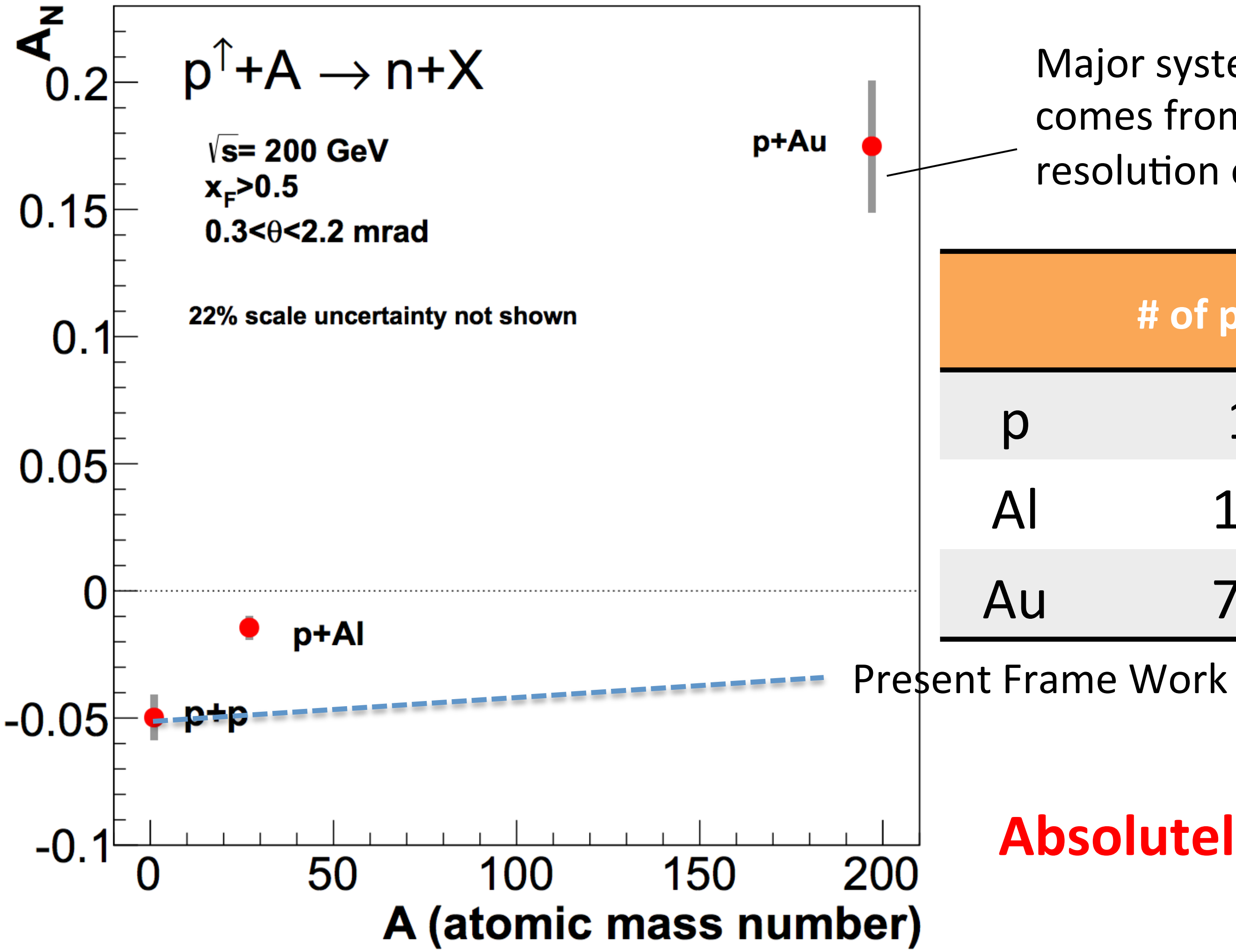
# Forward Neutron Asymmetry of p+A Measurement using Fixed Target

I. Nakagawa
for the RHICf Collaobration

# $A$-Dependent $A_N$ (inclusive)



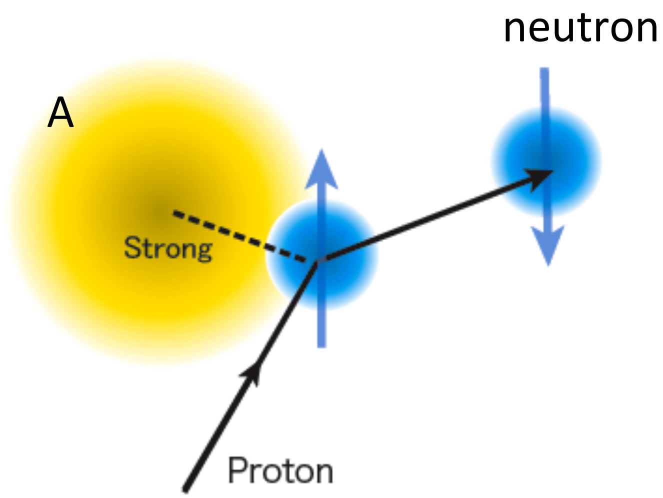

Major systematic error comes from poor position resolution of SMD.

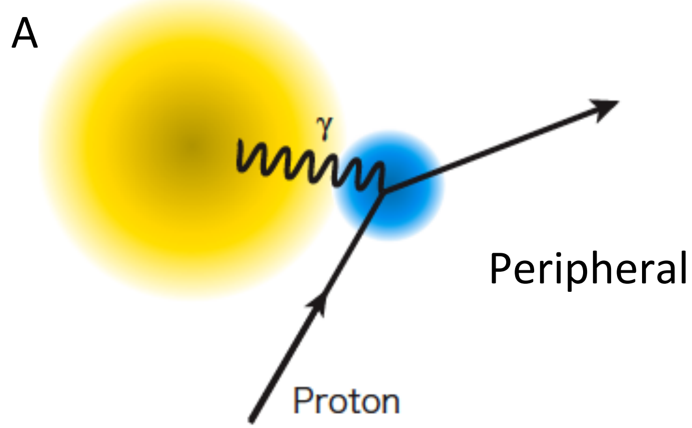
| | # of proton | # of neutron |
|---|---|---|
| p | 1 | 0 |
| Al | 13 | 14 |
| Au | 79 | 118 |

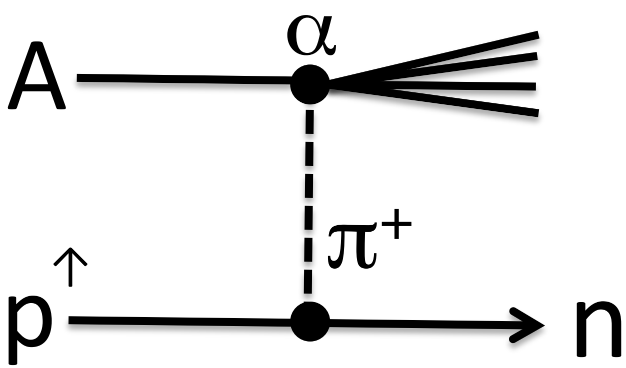
**Absolutely Unexpected!**

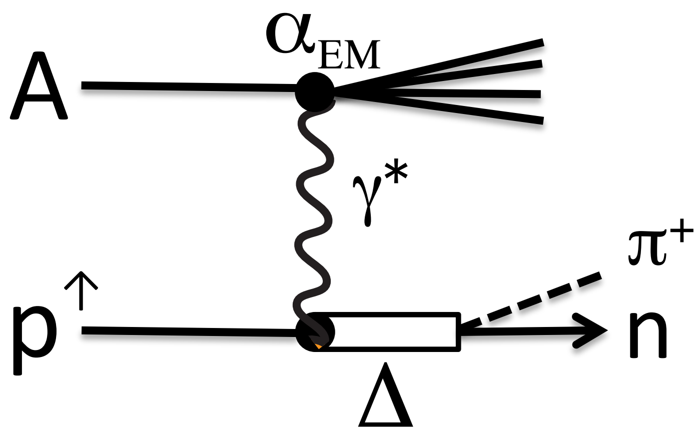
Analysis by
Minjung Kim (SNU/RIKEN)

# Ultra Peripheral Collision (UPC)



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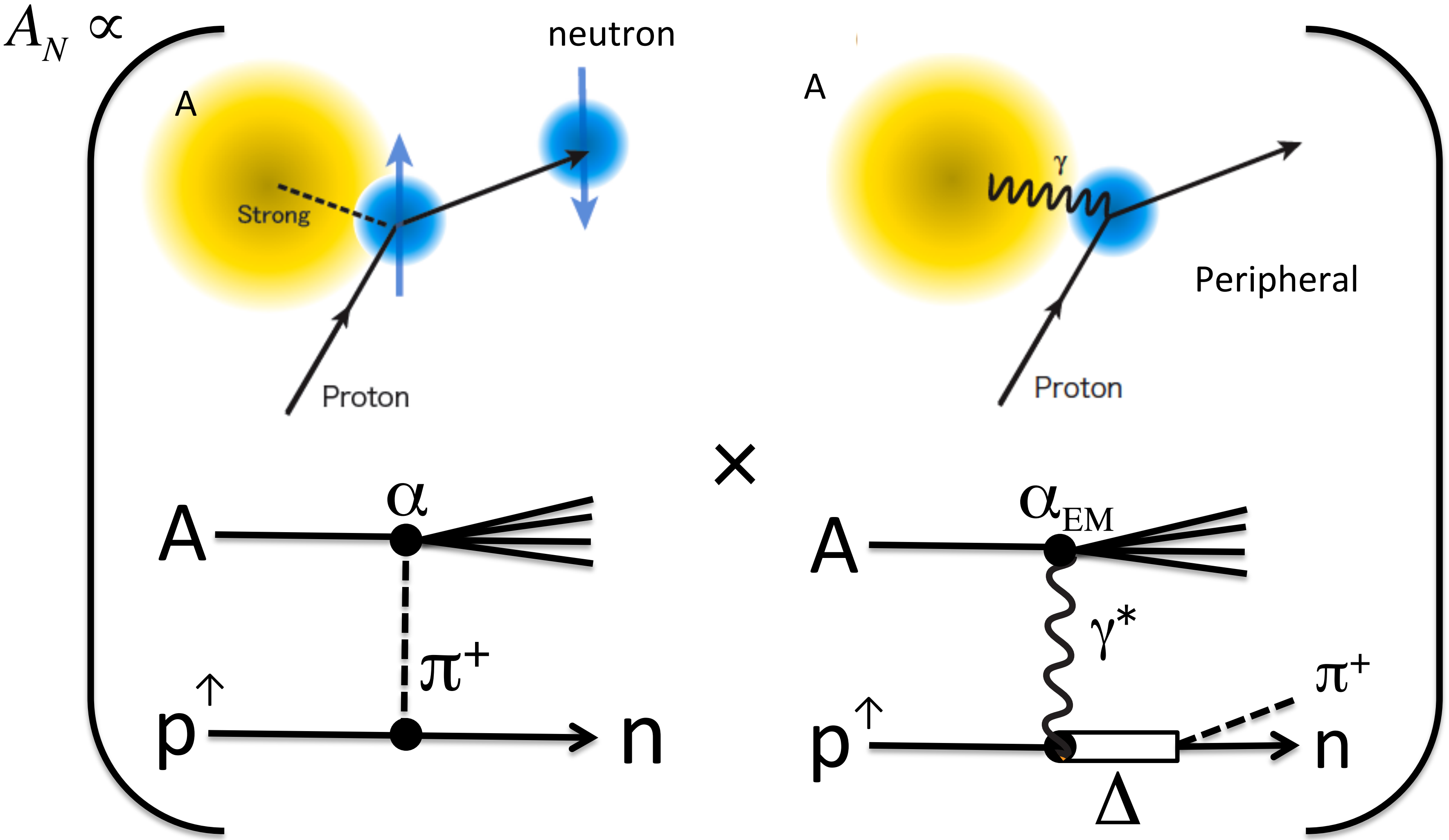
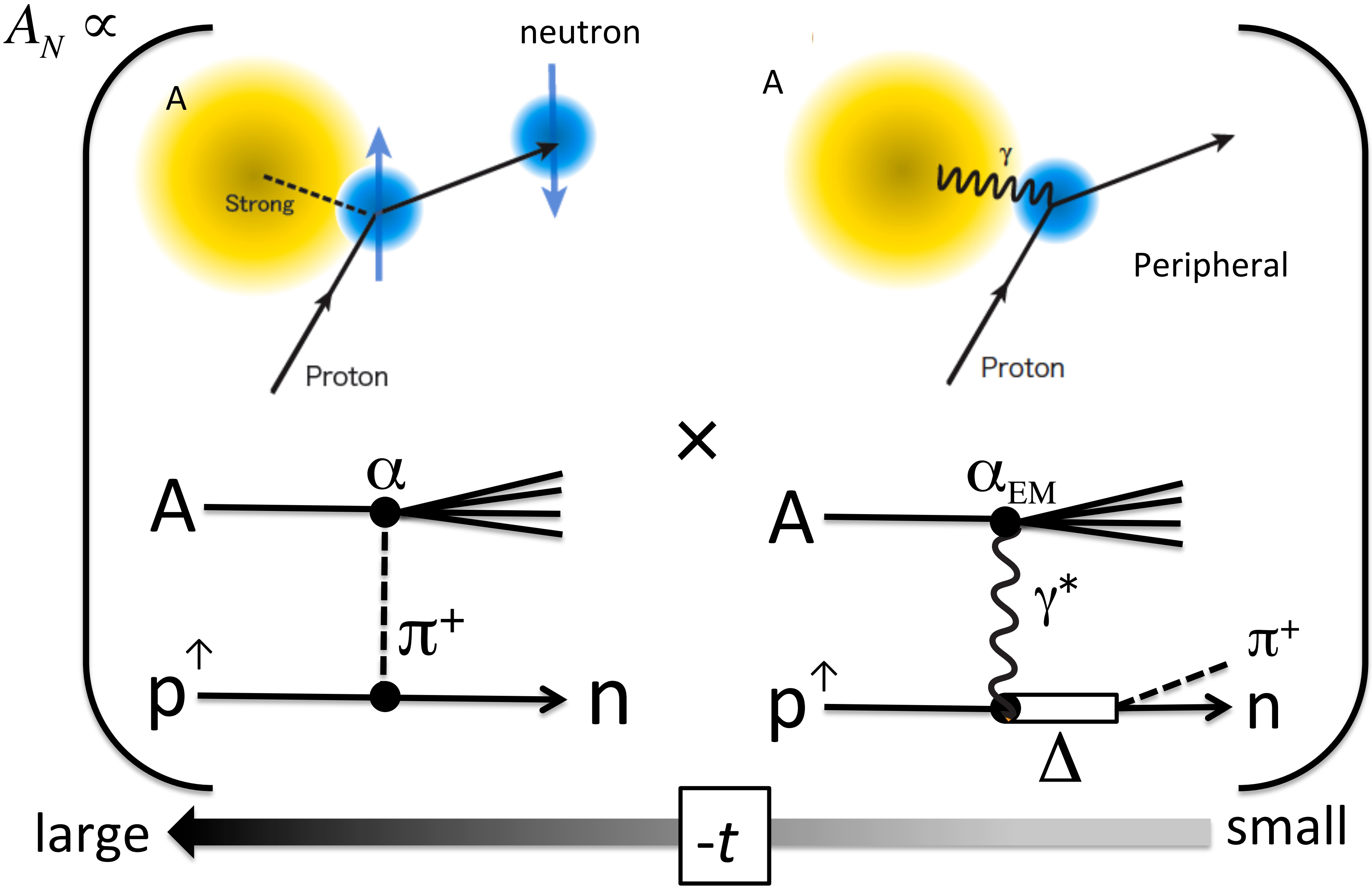
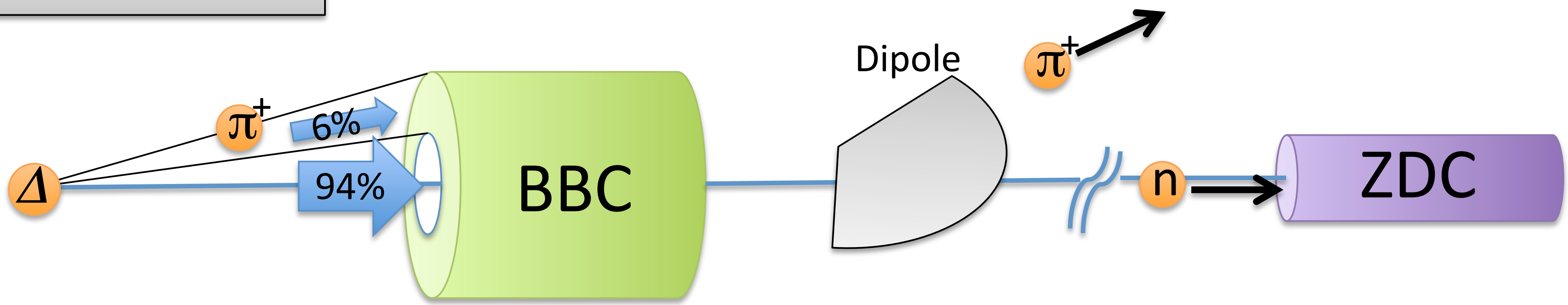


# Ultra Peripheral Collision (UPC)



# Can we identify UPC events?

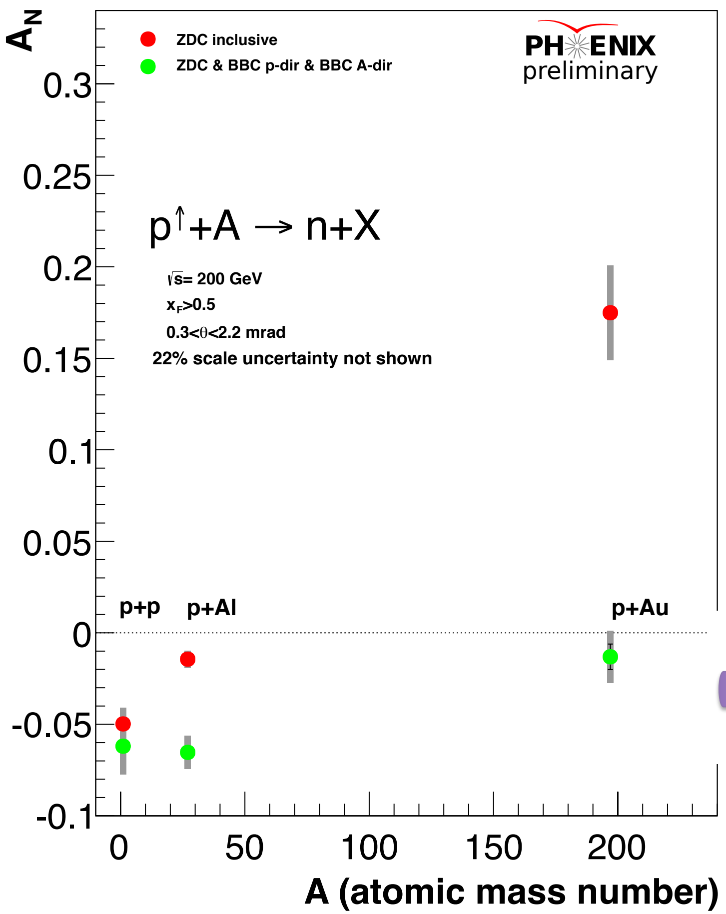
Semi-Inclusive

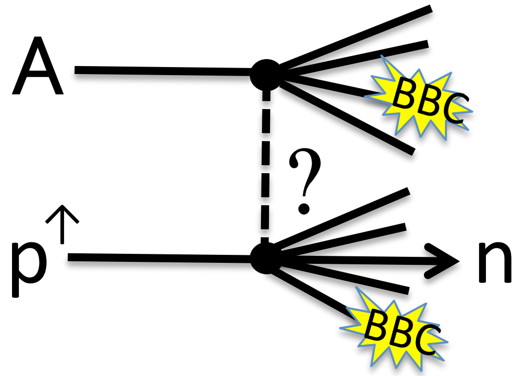



UPC MC : SOPHIA
G. Mitsuka, Eur. Phys. J.C. (2015) 75:614

| BBC | tag | veto |
|---|---|---|
| UPC | Small | Large |

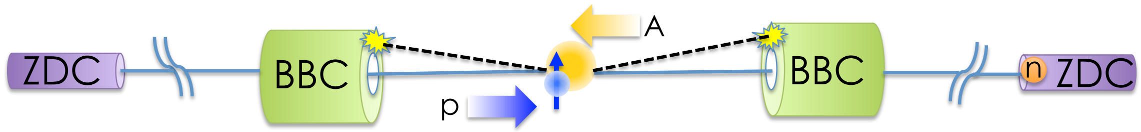
# BBC Tagging and Vetoing



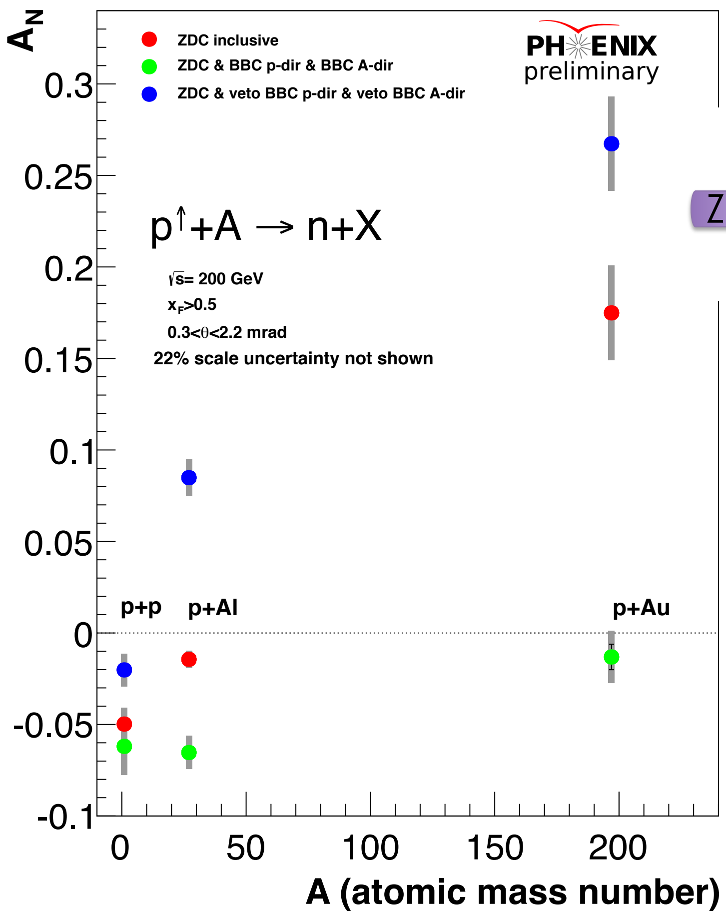

**Non-diffractive**

**BBC Tagging**

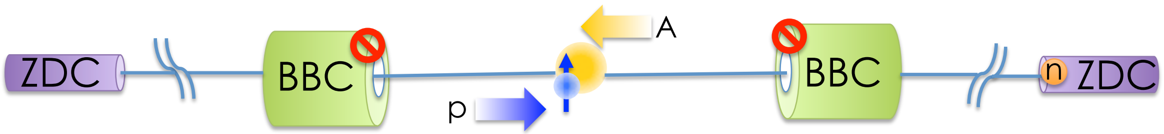


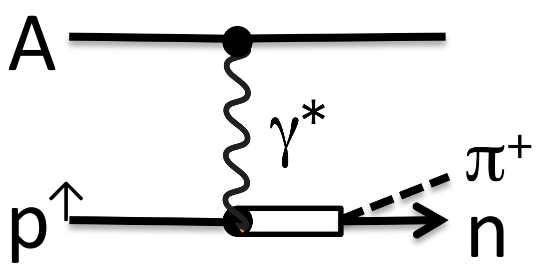

$$A_N \sim \boxed{had * had} + \overbrace{had * EM + EM * had + EM * EM}^{\text{EM surpressed}}$$

# BBC Tagging and Vetoing




**BBC Vetoing**

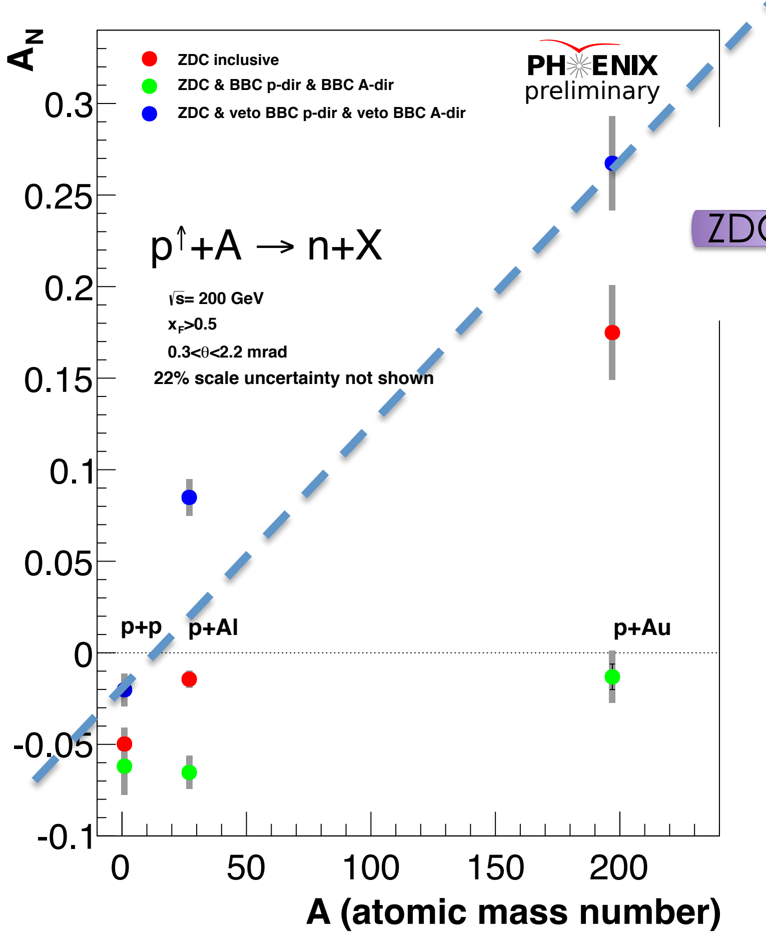


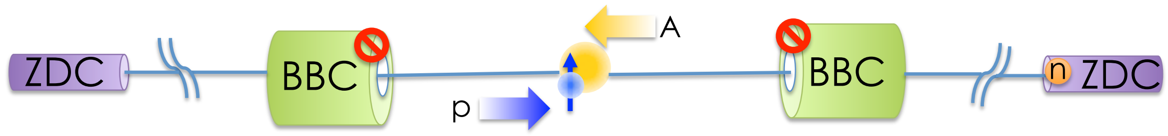

Diffractive

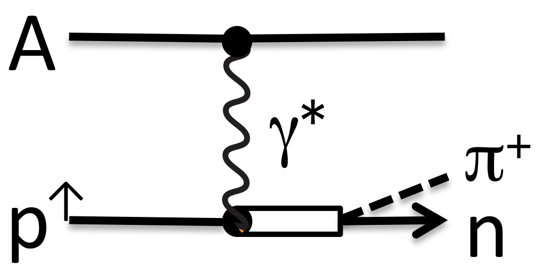
$$A_N \sim had * had + \overbrace{\boxed{had * EM + EM * had + EM * EM}}^{\text{EM enhanced}}$$

# BBC Tagging and Vetoing




**BBC Vetoing**




Diffractive

$$A_N \sim had * had + \overbrace{\boxed{had * EM + EM * had + EM * EM}}^{\text{EM enhanced}}$$

# Question arose from Run15

1. Is the evolution of A(Z)-dependence linear ***!?***

2. Diffractiveness plays key role***!?***

3. What is the role of hadronic and EM amplitudes***!?***

# Proposal for Run17

1. Is the evolution of A(Z)-dependence linear ***!?***

Explore A(Z)-dependence (p+Al, **p+Sn,** p+Au) using the Fixed Targets at STAR

2. Diffractiveness plays key role***!?***

Larger acceptance coverage for Semi-Inclusive using STAR detector

3. What is the role of hadronic and EM amplitudes***!?***

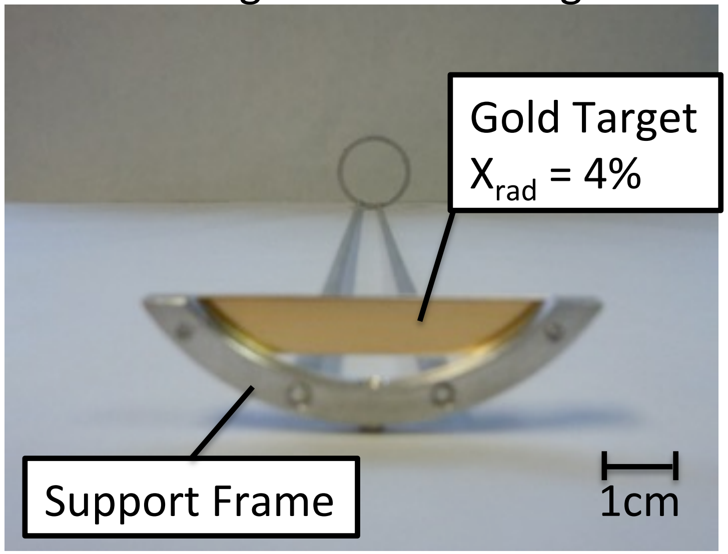
Larger $P_T$ coverage with better resolution

# Experimental Condition

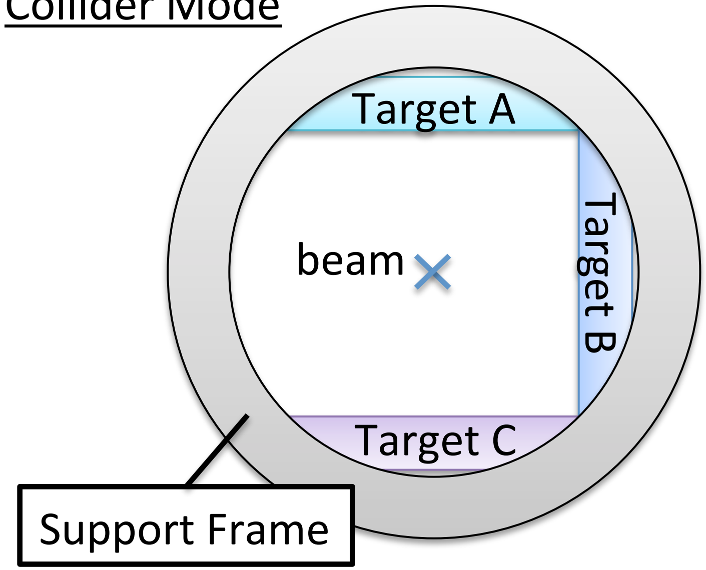
- Targets to be installed before Run17
- Same $\beta^*$=10m & radial pol tune with RHICf
- Only blue beam.
- Luminosity is not an issue (limited by DAQ bandwidth ~ 1kHz).
- Can be done at the end of RHICf store

# 1. Three Fixed Targets for A-dependence

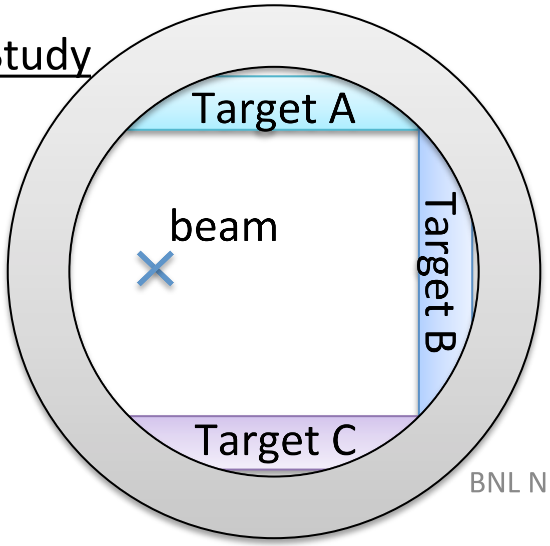
Existing STAR Fixed Target



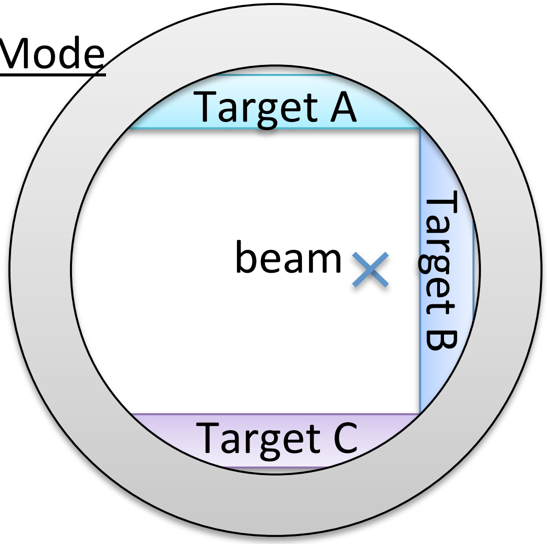

Collider Mode




Background Study Mode

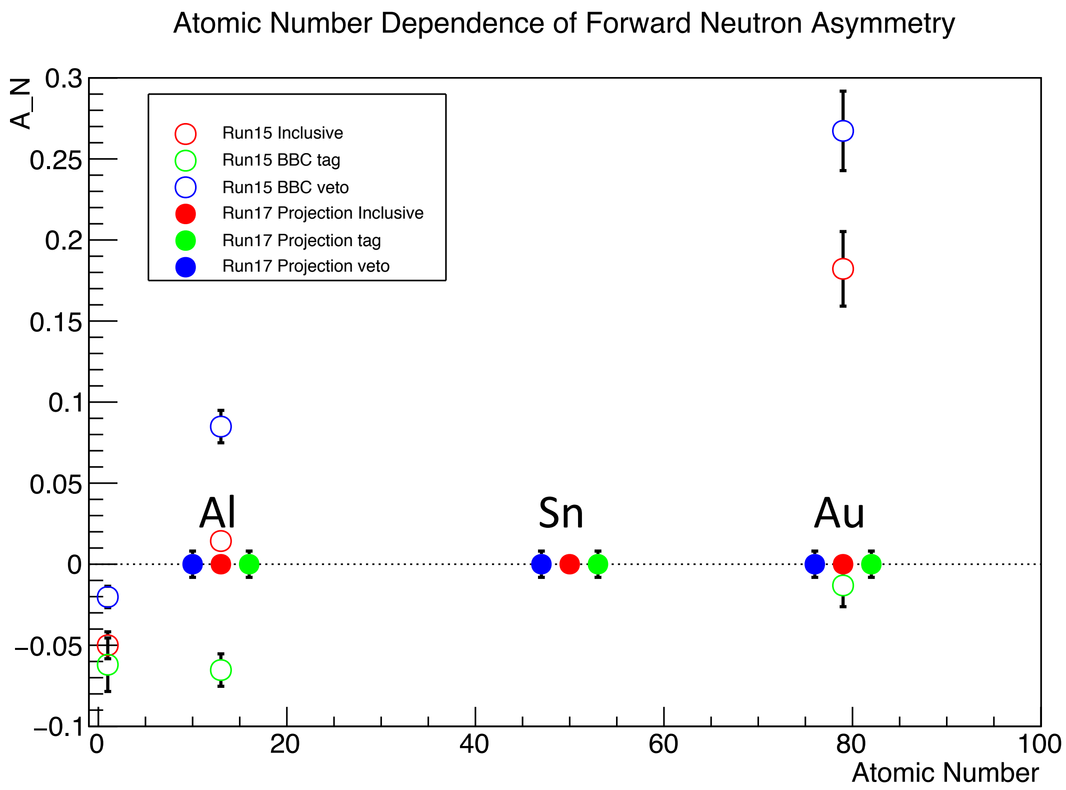



Fixed Target Mode

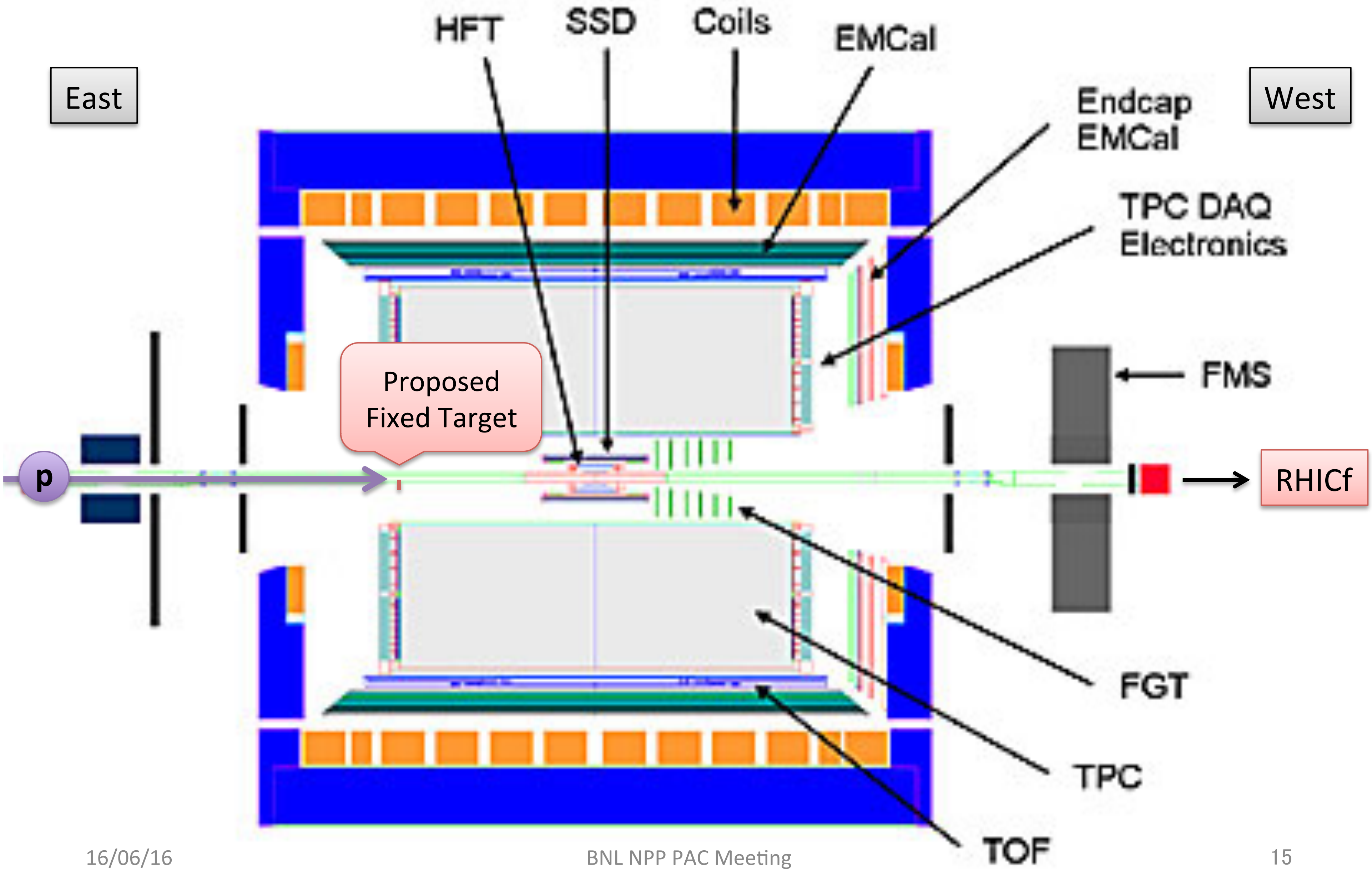


# 1. A(Z)-Dependent Analyzing Power

| Beam Energy [GeV] | Collision √s [GeV] | Fixed Target √s [GeV] |
|---|---|---|
| 100 | 200 | 14 |
| 250 | 500 | 22 |



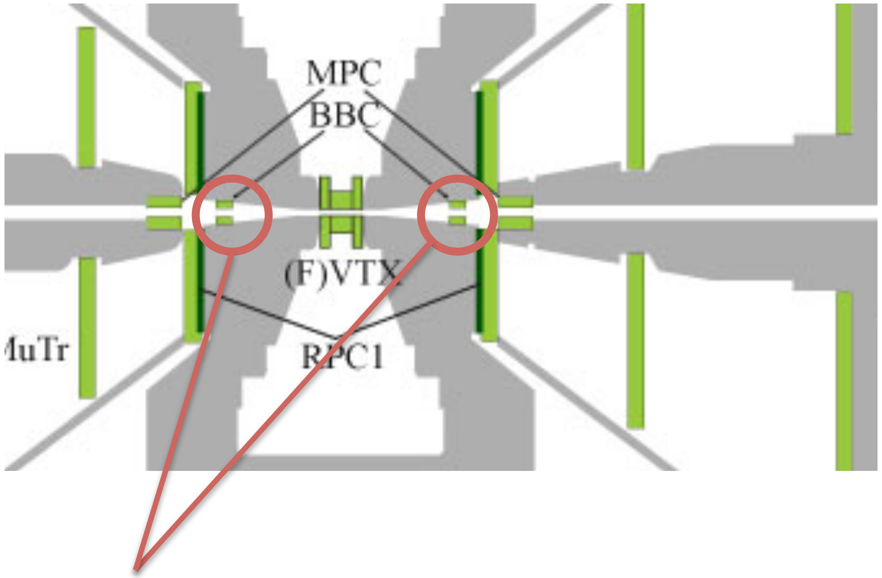
# STAR Fixed Target



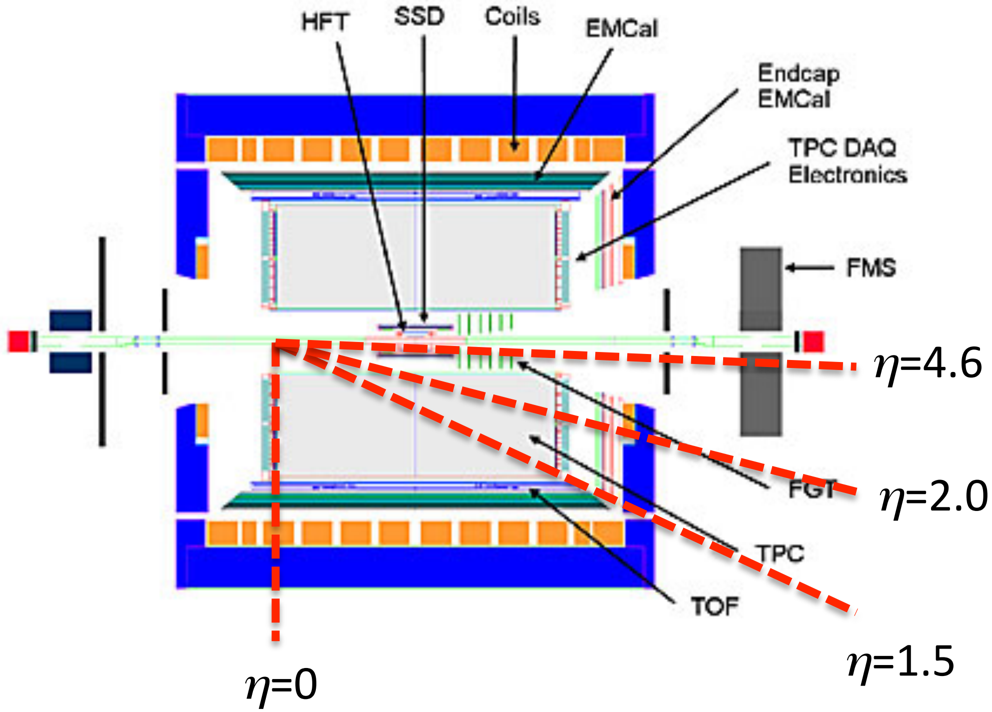
# 2. Acceptance for Semi-Inclusive

Run15 PHENIX

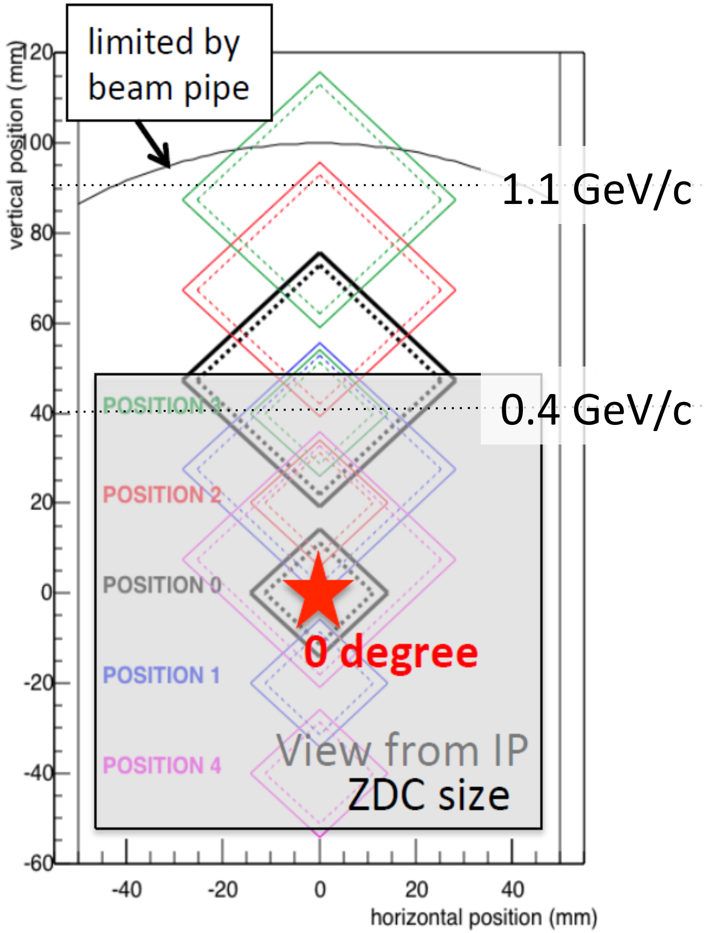
STAR Fixed Target

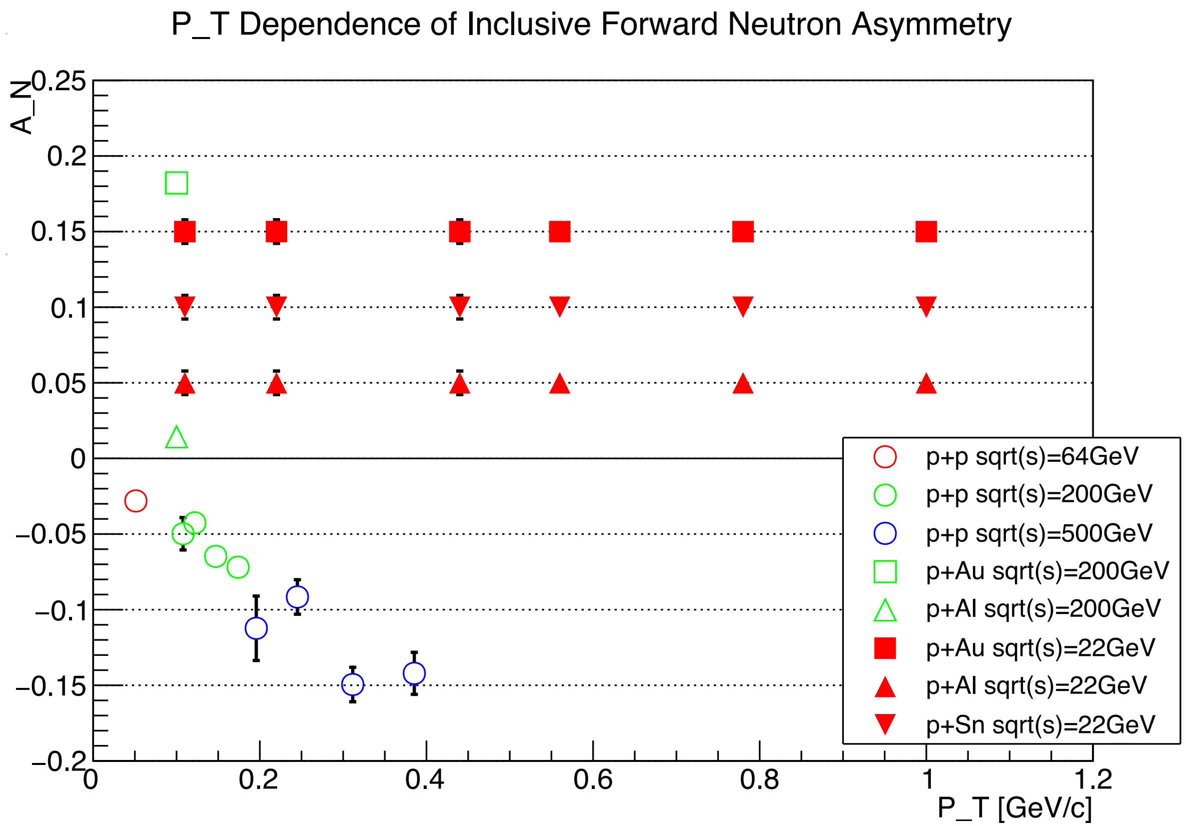



BBC 3.1 < $|\eta|$ < 3.9



# 3. Extended $P_T$ Coverage



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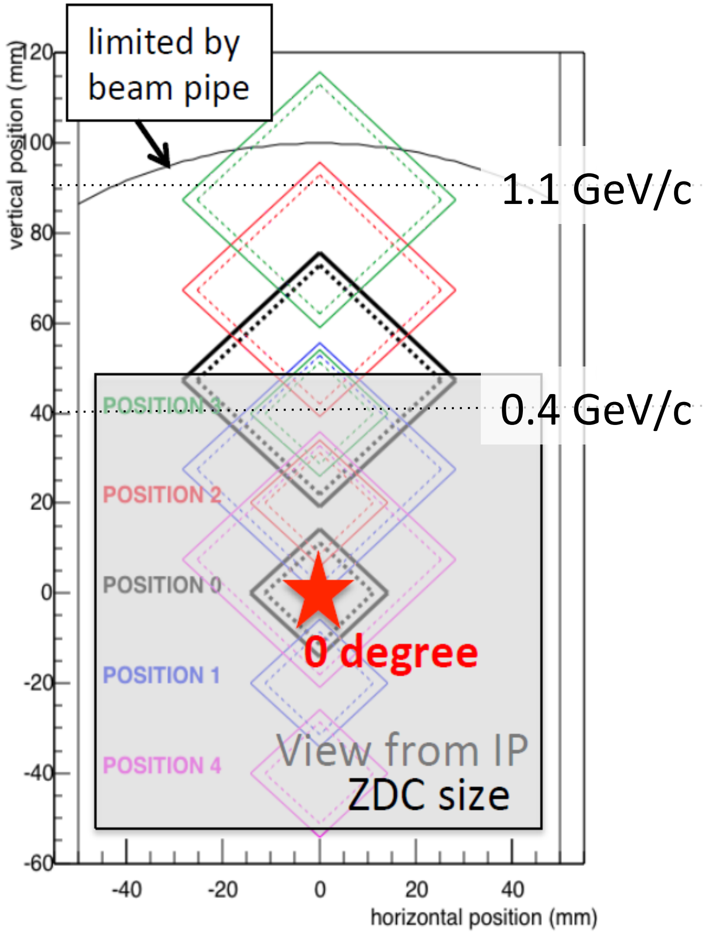
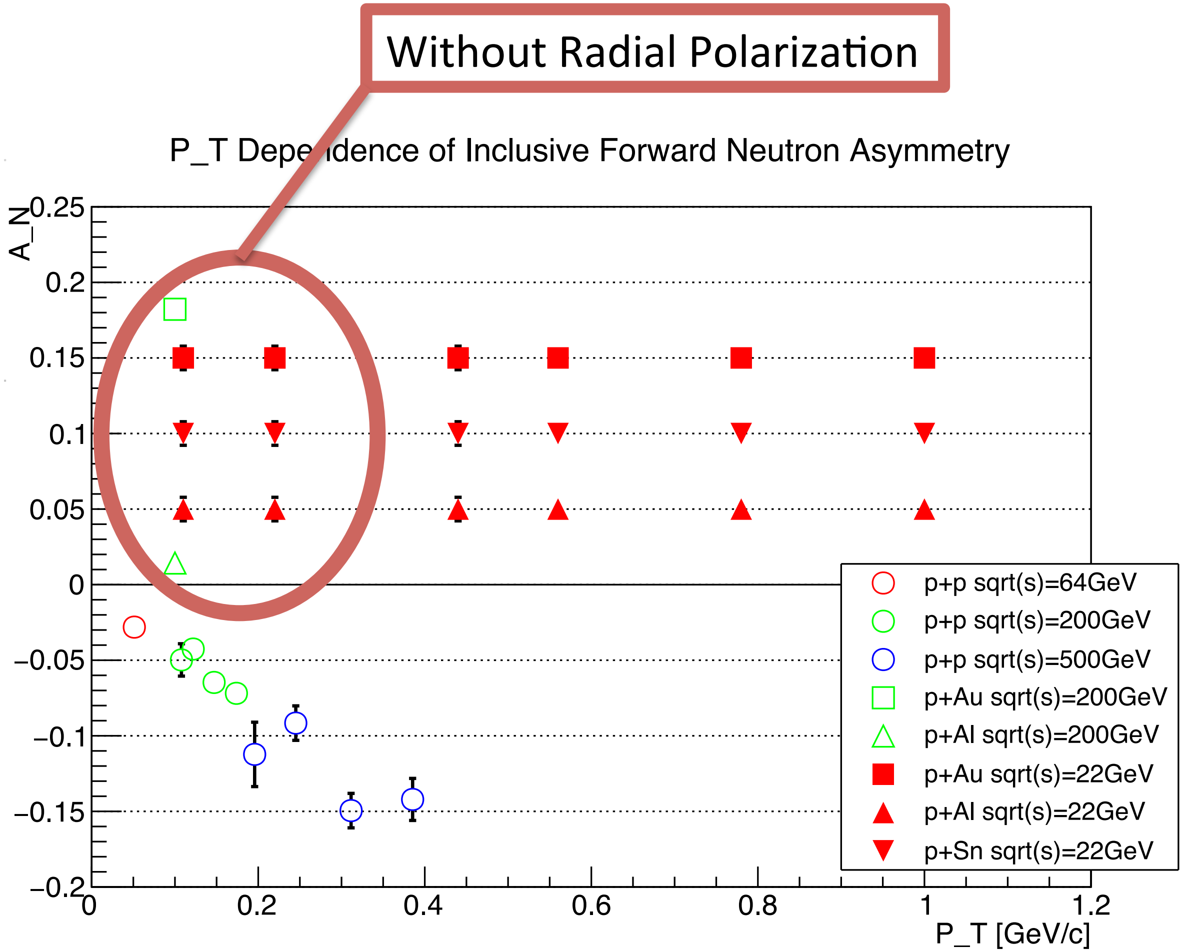


# Run Plan

1. Physics Data (9h)
   1 hour × 3 Targets × 3 RHICf positions = 1 hour × 9 physics runs

1h ~ 3.6M events : $\Delta A_N$~ 0.0026

2. Empty Target (3h)
   1. 1 hour × 3 RHICf positions = 3h
3. Beam position tuning (2h)
   0.5 hour × 4 positions = 2 hours
4. RHICf position change (1.5h)
   0.5 hour × 3 positions = 1.5h
5. Contingency (8.5h)

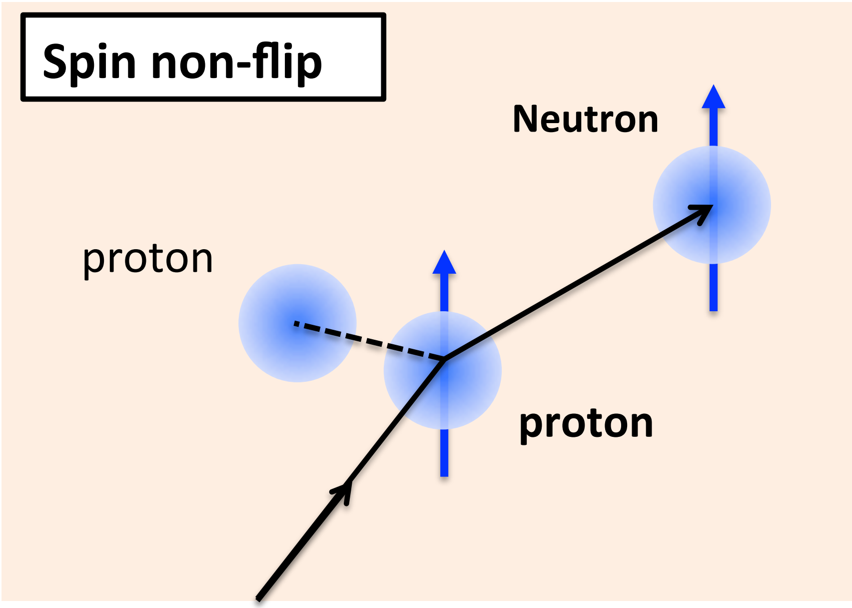
(9h + 3h) + 2h + 1.5h + 8.5h ~ 24 hours

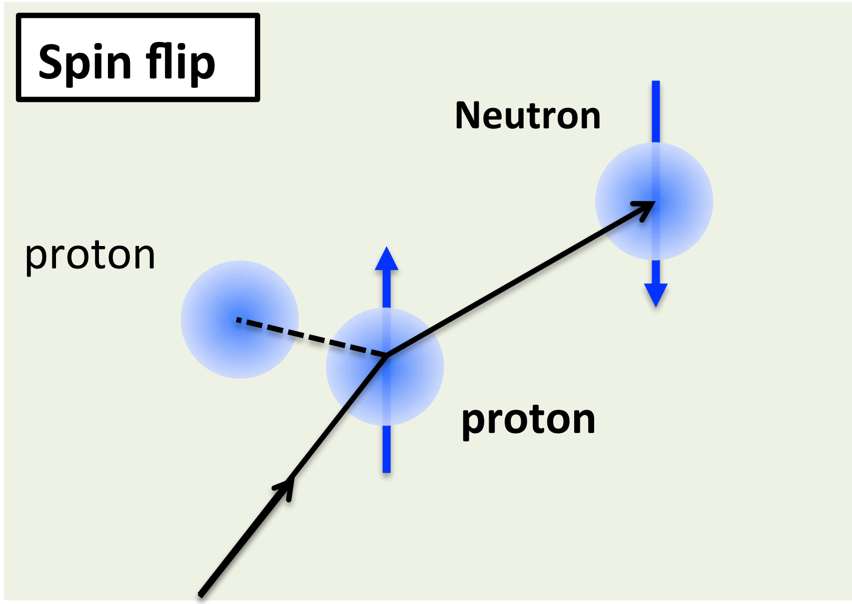
# Summary

- Proposal to explore forward neutron asymmetry in pA to address mysteries arose from Run15.
- 3 Fixed Targets at STAR
- Requesting 24 hours (12hours data taking)
- Same beam tune as RHICf ($\beta^*$, radial) no special tune. Only blue beam and can be done at the end of RHICf store.

# BACKUP

# p↑+p Forward Neutron $A_N$



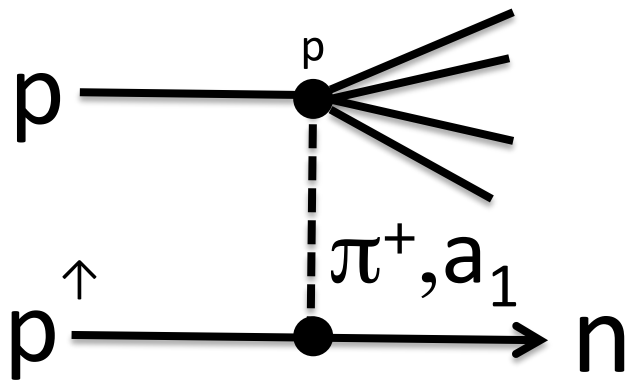



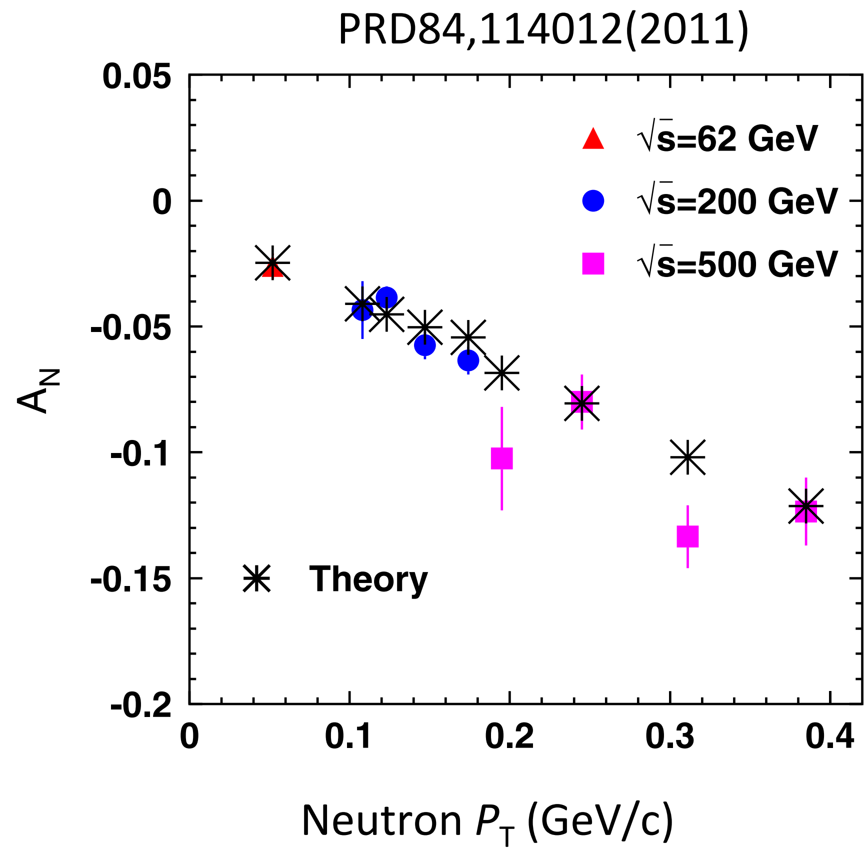

$$A_N \approx \frac{\left(\phi^*_{non-flip}\,\phi_{flip}\,\sin\delta\right)}{\left|\phi_{non-flip}\right|^2 + \left|\phi_{flip}\right|^2}$$

$\delta$ : phase shift

Unpolarized Cross Section

# p↑+p Forward Neutron $A_N$




Data are well reproduced by the interference between π and $a_1$ Reggeon

# Full Description of $A_N$

$$A_N \propto 2\,\mathrm{Im}\{\phi^{*}_{non-flip}\,\phi_{flip}\,\sin\delta\}$$

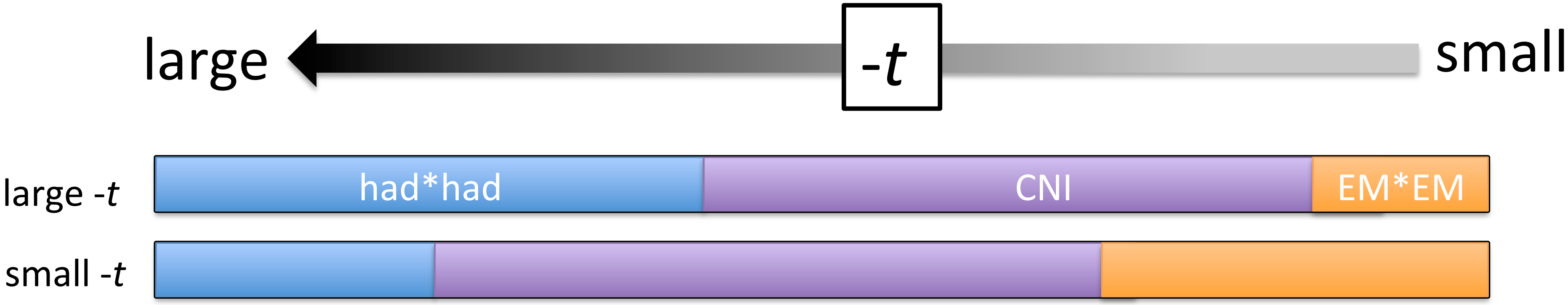
$$\phi_{flip} = \phi^{had}_{flip} + \phi^{EM}_{flip}$$

$$\phi_{non-flip} = \phi^{had}_{non-flip} + \phi^{EM}_{non-flip}$$

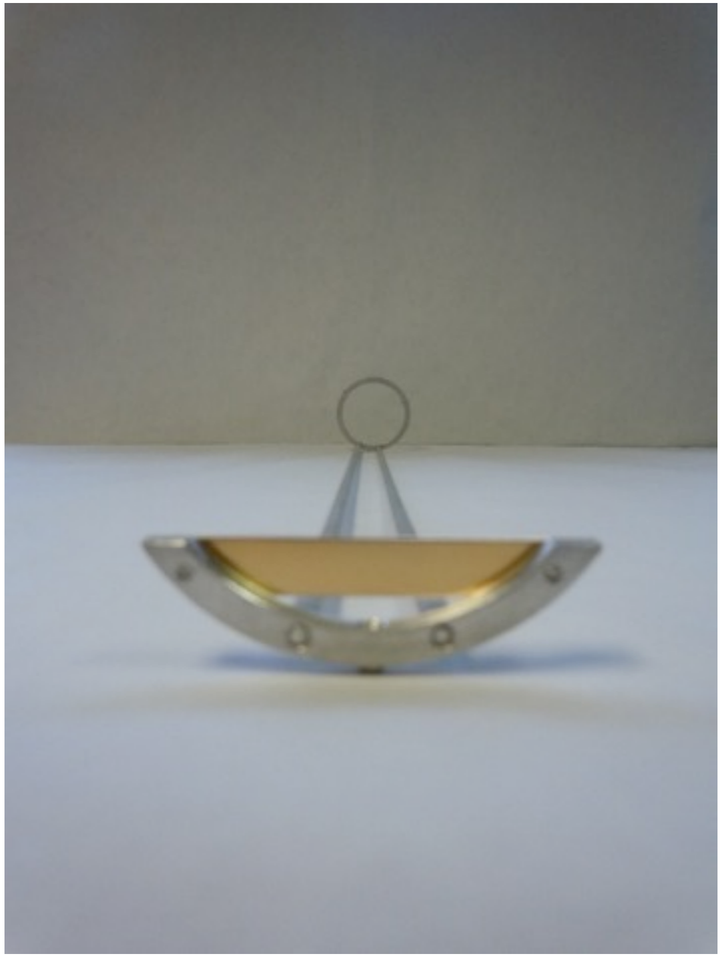
$\Delta_{1\sim4}$ : relative phase of amplitudes

$$A_N \propto 2\,\mathrm{Im}\left(\phi^{had}_{non-flip} + \phi^{EM}_{non-flip}\right)\left(\phi^{had*}_{flip} + \phi^{EM*}_{flip}\right)$$

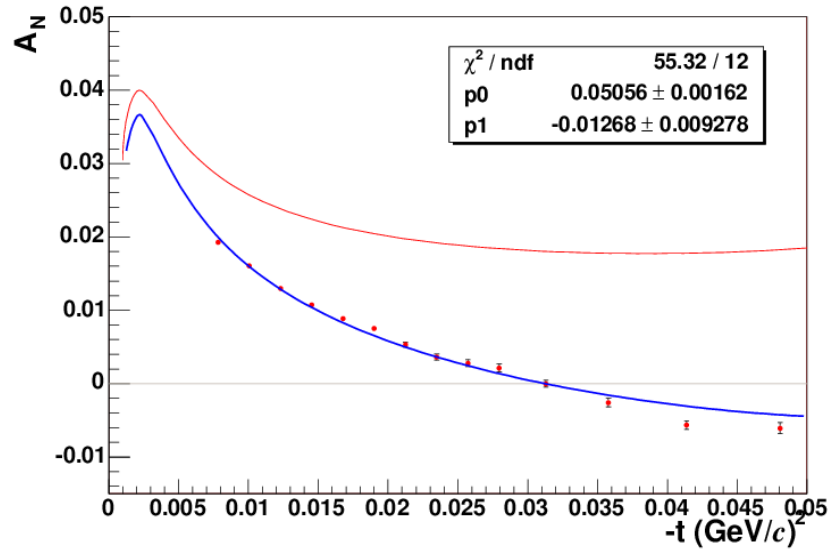
$$= 2\,\mathrm{Im}\Big(\underbrace{\phi^{had*}_{non-flip}\phi^{had}_{flip}\sin\delta_1}_{pp} + \underbrace{\phi^{EM*}_{non-flip}\phi^{had}_{flip}\sin\delta_2 + \phi^{had*}_{non-flip}\phi^{EM}_{flip}\sin\delta_3}_{\text{CNI}} + \underbrace{\phi^{EM*}_{non-flip}\phi^{EM}_{flip}\sin\delta_4}_{\text{Primakoff}}\Big)$$

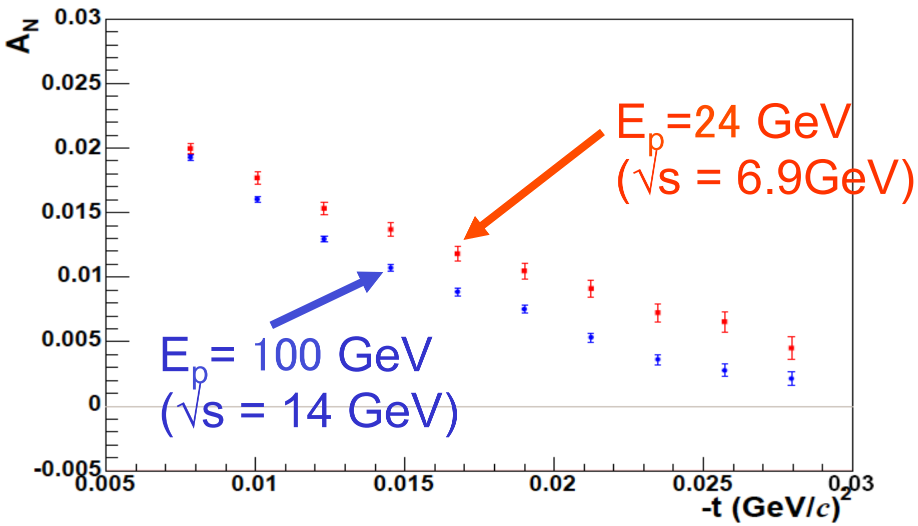


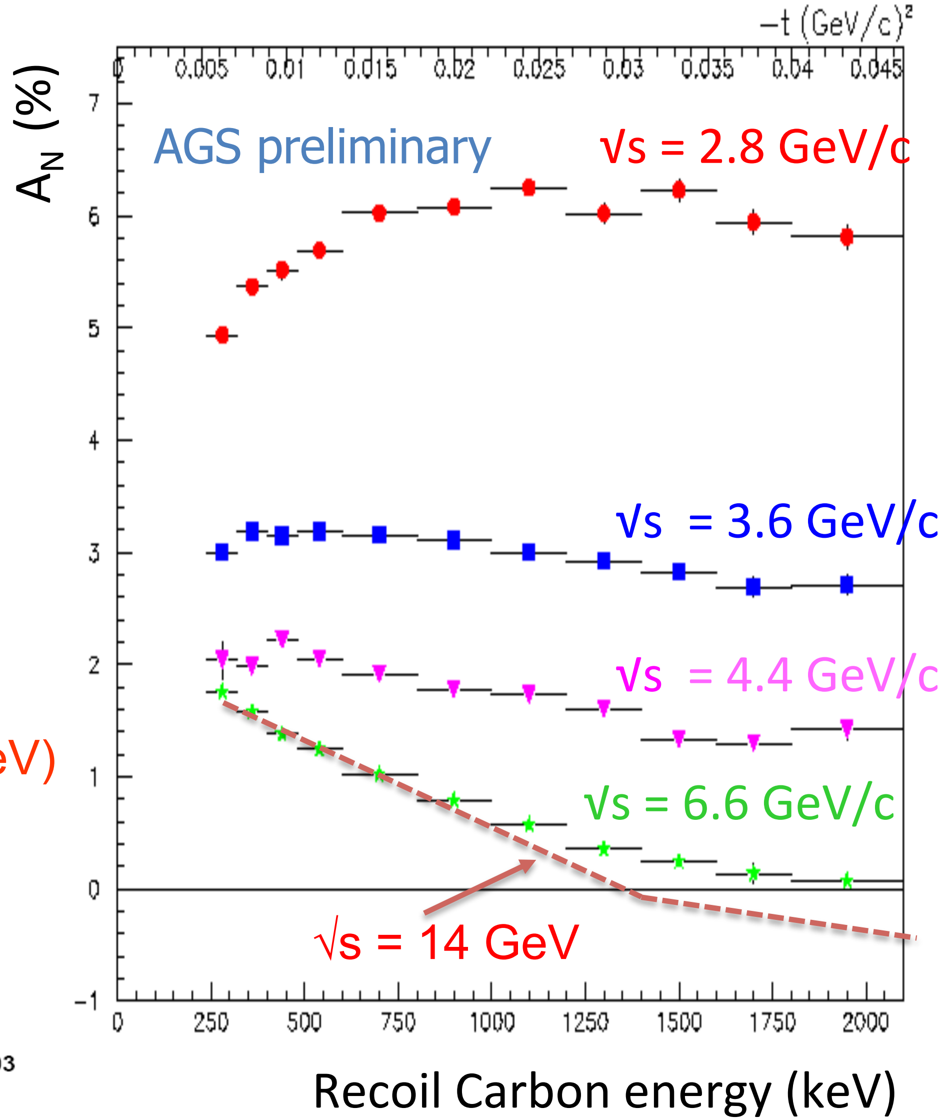
# Existing STAR Fixed Au Target



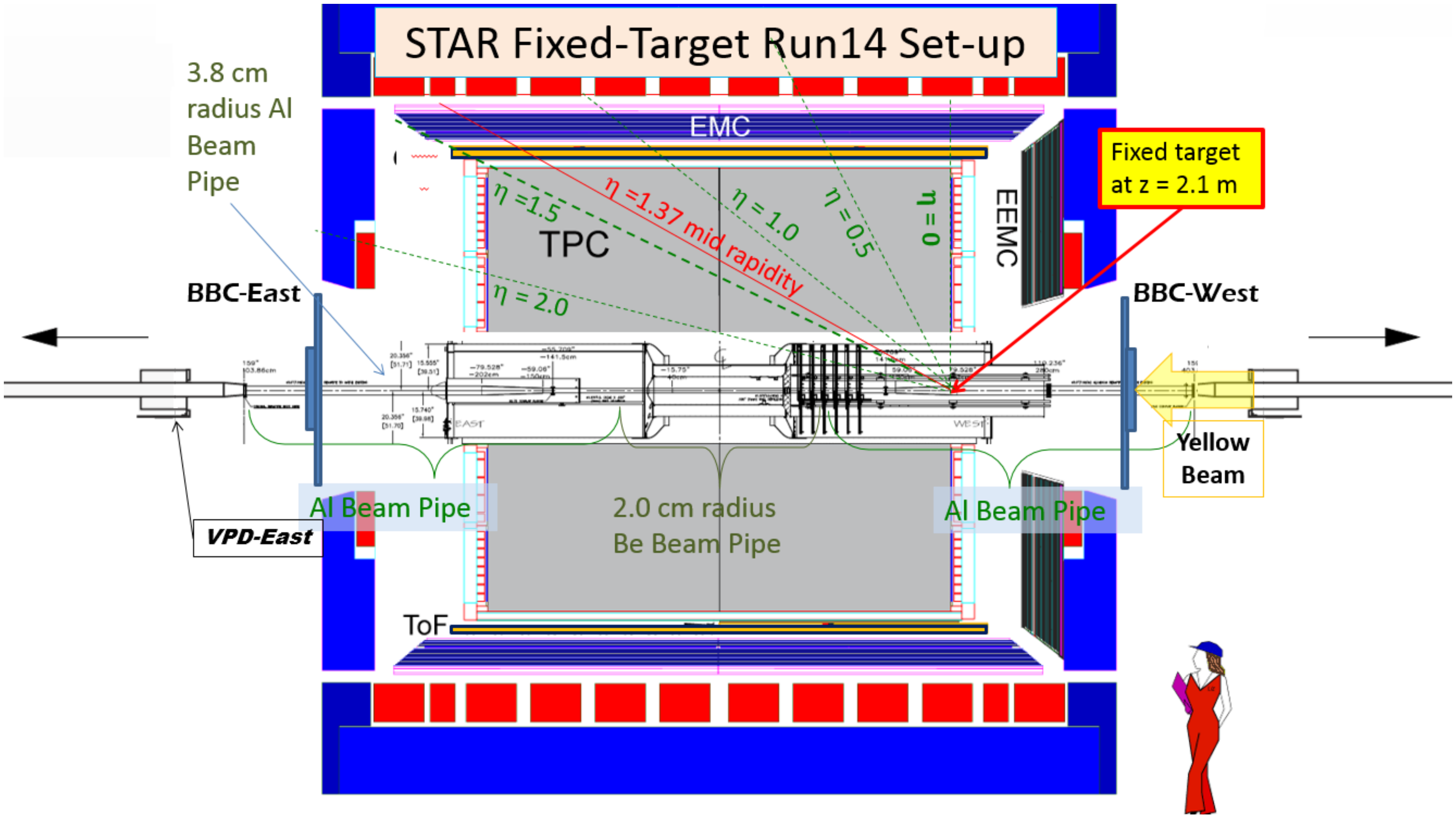
# Elastic p+C : Energy Dependent $A_N$



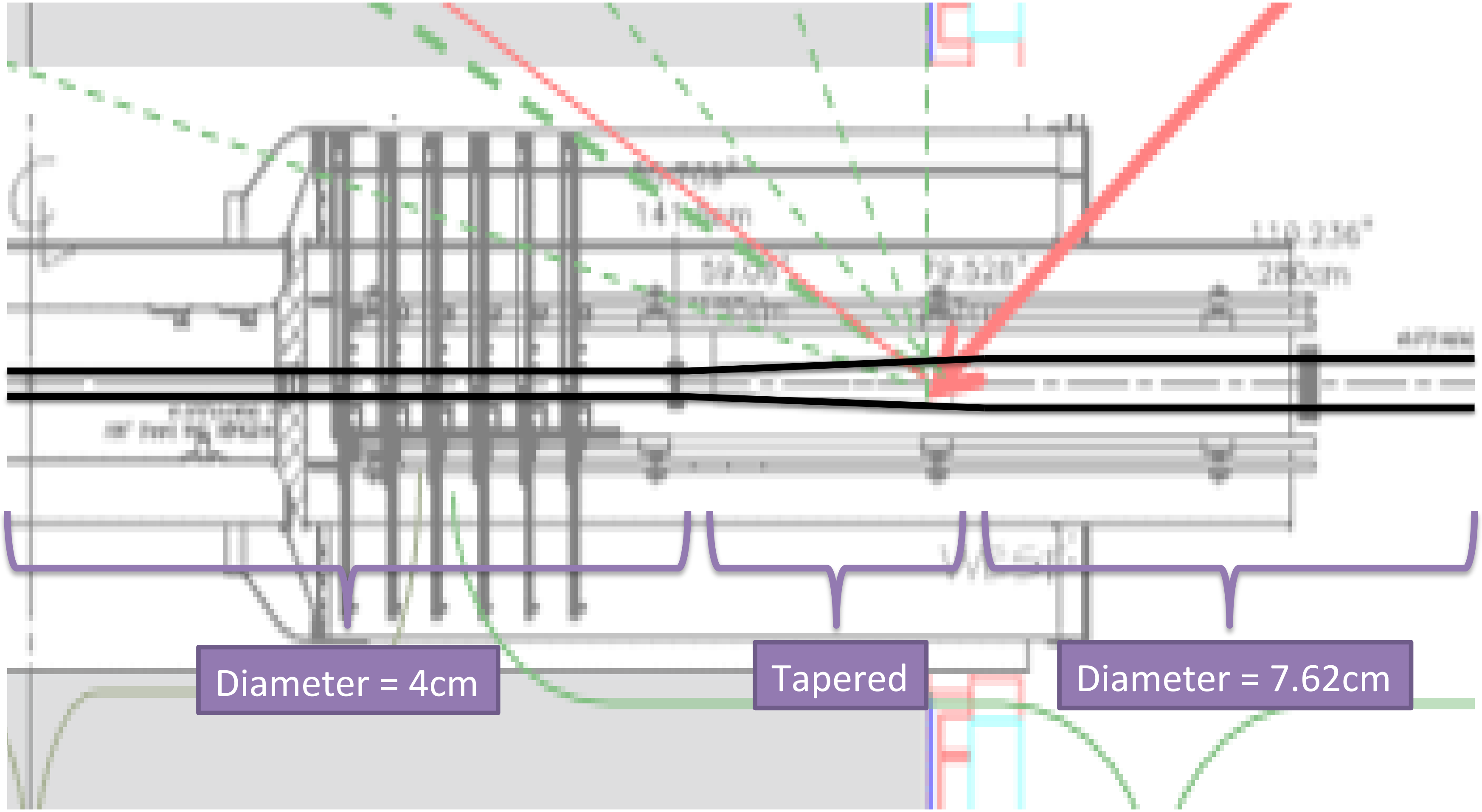



# Run 14 Test Run



# Beam Pipe Diameter



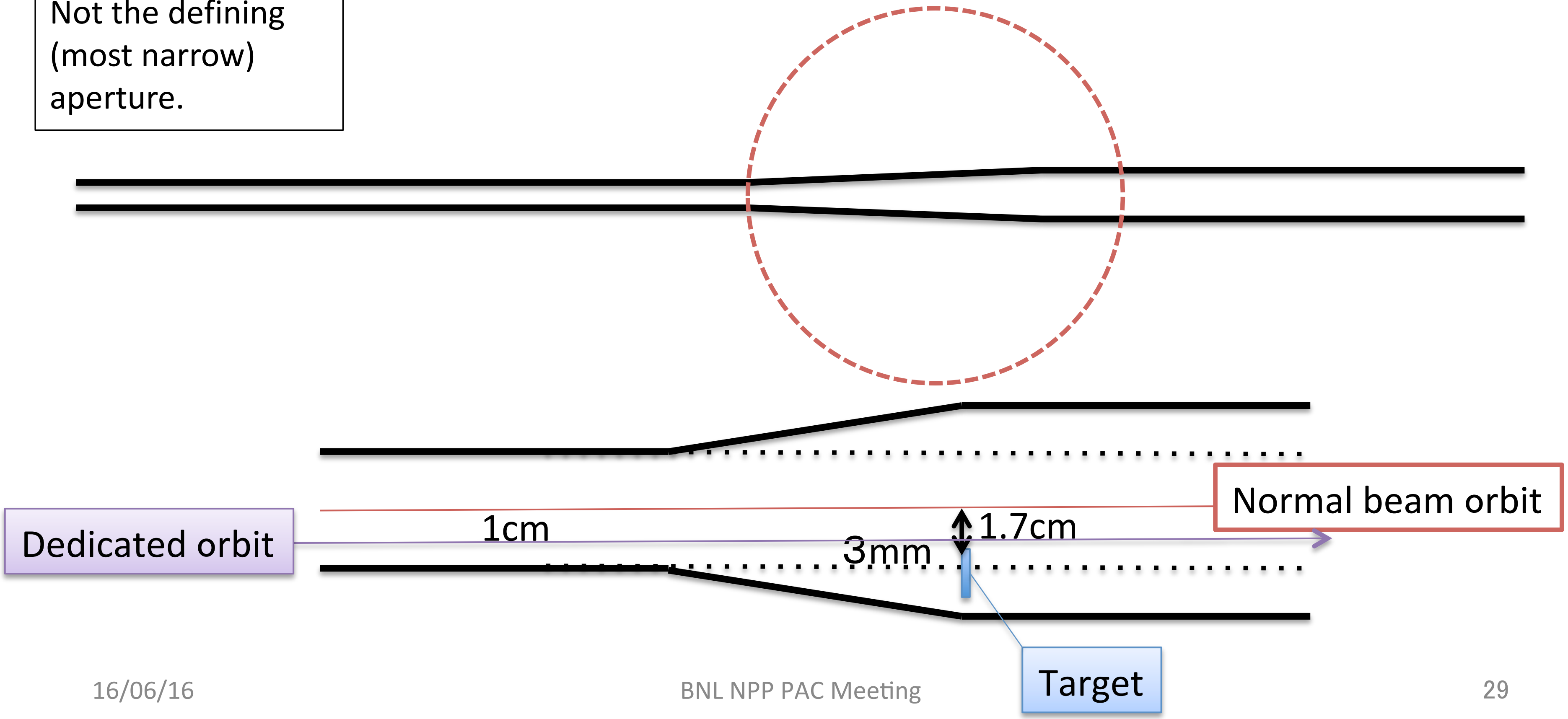
**Run 14 details:**

The target foil is held 2 cm below of the beam axis.

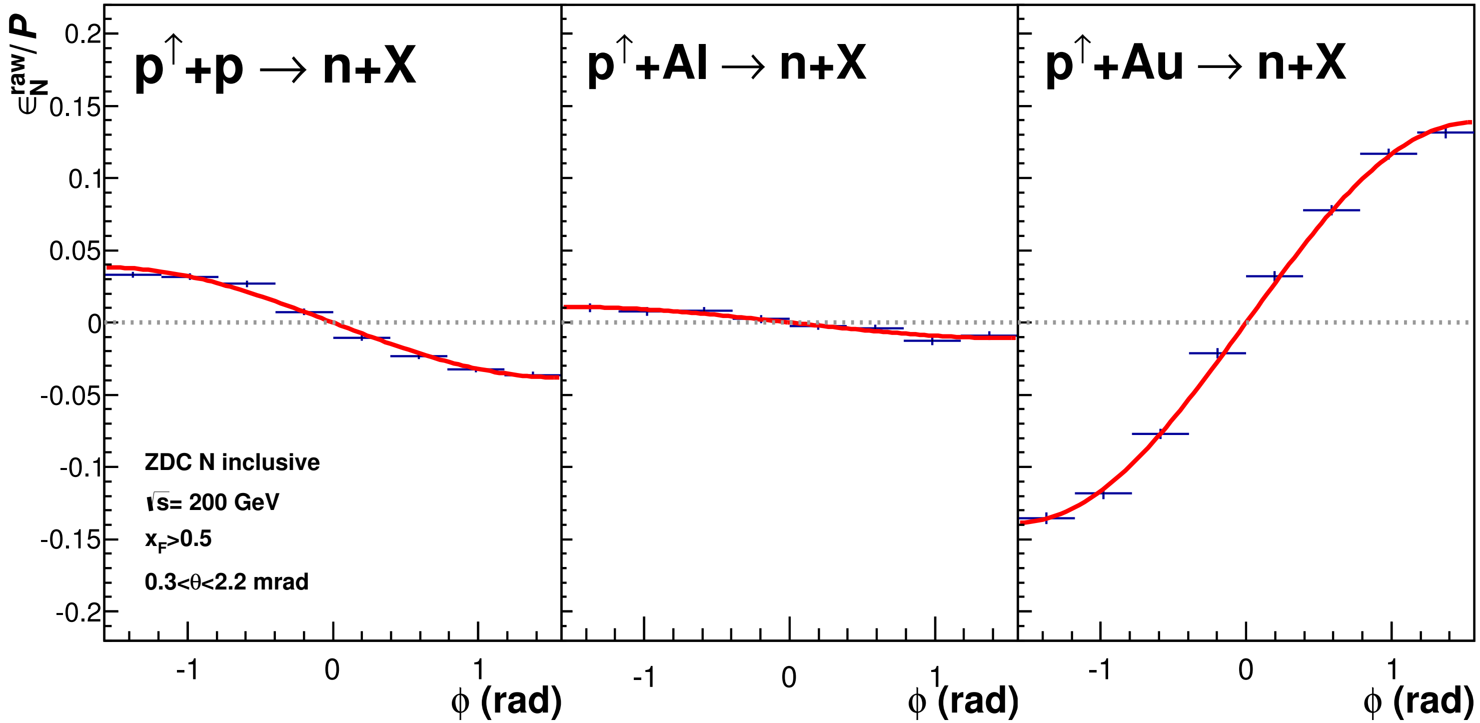
The foil is 1 mm thick (4%).

Not the defining (most narrow) aperture.

# Beam Pipe Diameter



# Run15 Statistics




| | p+p | p+Al | p+Au |
|---|---|---|---|
| $A_N \pm \Delta A_N$ | -0.0500±0.0014 | -0.0143±0.0019 | 0.1822±0.0019 |
| $\Delta A_N/A_N$ (relative) | 3% | 15% | 1% |

Approximately accumulated >10M ZDC triggers @ DAQ rate 4 to 5 kHz.
Survival fraction after QA cuts is about 20 ~ 30%.
Absolute error is very small : 0.0014 – 0.0019

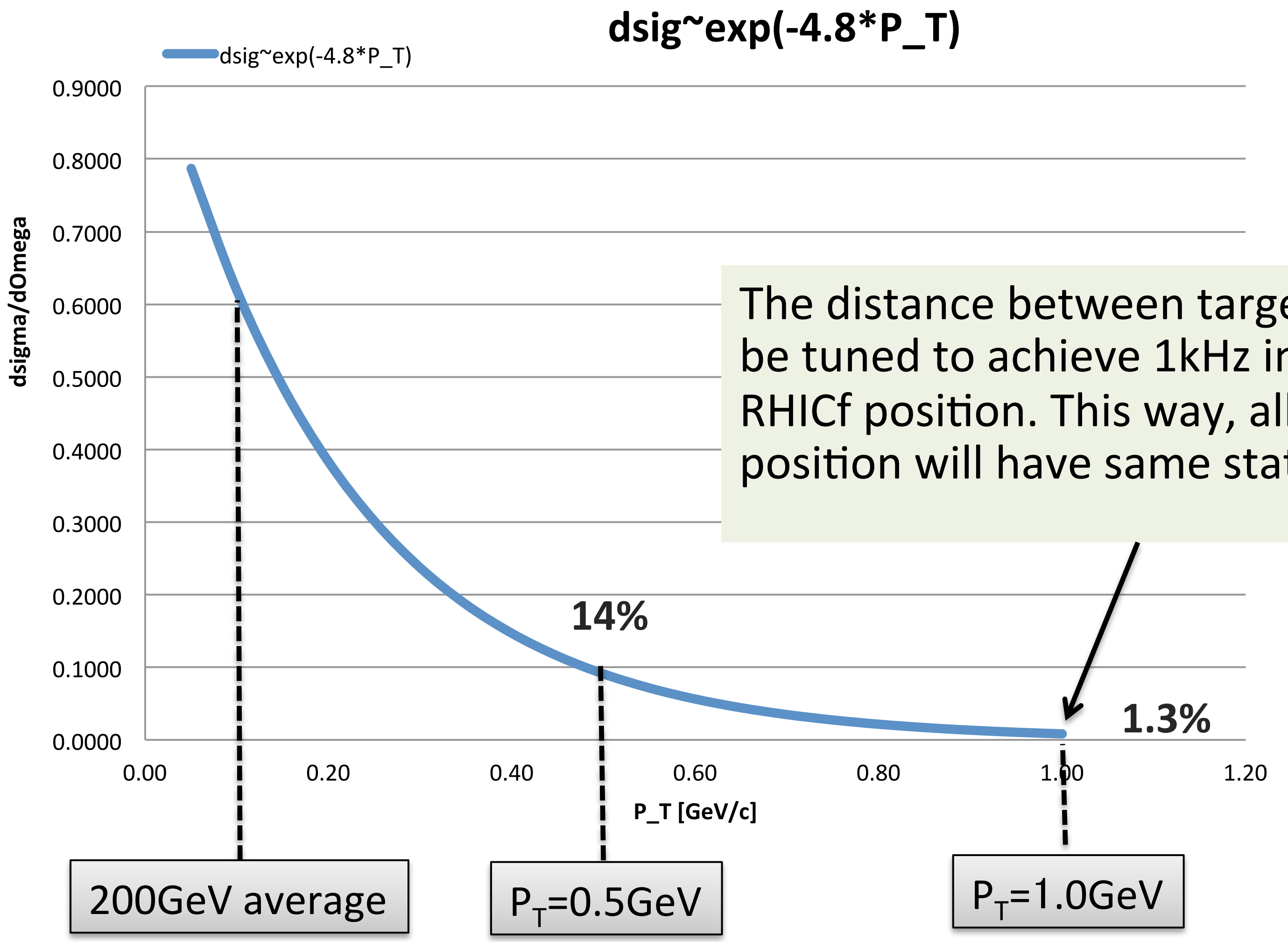
# DAQ time estimate

DAQ rates ~ 1kHz (detection efficiency is included in 1kHz)

| Time [hours] | Total Events | $\Delta A_N$ |
|---|---|---|
| 1 | 3.6 M | 0.0026 |
| 2 | 7.2 M | 0.0018 |
| 3 | 10.8 M | 0.0015 |

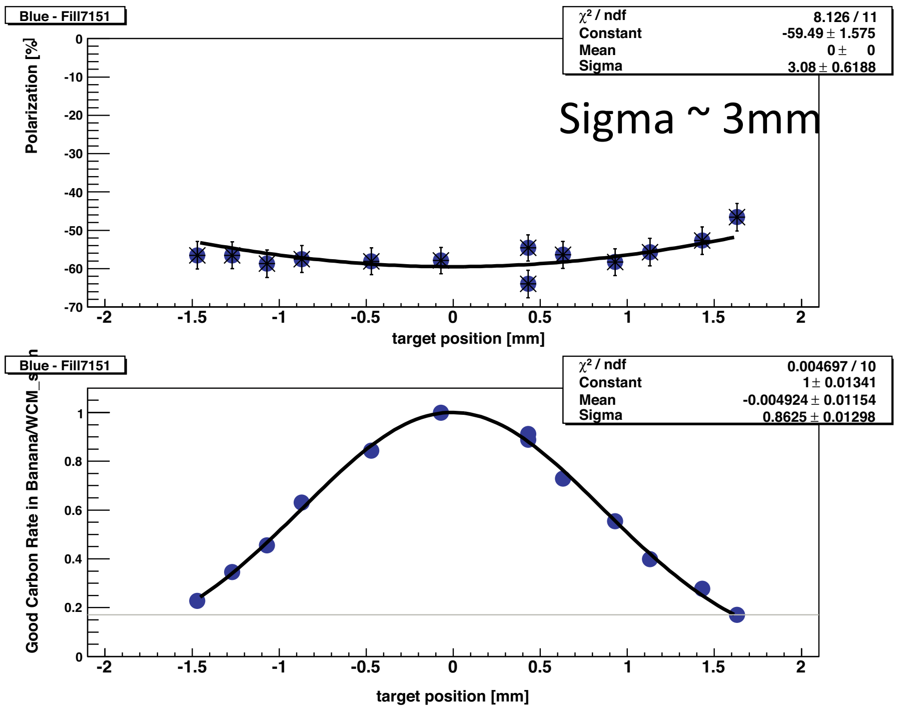
- 1Hour data taking achieves $\Delta A_N$ ~ 0.0026 which is factor of 4 smaller than the goal $\Delta A_N$ ~ 0.01. This leaves factor of 16 contingency in statistics.
- The contingency will be consumed by:
  1. Increased background (including EM) fraction in the trigger compared to collider mode.
  2. Active volume cut.

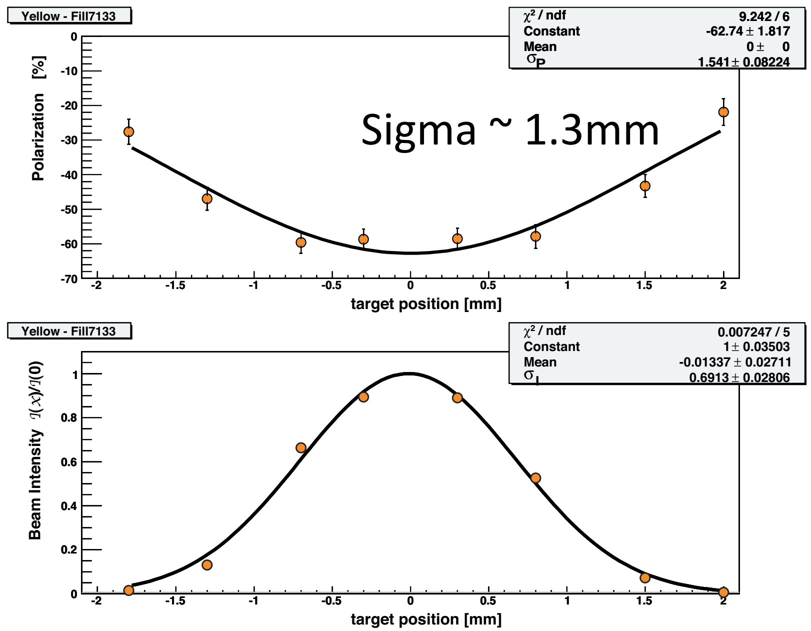
# $P_T$-Dependent Yield




The distance between target and beam will be tuned to achieve 1kHz in the largest $P_T$ RHICf position. This way, all 3 RHICf position will have same statistical precision.

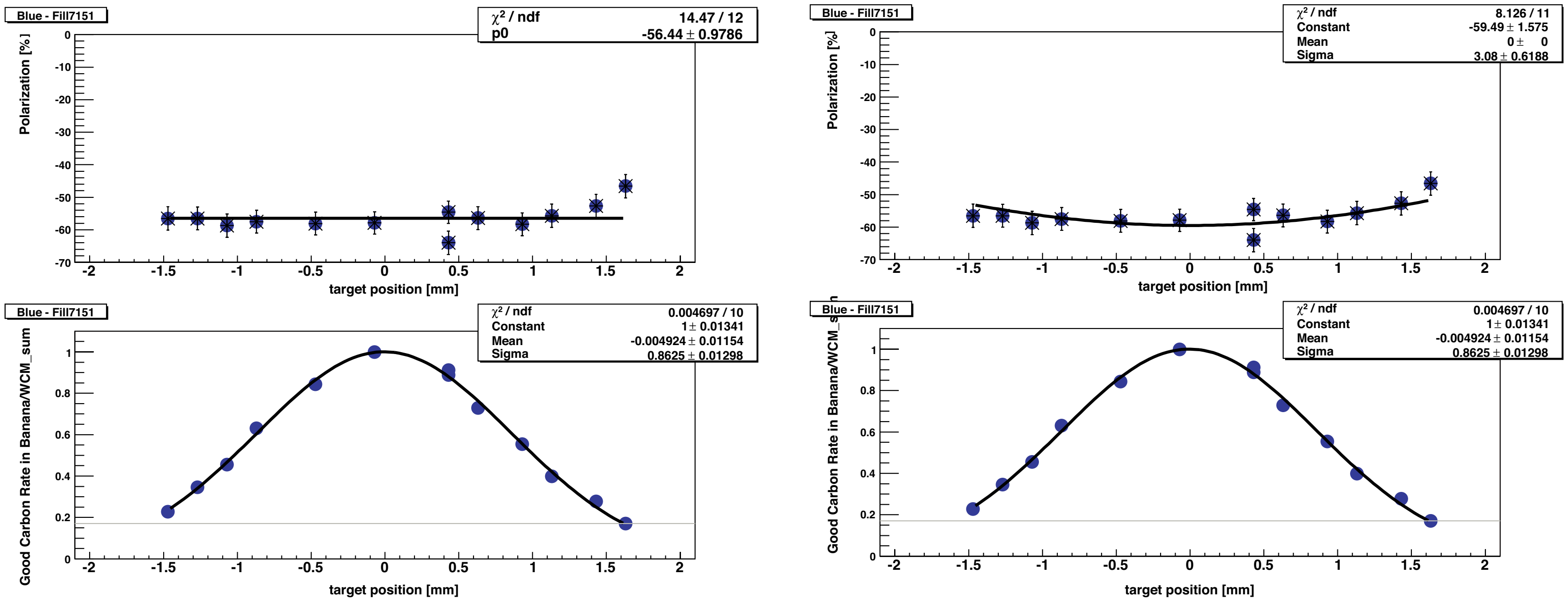
# Polarization Profile




Distance from beam center to the target ~ 3 mm.

# Polarization Profile (Blue)



# Polarization Profile (Yellow)