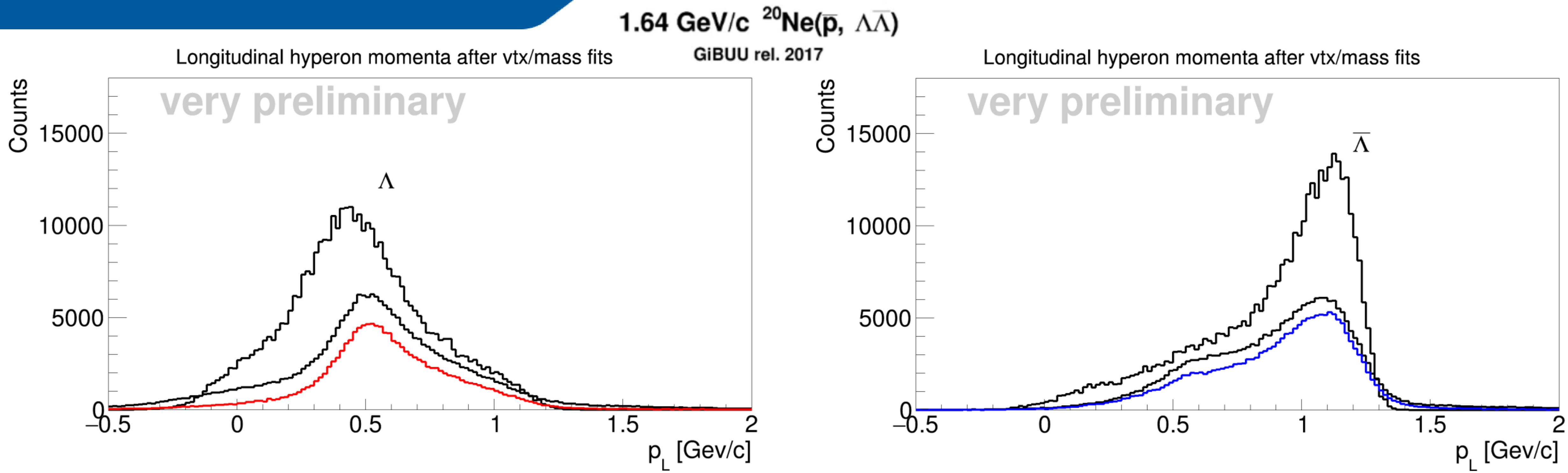
1.64 GeV/c $^{20}Ne(\bar{p}, \Lambda\bar{\Lambda})$

GiBUU rel. 2017





PandaRoot reconstruction for potential 1.0



Hyperon	MC Events	Ideal reco efficiency	Efficiency after Fits
Λ	3,9 $*10^5$	60,7%	37,1%
$\bar{\Lambda}$	3,9 $*10^5$	59,1%	46,7%

- Pair reco efficiency charged decay: ~ 17%
- **Total reco efficiency: ~ 6%**

- Compared to $p\bar{p}$->$\Lambda\bar{\Lambda}$: 15,7%

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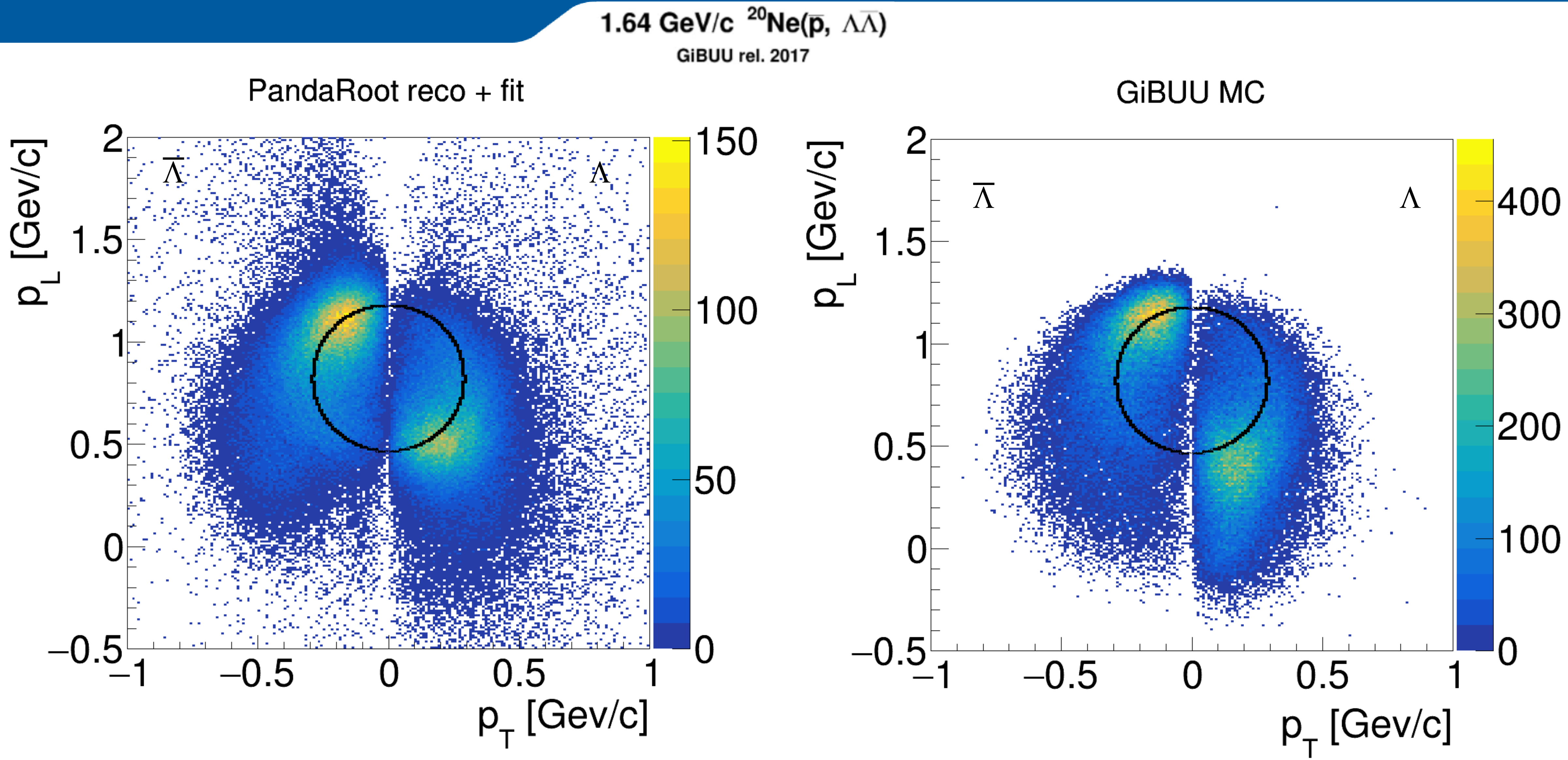
PandaRoot reconstruction for potential 1.0



HIMster2 simulations

Momentum GeV/c	Potentials	Simulated events per potential	YY for potential 0.5	PANDA runtime*	Simulation time req. on HIMster2
1,52	5	1,35 $*10^8$	37628 $\Lambda\,\bar{\Lambda}$	9,3 h	1,5 month
			4002 $\Sigma^0\,\bar{\Lambda} + \bar{\Sigma}^0\,\Lambda$		
			6724 $\Sigma^{+/-}\,\bar{\Lambda}$ + c.c.		
1,64	7	1,63 $*10^8$	82983 $\Lambda\,\bar{\Lambda}$	11,2 h	2 month
			17888 $\Sigma^0\,\bar{\Lambda} + \bar{\Sigma}^0\,\Lambda$		
			31903 $\Sigma^{+/-}\,\bar{\Lambda}$ + c.c.		
2,90	3	8,13 $*10^8$	13635 $\Xi^-\,\bar{\Xi}^+$	112 h = 4,7 d	5 month

* With 10% reco efficiency, $\Lambda\bar{\Lambda}$ charged decay prob. and HESR luminosity taken into account

- All simulations done on HIMster2 (320 nodes: Cores: 10240)
- Part of Mogon2 supercomputer
  - Johannes Gutenberg-University Mainz

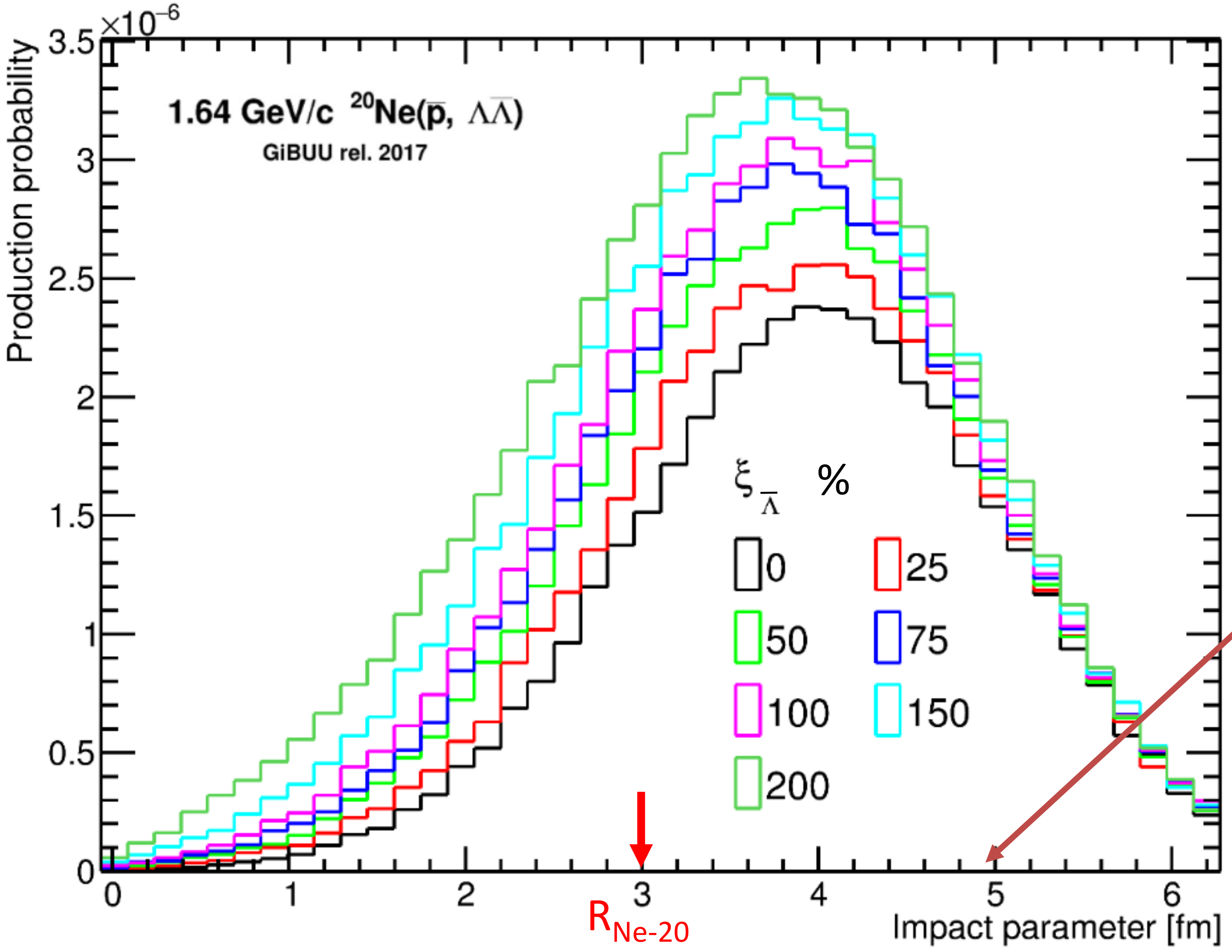
Summary/Outlook

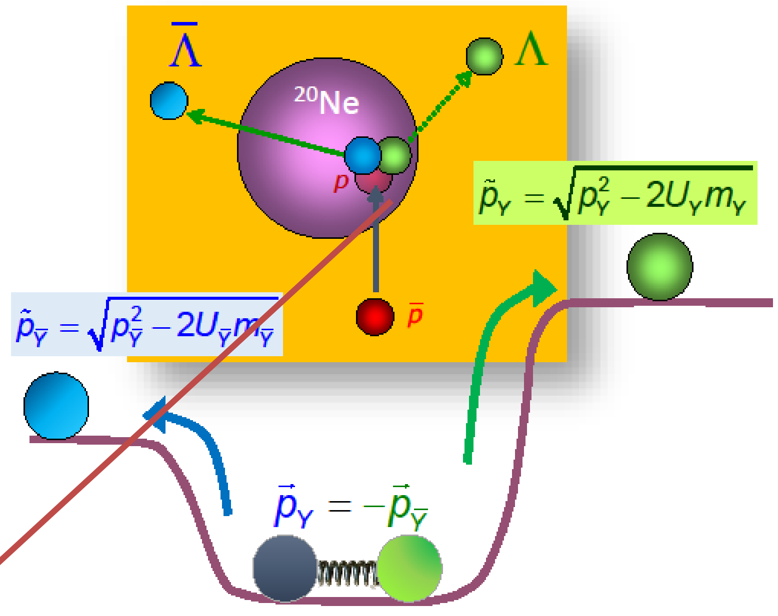
- Unique measurement of antihyperon potential in nuclei during Phase One of PANDA
- GiBUU simulations were completed for several hyperon pairs in for $\bar{p}A$ reactions
- Started with PandaRoot studies of GiBUU events

- Additional channels to study: $\Sigma^0\overline{\Lambda}$, $\Xi\overline{\Xi}$
  - Feasibility in Panda Phase One?

Thank you for your attention!

BACKUP: Hyperon absorption in nuclei





- Antihyperon strongly absorbed
  - Mainly periphery contributes
- Many simulated events will pass nuclei without reaction