Global polarization and Lambda finding in the forward upgrade

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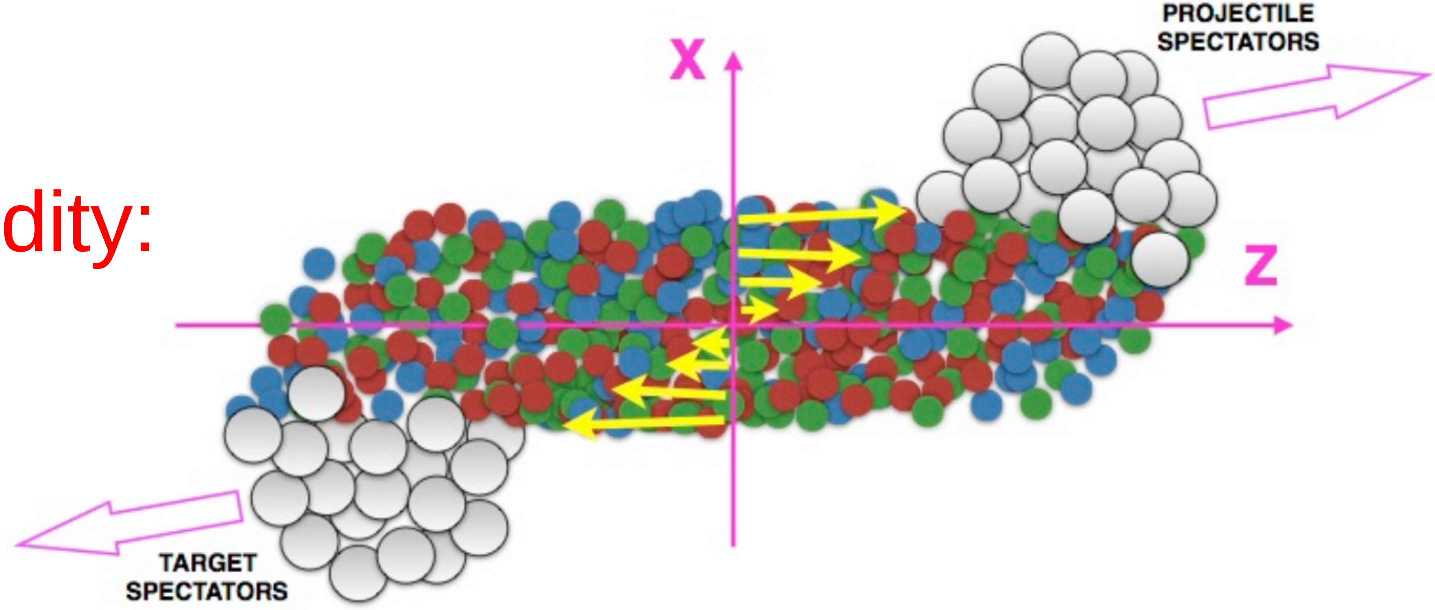
Overview

- This talk is in three basic parts
  - Polarization and the forward upgrade
  - Simulation of Lambdas in the forward upgrade
  - Tracking considerations for Lambdas

System angular momentum

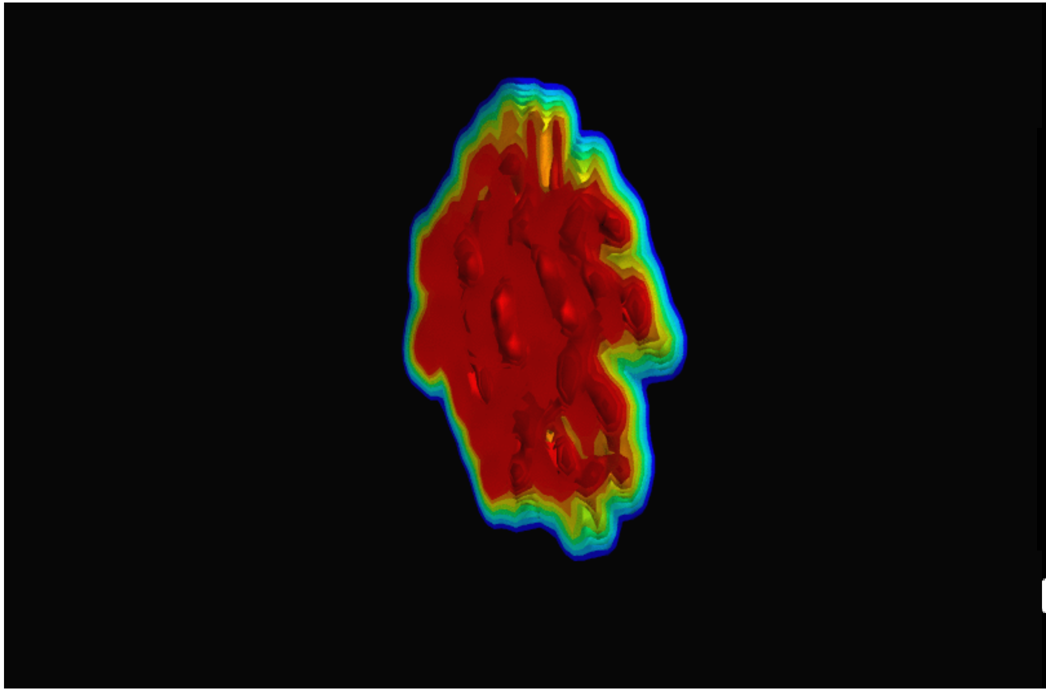
At mid-rapidity:

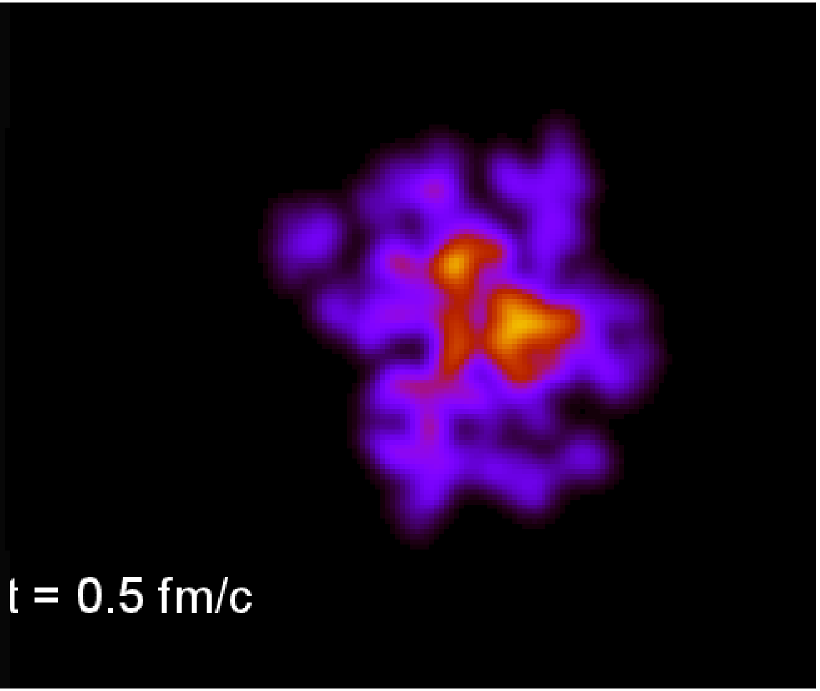
$\otimes \vec{L}$



- $|L| \sim 10^5\ \hbar$ in non-central collisions
- Dissipative processes → thermalization of angular momentum, transference to fireball
    - Hydrodynamically this is described by vorticity: $\vec{\omega} \equiv \frac{1}{2} \vec{\nabla} \times \vec{v}$

Hydrodynamic evolution





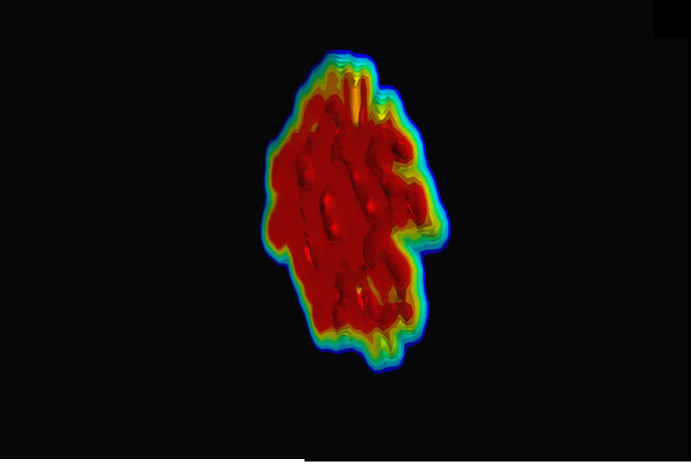
From a (lumpy) initial state, solve hydro equations:

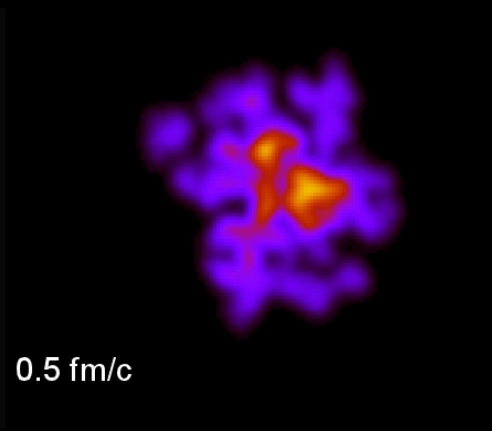
movies by Bjorn Schenke

$$d_\mu T^{\mu\nu} = 0 \qquad T^{\mu,\nu} = e u^\mu u^\nu - (p + \Pi)\Delta^{\mu\nu} + \pi^{\mu\nu}$$

$$u^\mu d_\mu \Pi = -\frac{1}{\tau_\Pi}(\Pi + \zeta\theta) - \frac{1}{2}\Pi\frac{\zeta T}{\tau_\Pi} d_\lambda\left(\frac{\tau_\Pi}{\zeta T}u^\lambda\right)$$

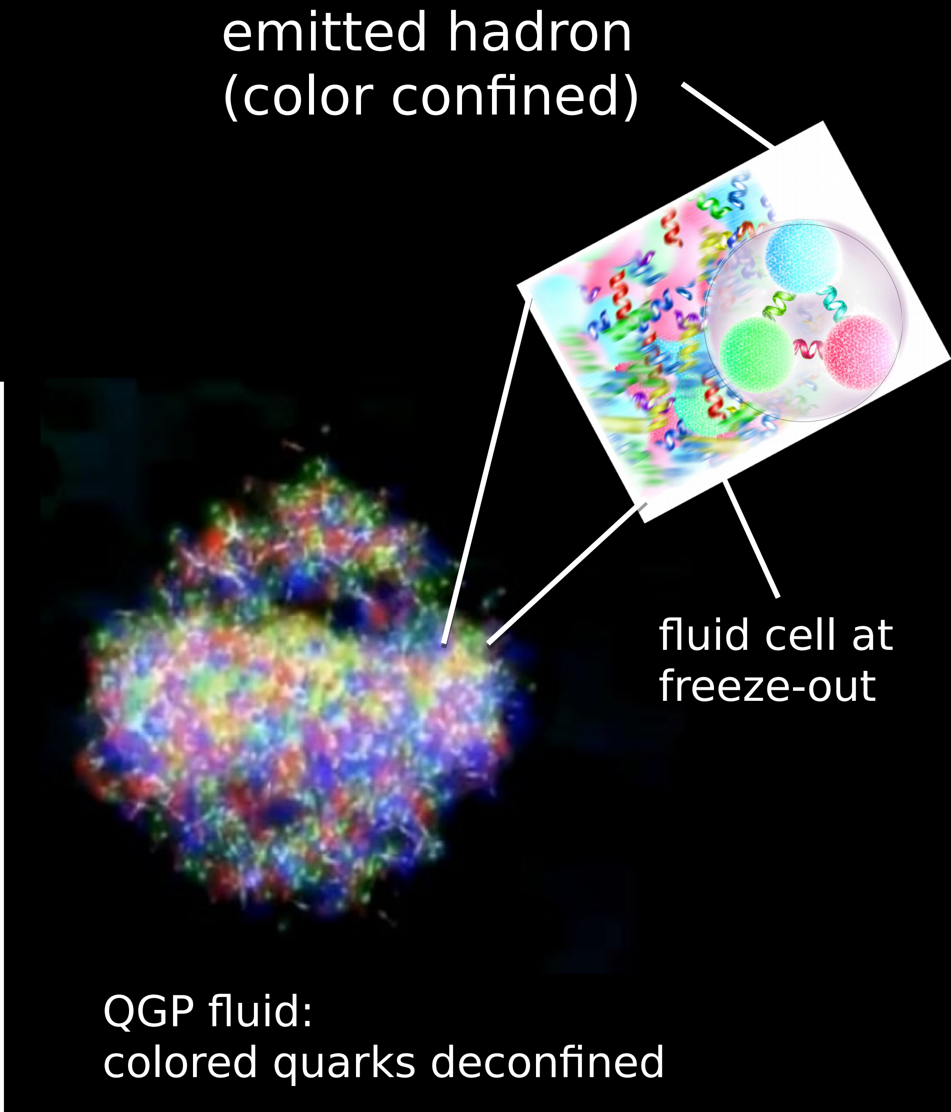
& many more terms...





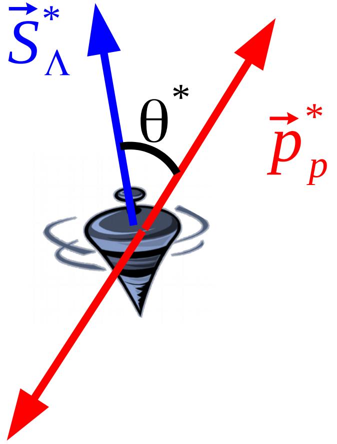
System cools & expands → Hadronization & “Freeze-out”

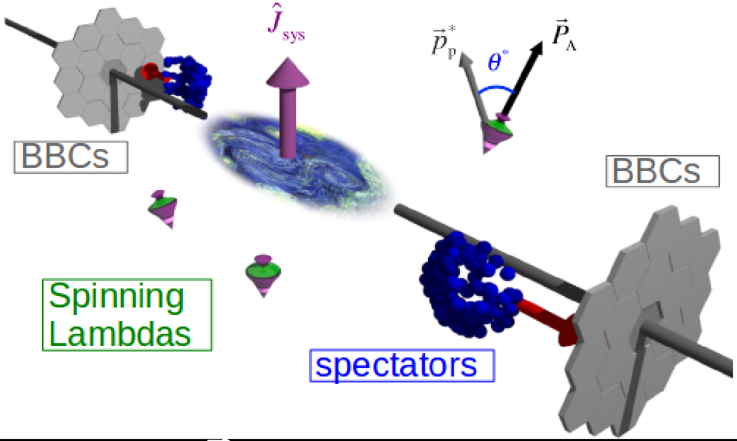
- emitted particles reflect properties of parent fluid cell (Cooper-Frye)
  - chemical potentials, thermal & collective velocities
  - In regions of local vorticity spin degrees of freedom are frozen out into particles with net polarization



Measuring polarization

- Lambdas are "self-analyzing"
  - Reveal polarization by preferentially emitting daughter proton in spin direction





Λs with Polarization $\vec{P}$ follow the distribution:

$$\frac{dN}{d\Omega^*} = \frac{1}{4\pi}\left(1+\alpha\,\vec{P}\cdot\hat{p}^*_p\right) = \frac{1}{4\pi}\left(1+\alpha\,P\cos\theta^*\right)$$

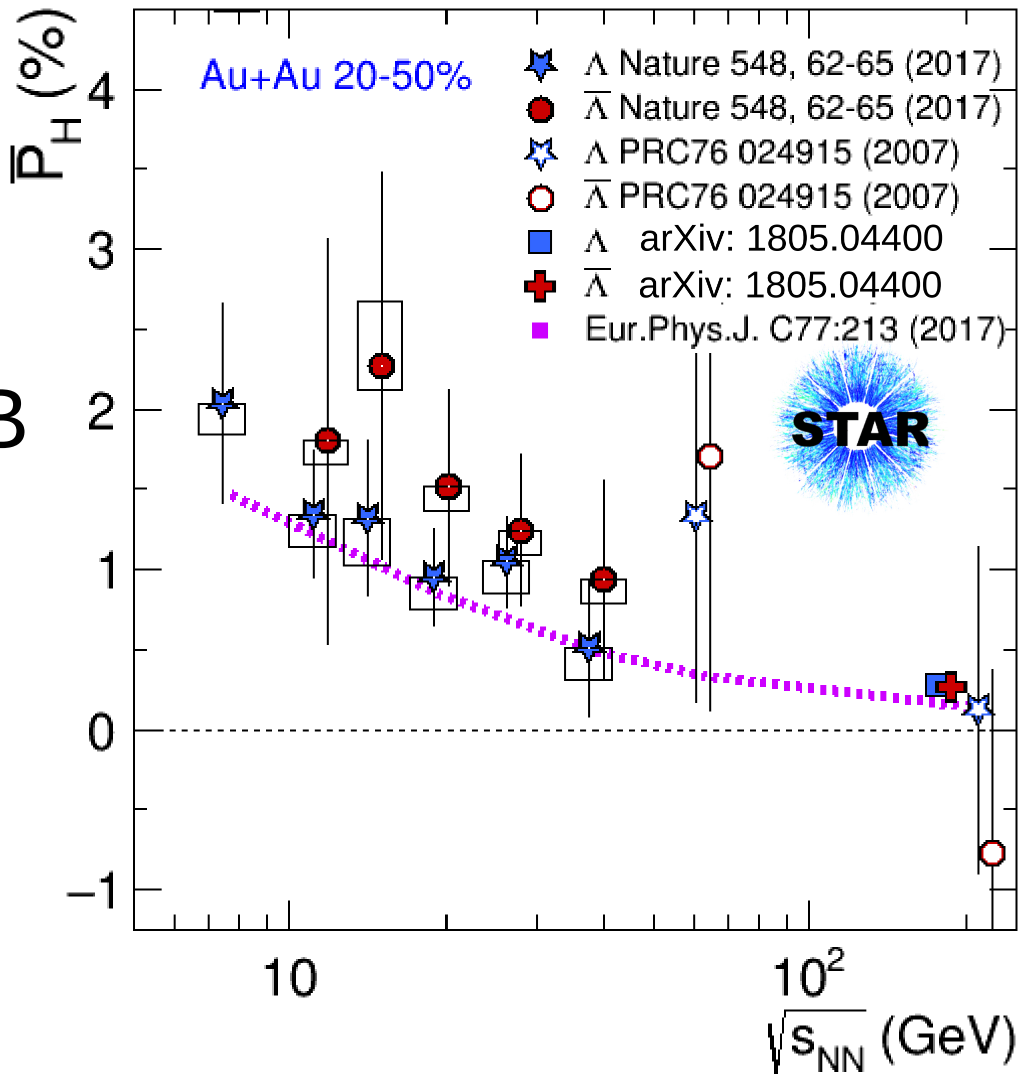
$$\alpha = 0.642 \pm 0.013 \quad \text{[measured]}$$

$\hat{p}^*_p$ is the daughter proton momentum direction *in the Λ frame*

$$0<|\vec{P}|<1: \quad \vec{P} = \frac{3}{\alpha}\overline{\hat{p}^*_p}, \qquad P_{AVE} = \frac{8}{\pi\alpha}\frac{\langle\sin(\Psi_1-\phi^*_p)\rangle}{R^{(1)}_{EP}}$$

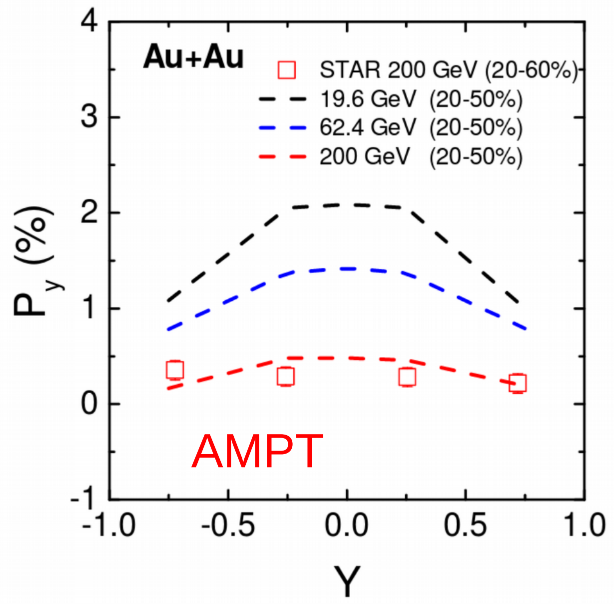
Measurements

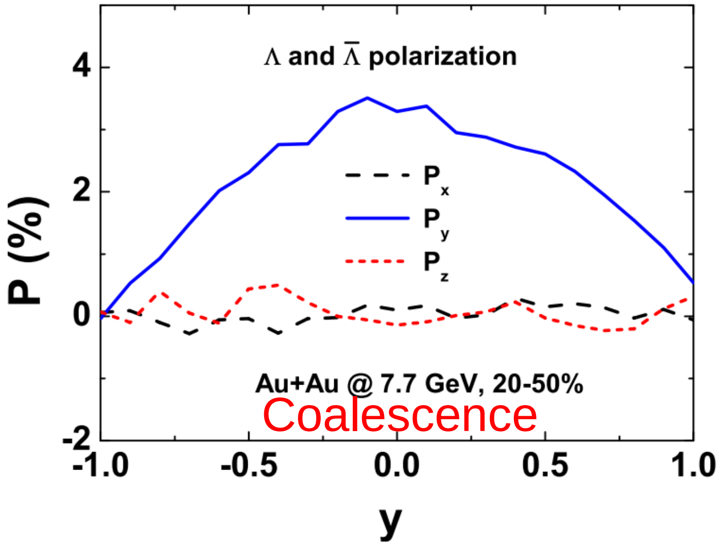
- At 200GeV this is ~ a 5σ result utilizing ~1.5B events (2010 + 2011 + 2014)
- Theory (both AMPT and hydro) describes data well



Forward polarization

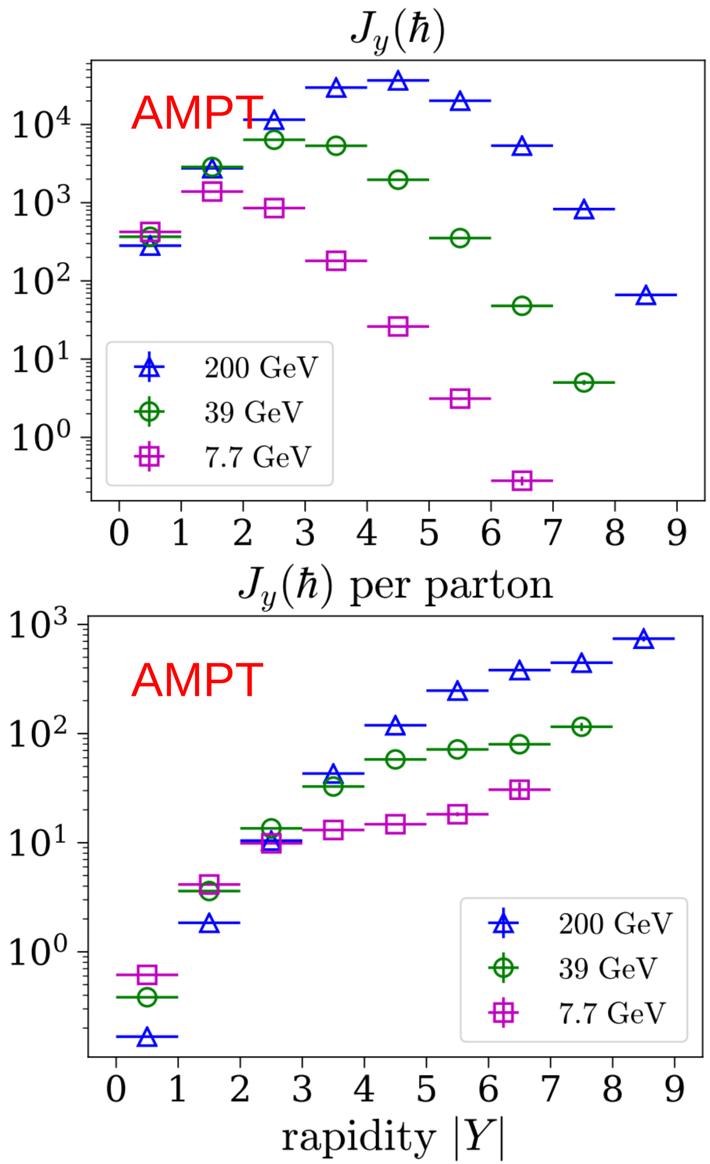
- AMPT and coalescence model predict polarization will fall for forward Lambdas
- If we the trend goes to zero in the FWD acceptance
  - If we collect ~ same statistics as combined mid-rapidity measurement we would have a ~3σ result





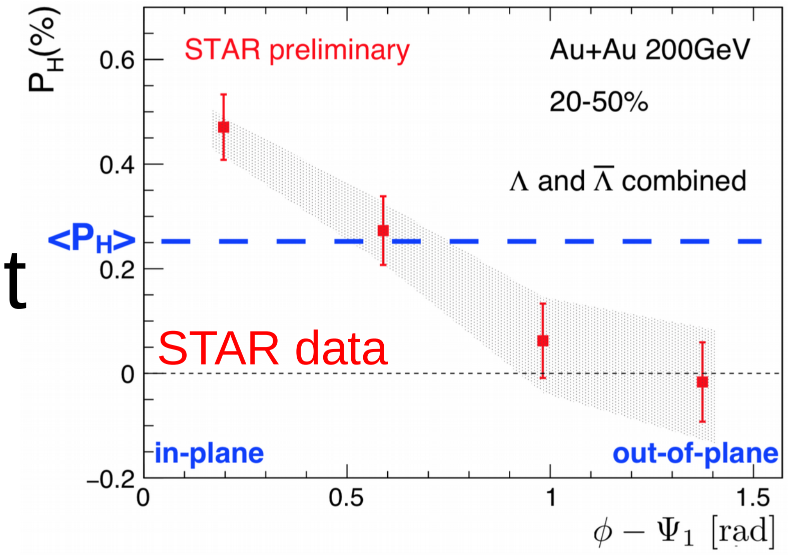
Alternate possible trend

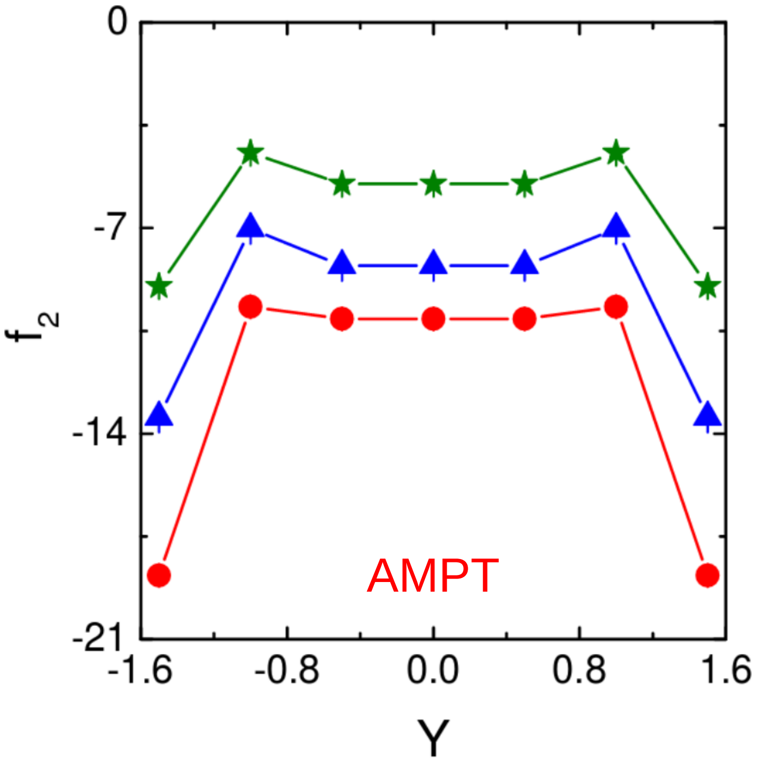
- The angular momentum increases with rapidity
  - forward region is often parallel to lower energies
  - Perhaps the model calculations predictions are not quite right
- If we want to distinguish between increasing and decreasing polarization the statistics requirement is significantly less



Related measurements I

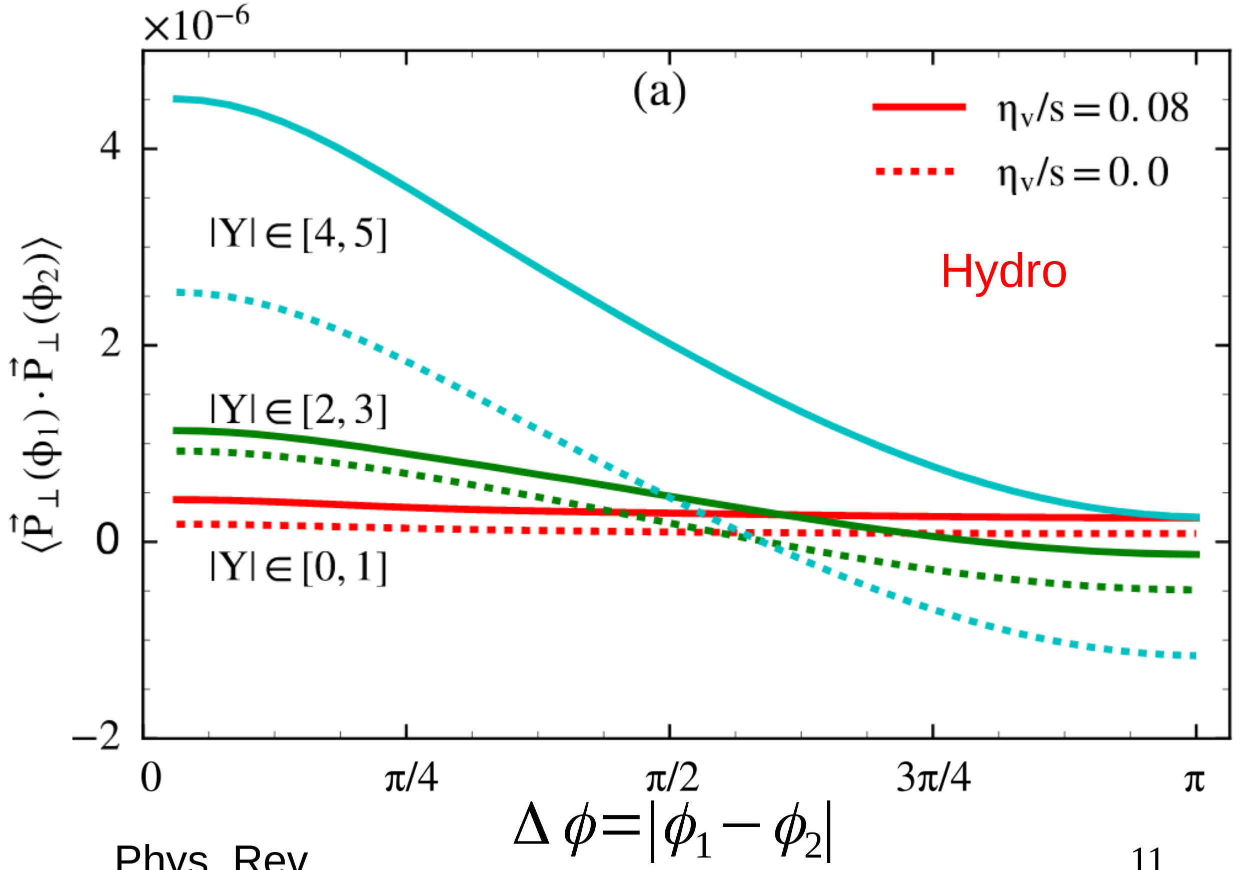
- Lambda emission angle dependence of polarization might be strongly dependent on rapidity
- f2 is proportional to the data fit by a cosine





Related measurements II

- Two particle spin-spin correlations may be very sensitive to rapidity
  - (as seen in this hydro calculation)



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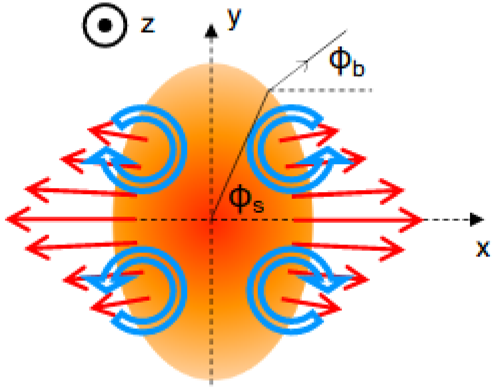
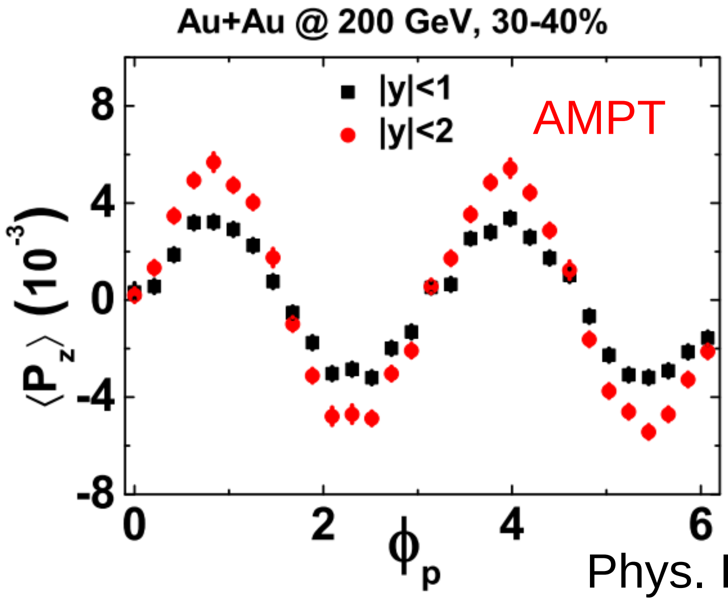
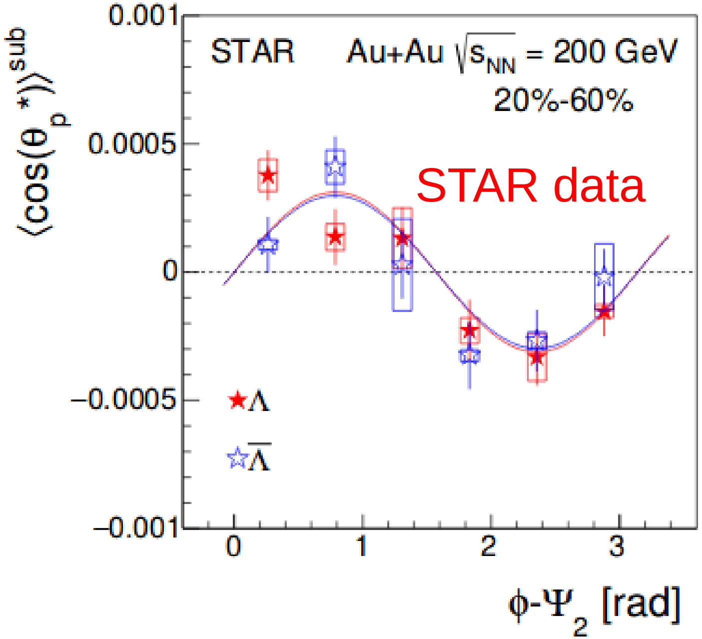
Related measurements III



- Longitudinal polarization
  - V2 velocity gradients → vorticity quadrupole
- Measure as a function of rapidity



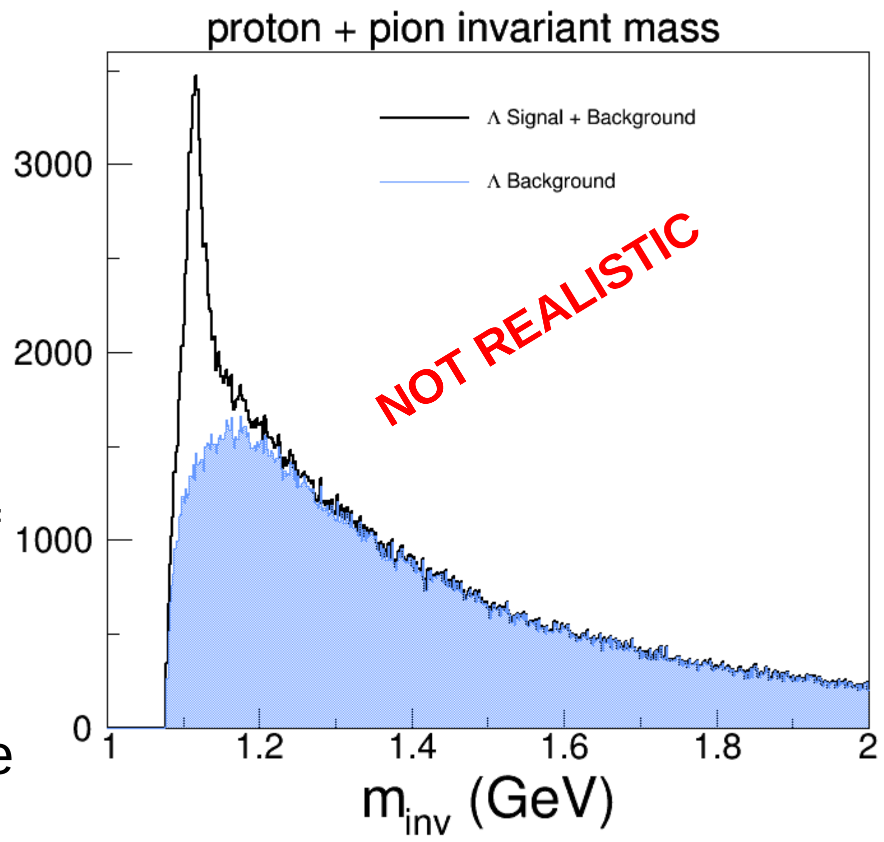


Phys. Rev. C 99.011903

Detailed forward upgrade simulation

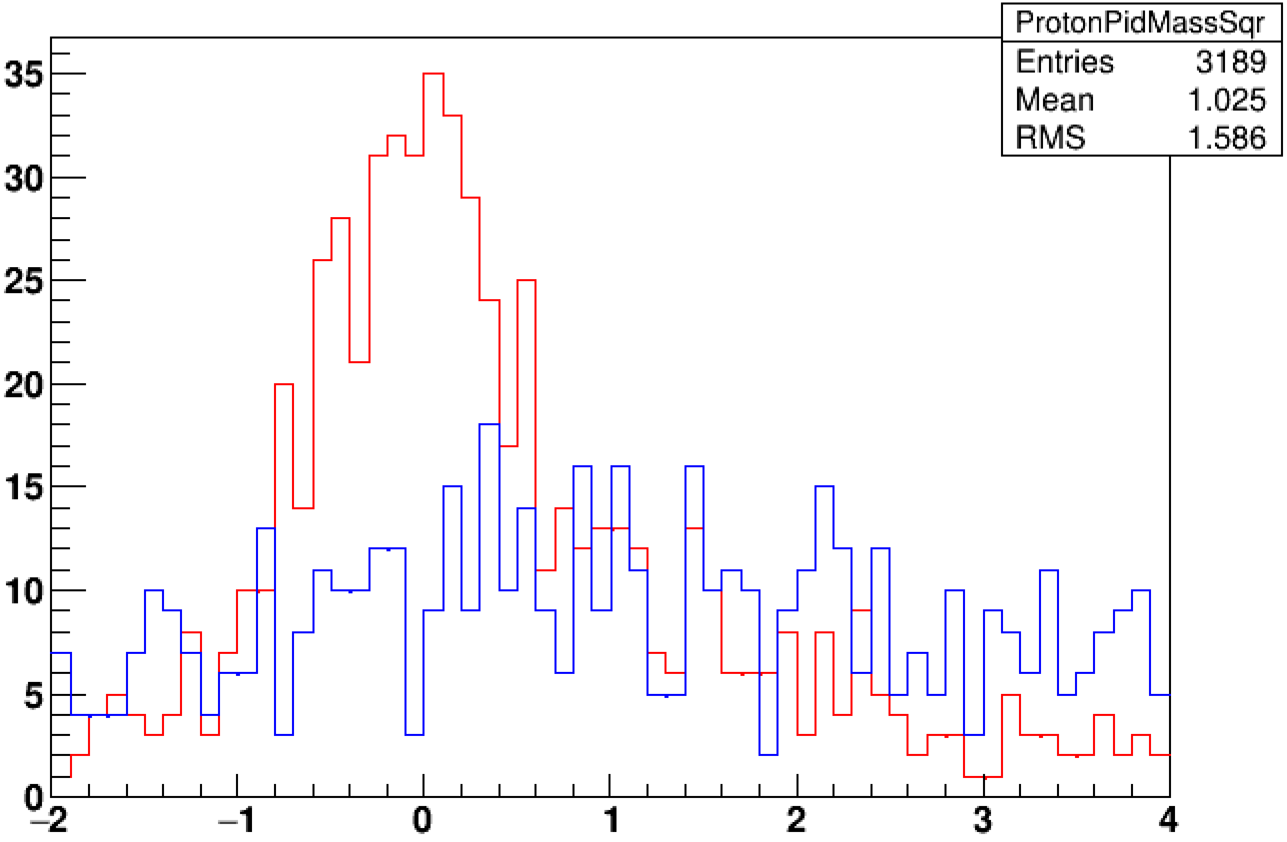
Forward upgrade simulation report

- PYTHIA simulation from review of forward upgrade in November
  - old geometry
  - old tracker
  - uniform B field
- Assumptions
  - Perfect PID (this is big), MC p + π match
  - Perfect matching with FCS
  - FCS simulator is simply Gaussian smearing of 50%/sqrt(E) (energy is from MC track)
- 28% efficiency for reconstruction
- We need to figure out PID, or how to do the measurement without it



Forward PID

- Here I find mass squared by using the FCS energy “measurement” and the FTS momentum measurement
- Protons are in blue
- Pions are in red
- There is no chance to use this alone for PID



Mass squared (GeV^2)

Considerations for no PID measurement

- Both Lambda and AntiLambda are polarized along the direction of the *positive* daughter (proton for Lambda and π+ for AntiLambda)
- Unlike some measurements (e.g. flow, HBT, etc.) combinatorial background is expected to have no residual or false signal

Lambda-specific forward tracking considerations

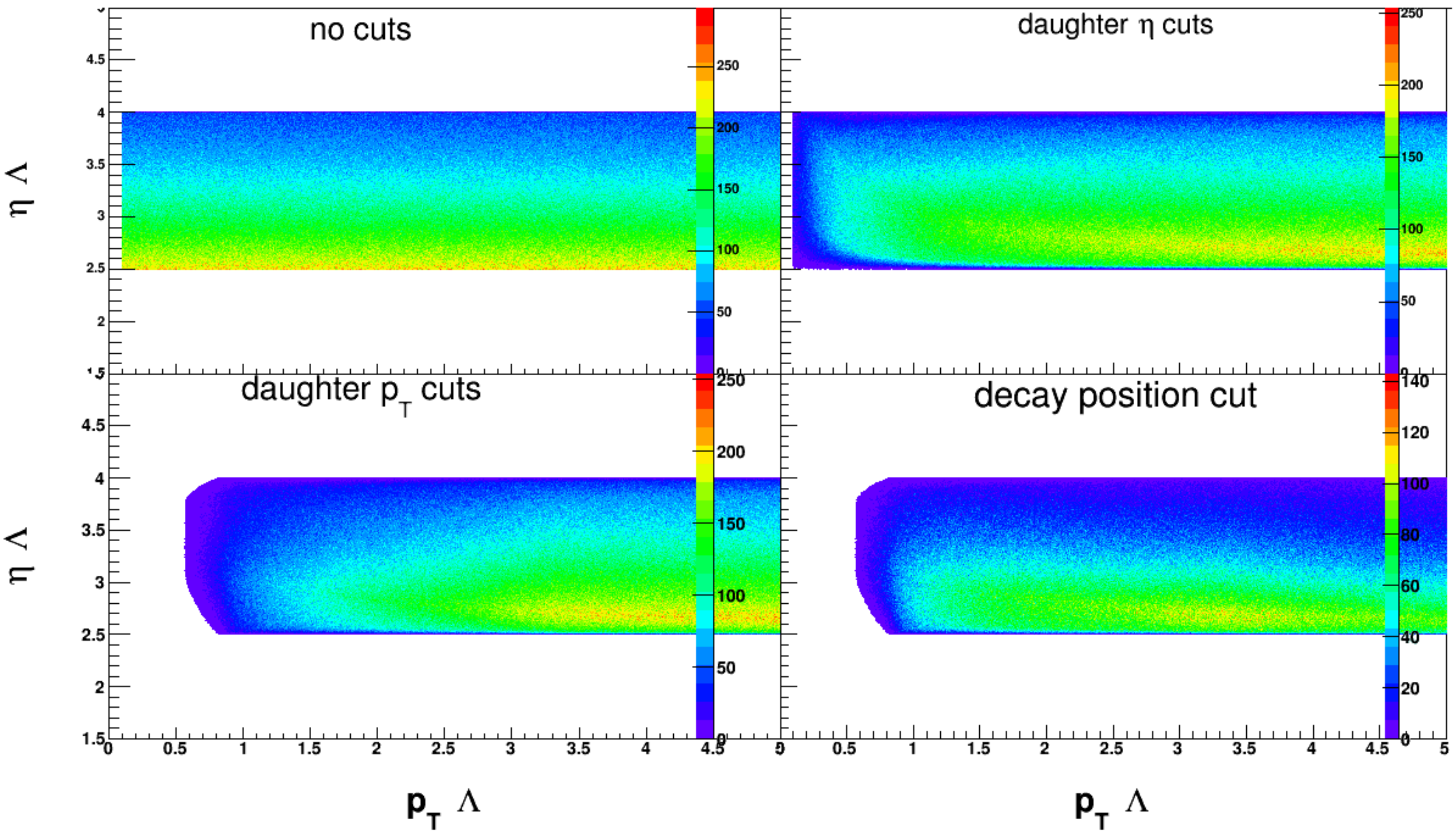
Tracking considerations

- For the forward upgrade the primary vertex is by far the most precise fit point, so secondaries are missing an important part of the projection
  - This can decrease resolution of non-primary global tracks
  - If tracks creation vertex is far from the PV, then cones for finding hits working backwards may miss creation vertex altogether
- Use a very basic simulation to inform tracking strategy for secondaries

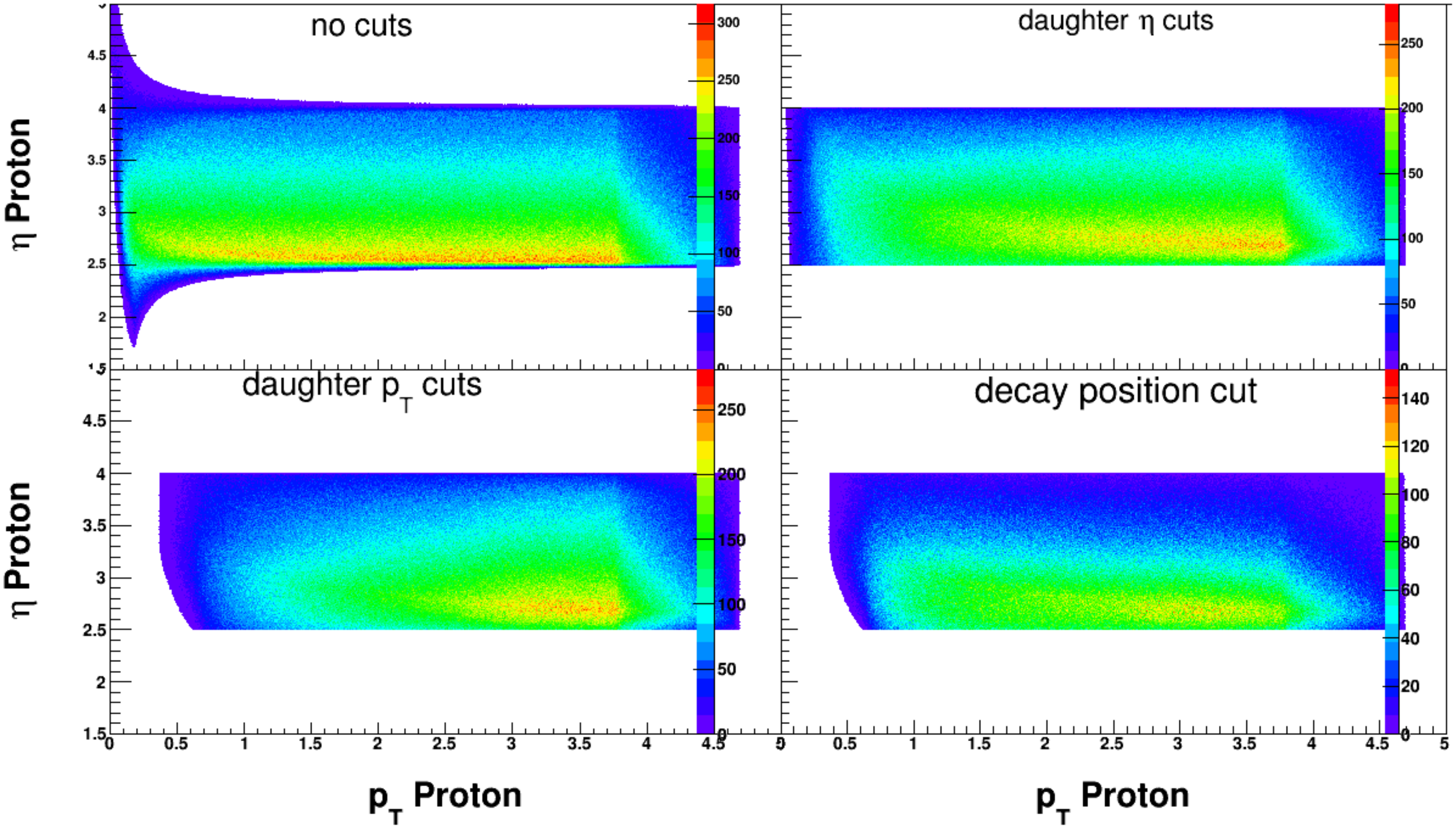
What to test

- What do geometric distributions look like as basic track-type cuts are applied?
- Method: shoot Lambdas in FTS acceptance ($2.5 < \eta < 4$) and compare effects as daughter track cuts are applied
- Types of track cuts
  - No cuts (generator level)
  - Eta cuts: apply $2.5 < \eta < 4$ to Lambda daughters (82% of generated Lambdas pass)
  - pT cuts: analyses process with pT > 0.2GeV → apply this to daughters (63% of generated Lambdas pass)
  - Decay position cut: Z component of Lambda decay position must be before the Si disks, nominally require < 140cm (29% of generated Lambdas pass)
- In terms of relative ratios these are 82%, 77%, and 38% respectively

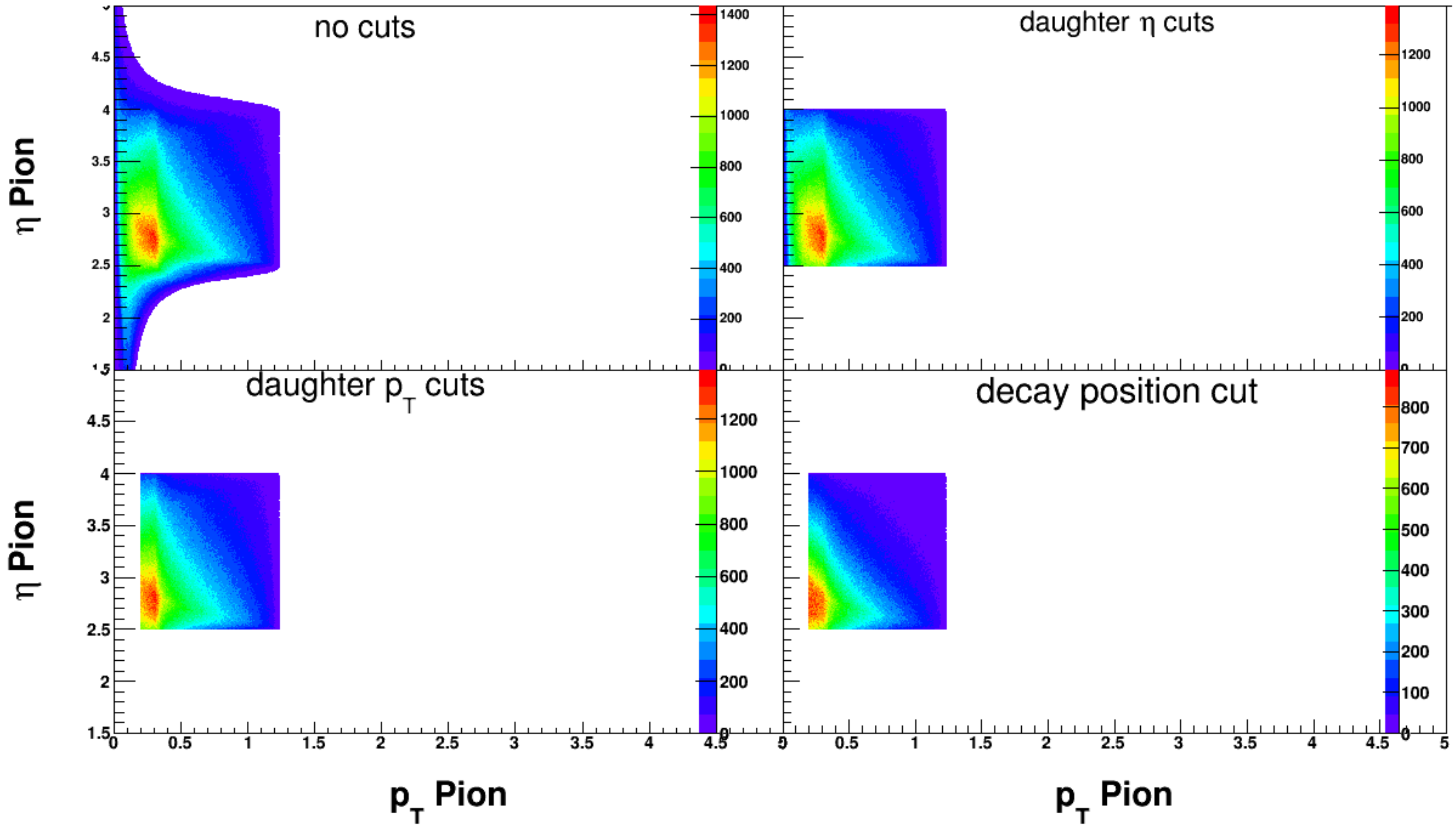
Sampled Lambda phasespace



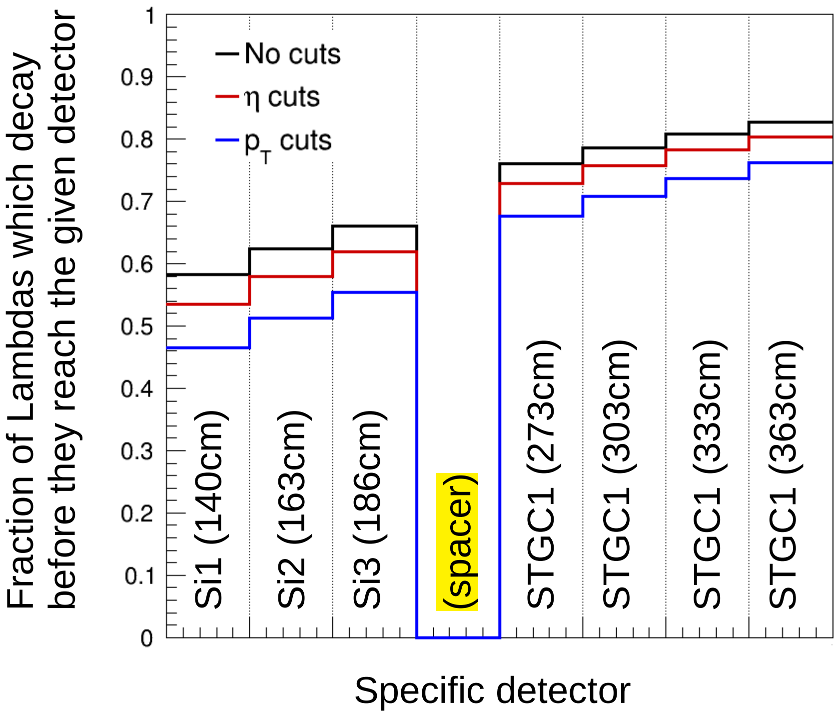
Proton phasespace

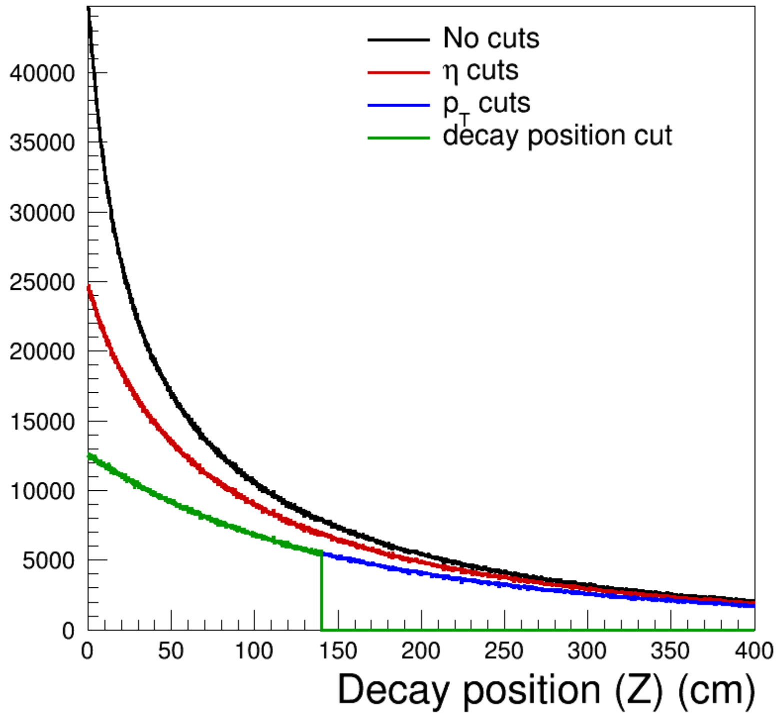


Pion phasespace

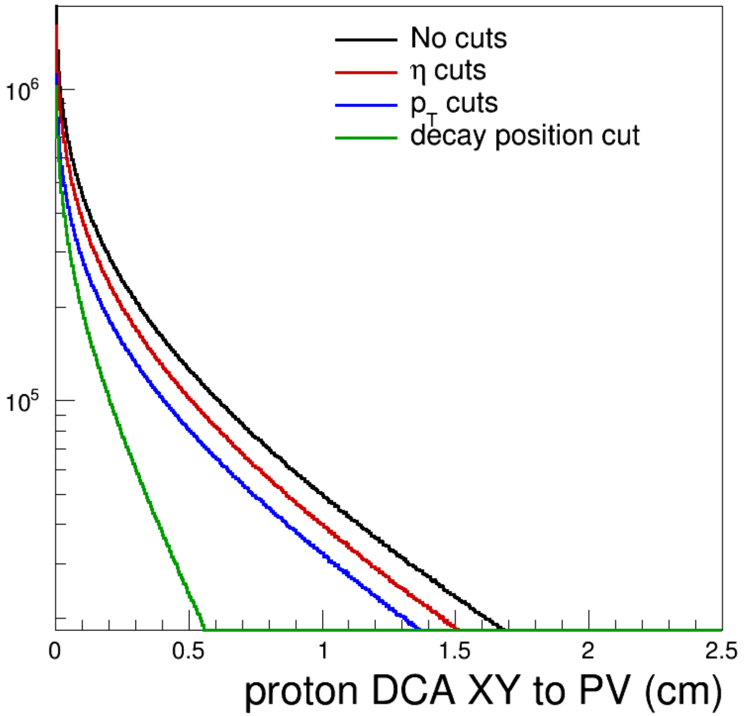


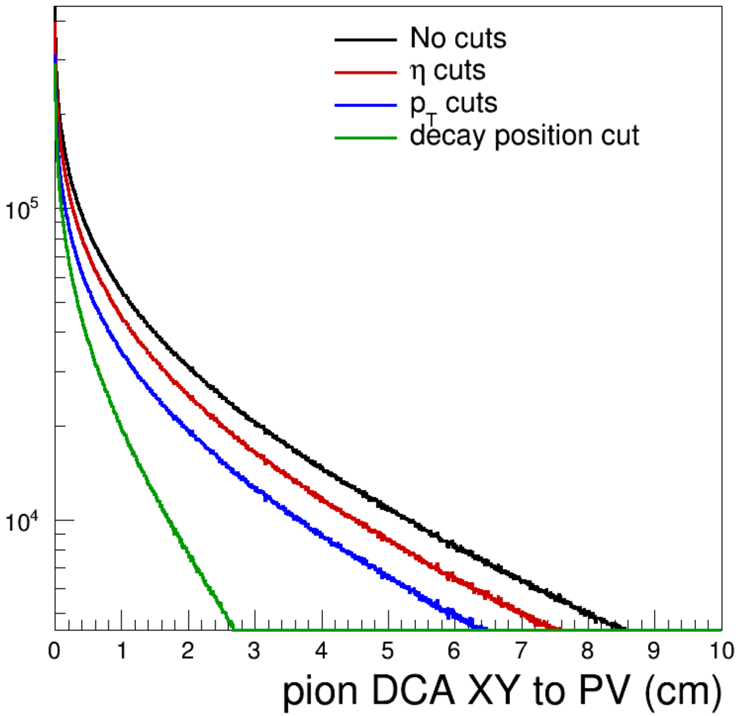
FWD detector exclusion as a function of decay position



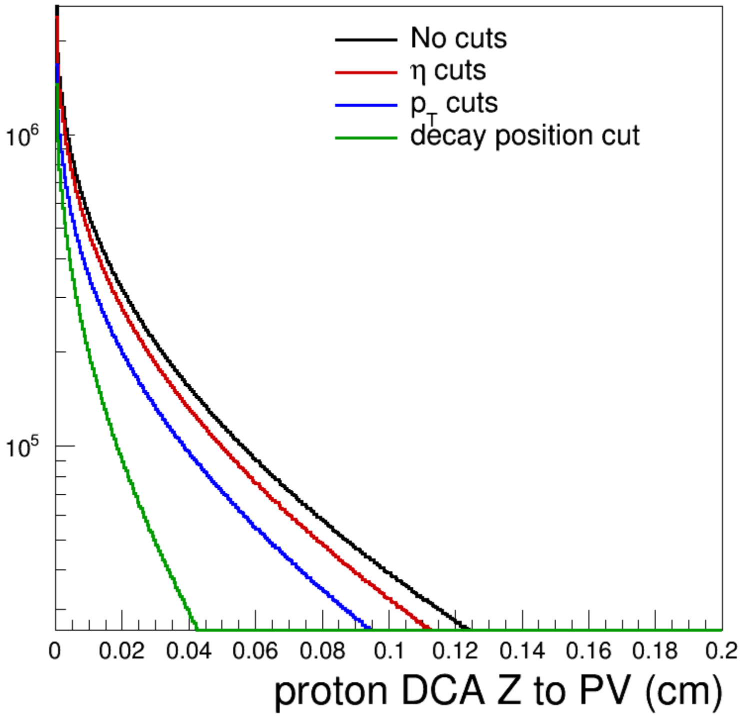


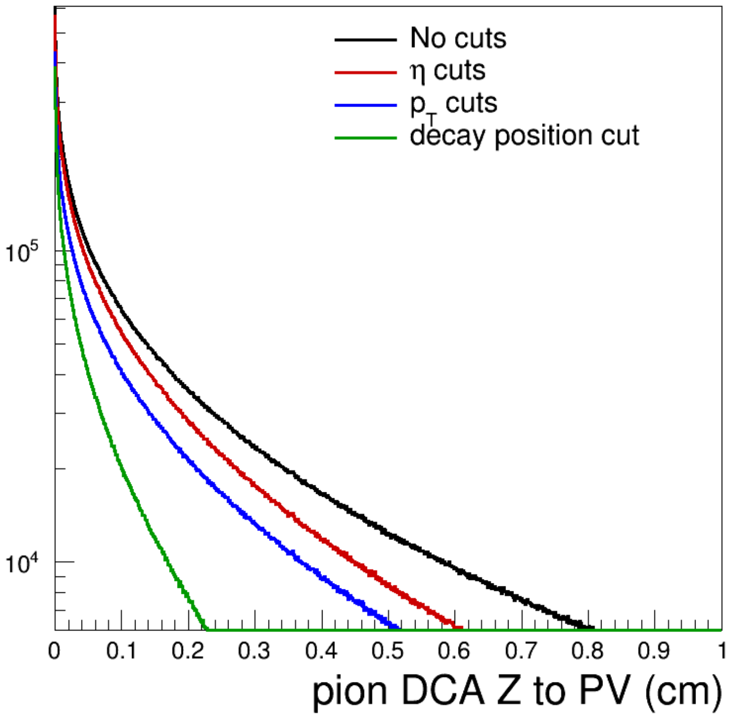
Transverse component of proton and pion DCA to PV





Longitudinal component of proton and pion DCA to PV





Conclusion

- Polarization measurements for rapidity dependence
  - Averaged polarization
  - Spin-spin correlation
  - Lambda emission angle dependence
  - Longitudinal polarization
- Lambda reconstruction
  - Simulation studies look okay, but have not been realistic
  - PID strategy is unknown
  - This needs to be revisited once the tracker is in better shape
- Tracking considerations
  - Many Lambdas in acceptance are still unmeasurable
  - DCAs of secondaries are well within reasonable track-finding windows