

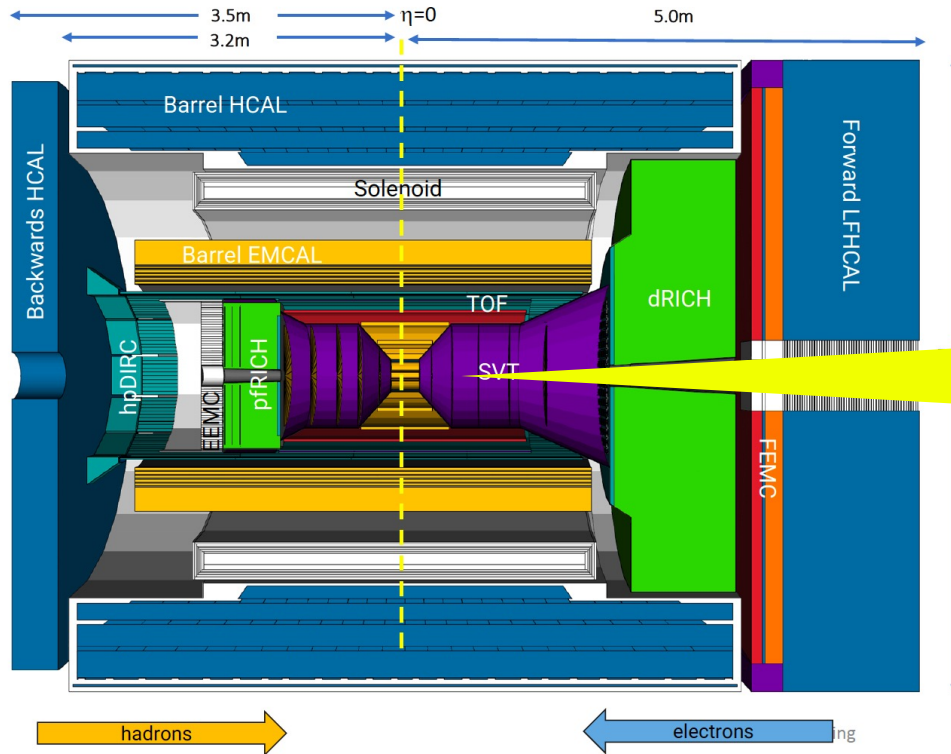
Far-Forward physics and detector R&D

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2nd APCTP Workshop on the Physics of EIC

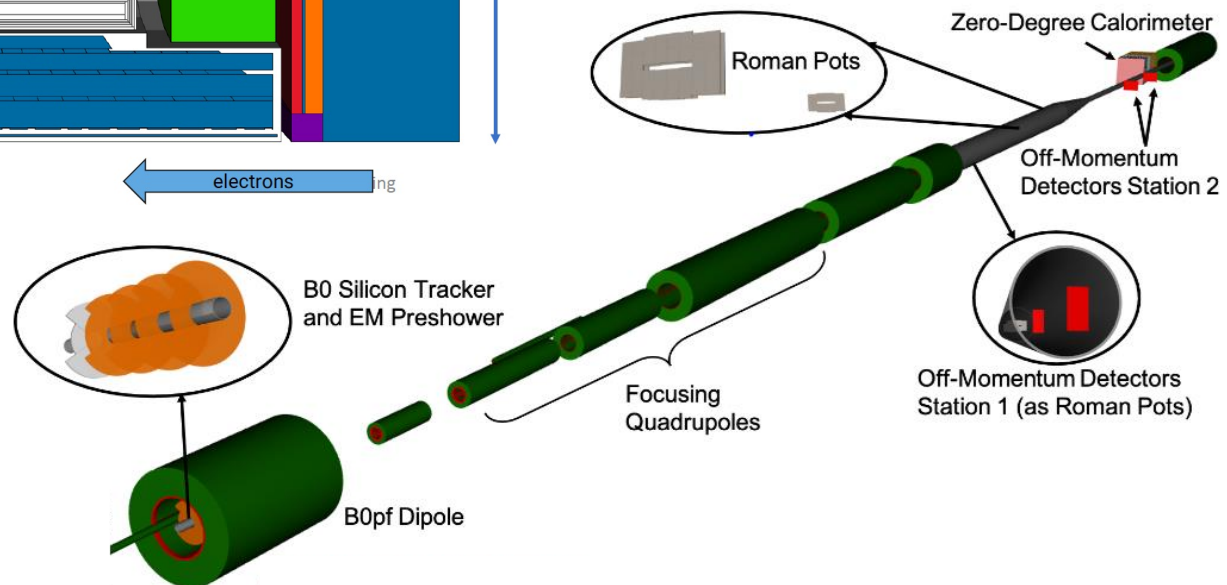
Daegu, Nov 30 2023

ePIC far forward system

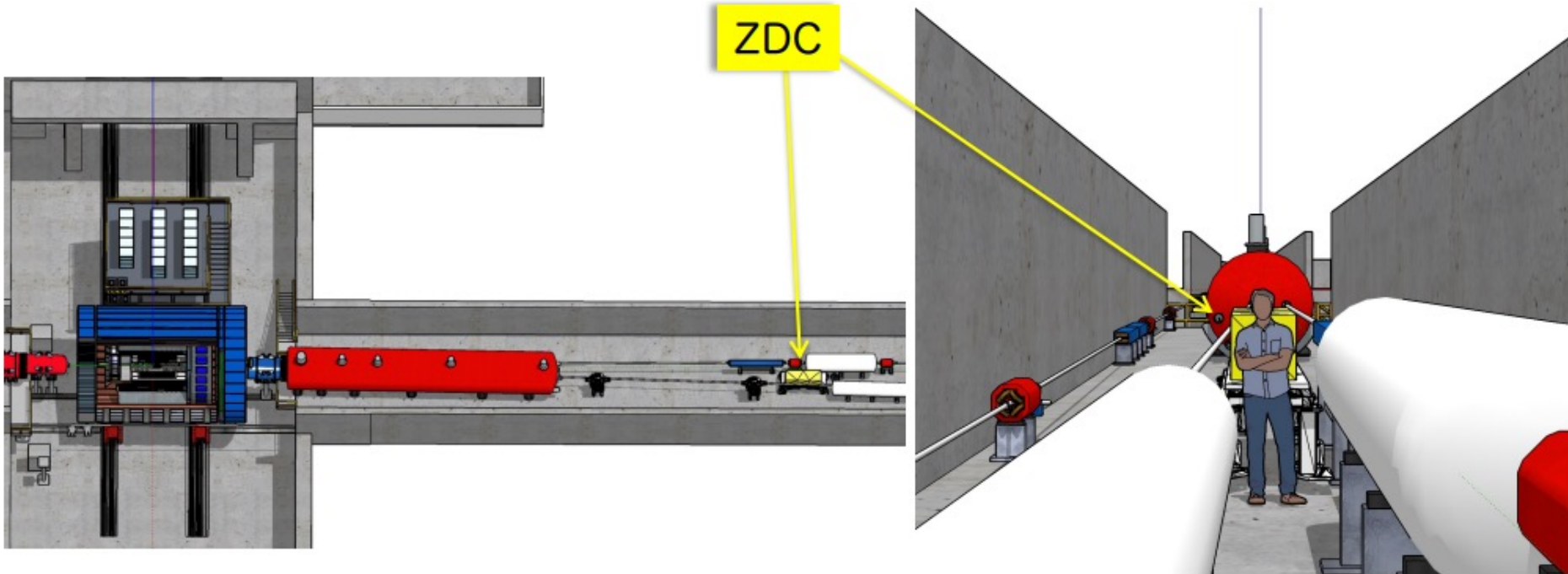


- Mid/fwd system covers $|\eta| < 4$
- Far forward means $\eta > 4$ in the p/A going direction, corresponding to $\theta < 2.1^\circ$

→ FAR FORWARD

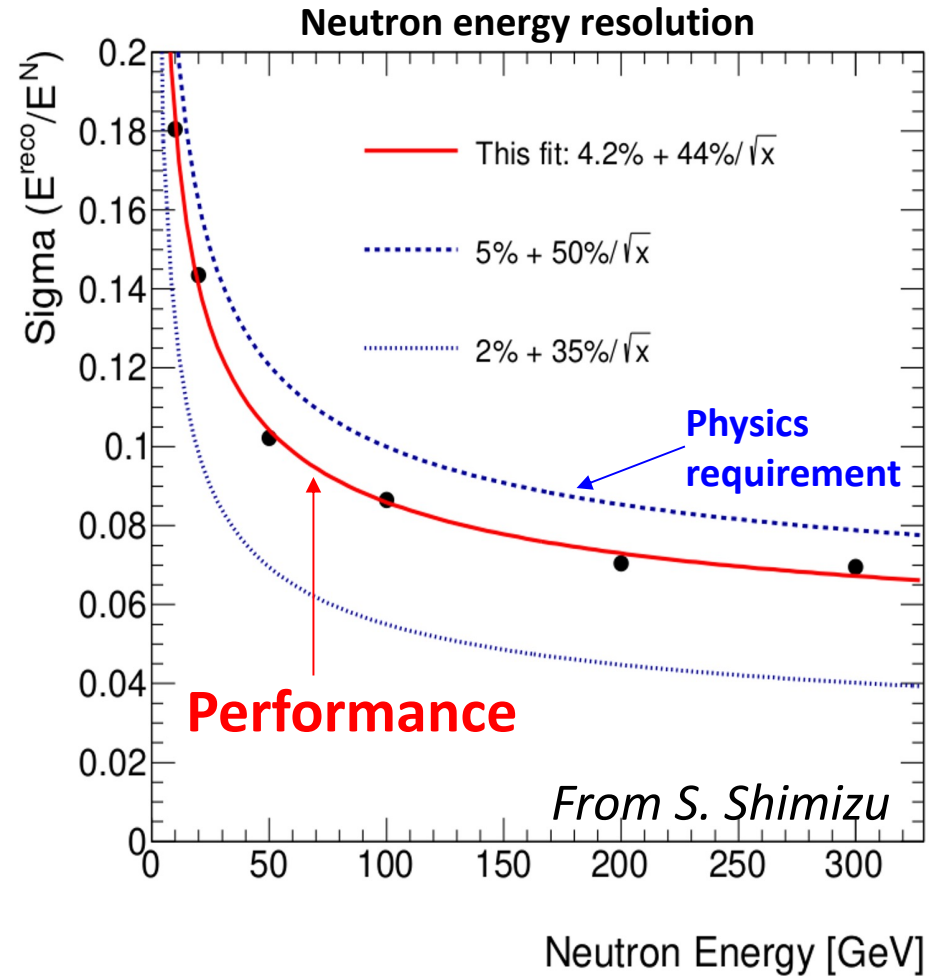
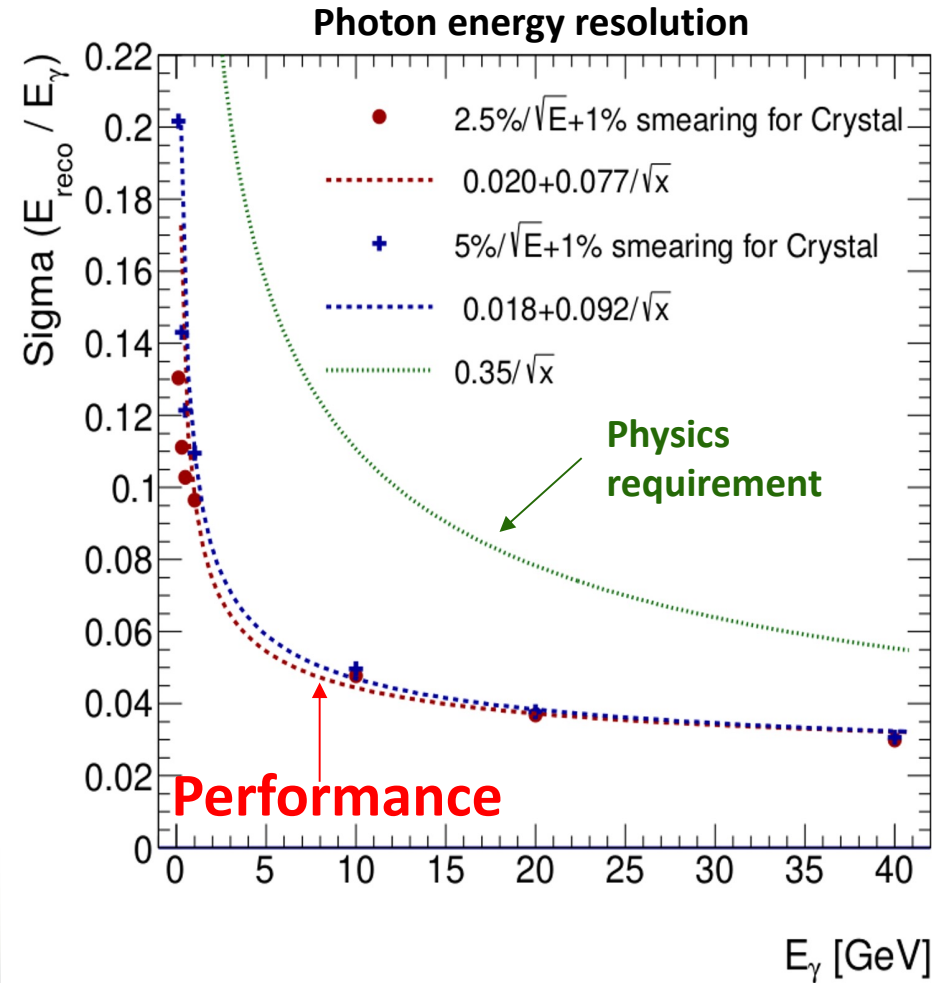


Zero degree calorimeter



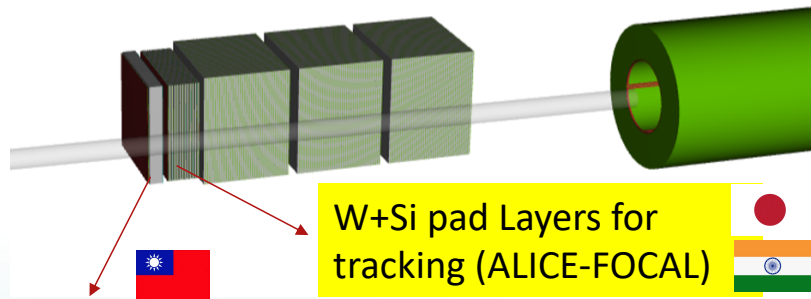
- 35 m away from the vertex
- ~60x60x200 cm space available
- Measure γ , π^0 , and n

Detector requirement



- The performance plot was made in the old version detector design (prior than March 2023), and already meet the YR requirement

ZeroDegree Calorimeter

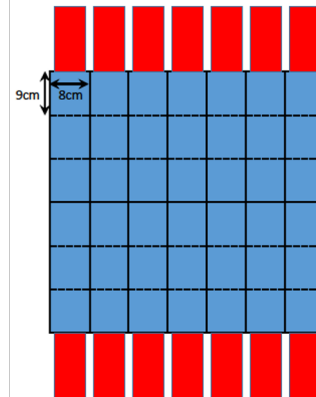
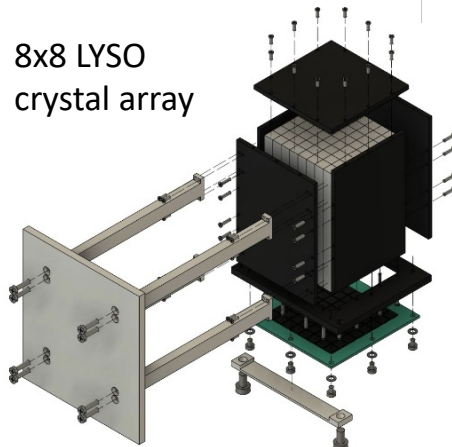


LYSO Crystals



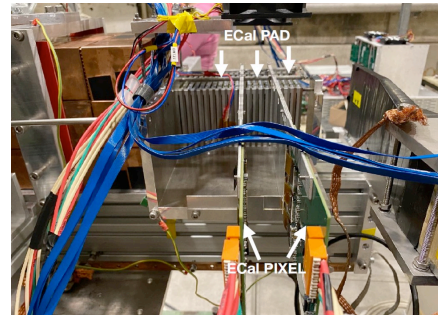
beam test at ELPH in February 2024

8x8 LYSO crystal array

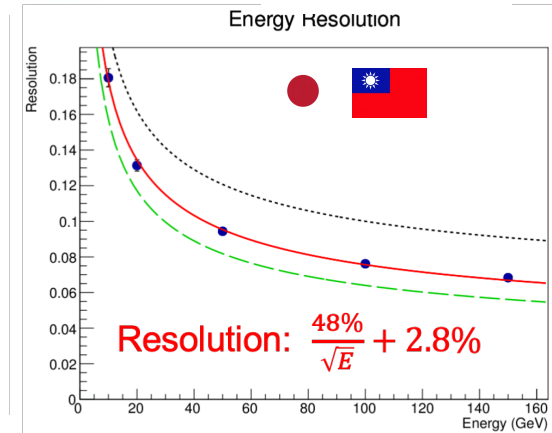
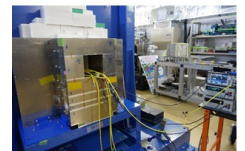


W+Si pad Layers for tracking (ALICE-FOCAL)

ALICE-FoCAL beam test@CERN



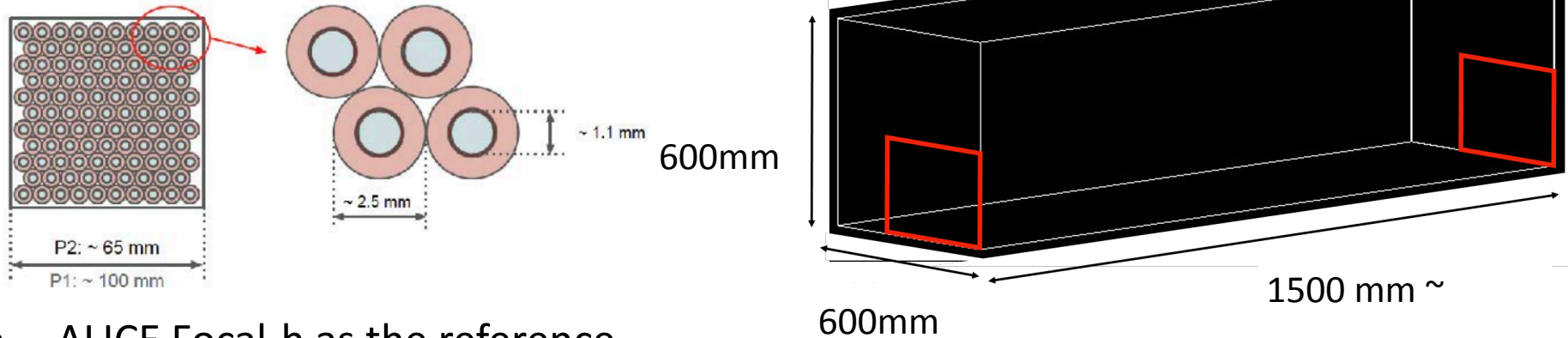
Neutron irradiation at RIKEN RANS



From T. Guji

ZDC-h design (proposed)

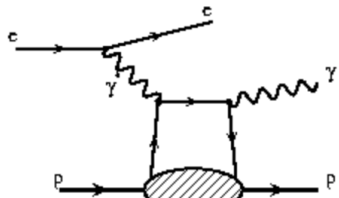
- 2nd design
 - No Pb-Si imaging calorimeter
 - Pb-(Scintillator + Fused silica) by Korea group (Sejong U. & Korea U.)
 - Capillary design
 - 1 on 1 SiPM: each SiPM connected to single fiber
 - Or grouping SiPM: each SiPM to 9 fibers



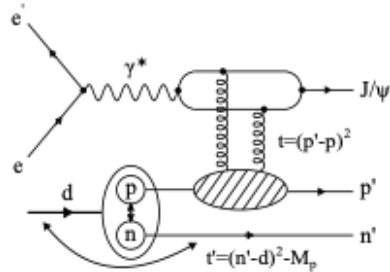
- ALICE Focal-h as the reference
- Fiber size : 1mm
- Spacing = 2.5 cm
- Good energy resolution
- Mix with Quartz fibers can be resilient against radiation damage

Physics sensitive to ZDC

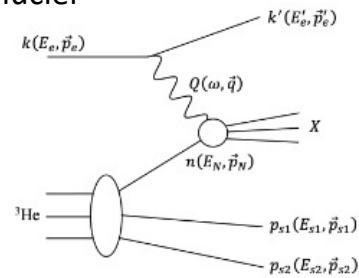
e+p DVCS



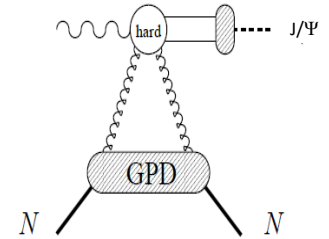
e+d exclusive J/Psi with p/n tagging



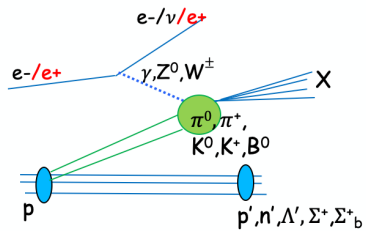
spectator tagging in light nuclei



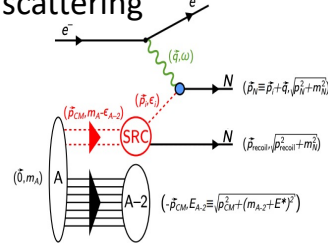
coherent/incoherent J/ψ production in e+A



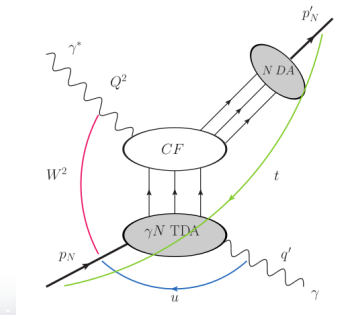
Sullivan process



Quasi-elastic electron scattering



u-channel backward exclusive electroproduction

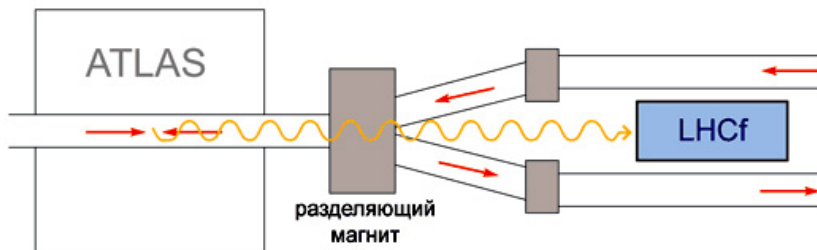
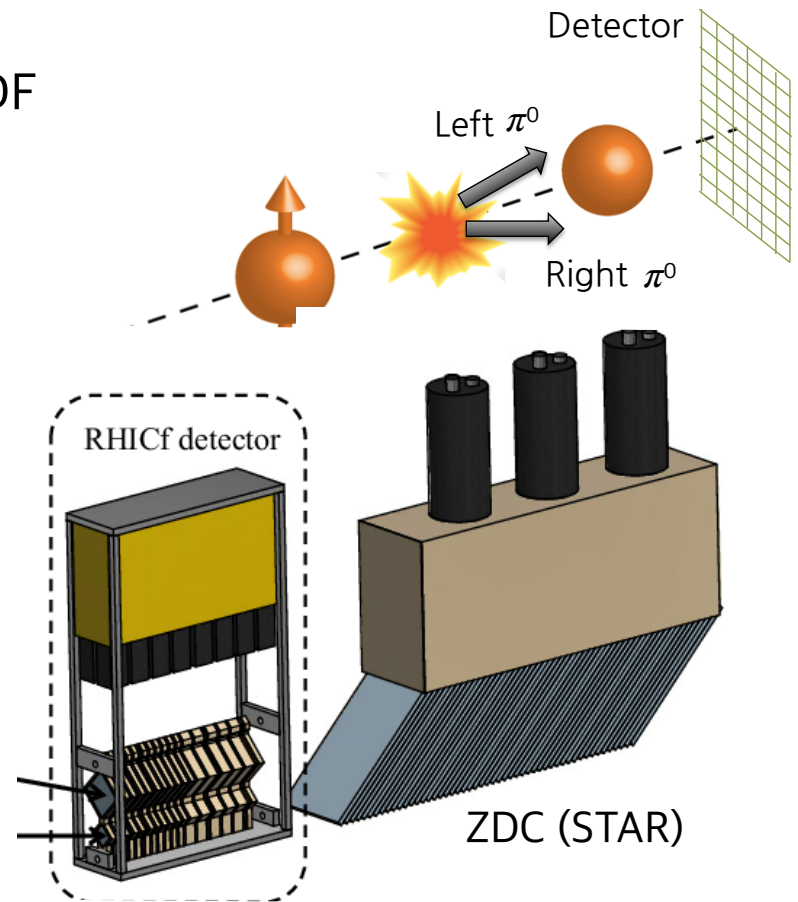


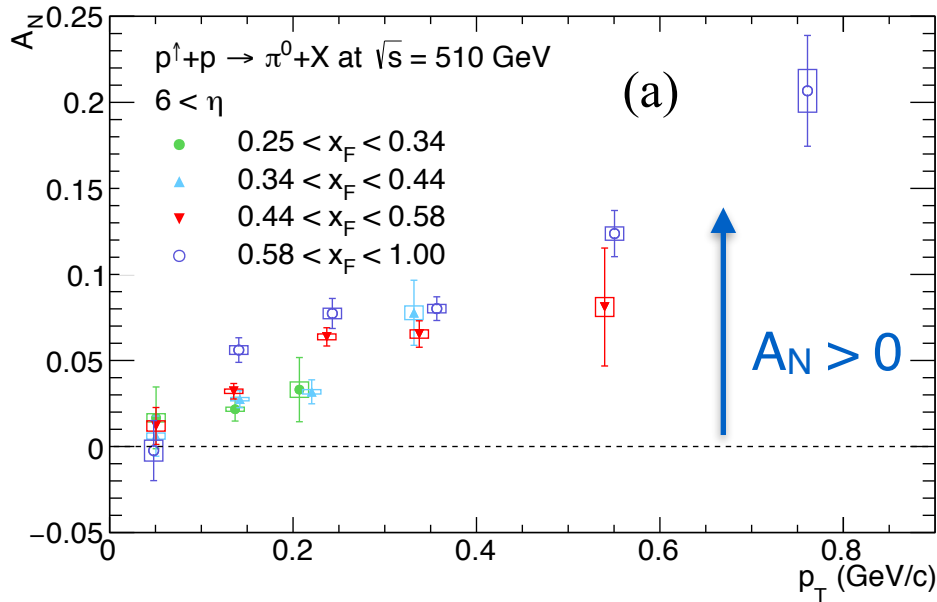
...and MANY more!

Transverse Spin Asymmetry

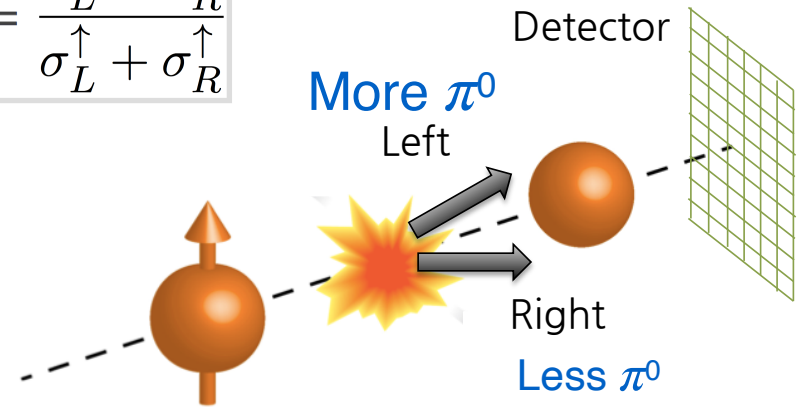
- A_N is left-right cross section asymmetry of particle production in $p\uparrow + p$ collision
- Spin dependence of forward hadrons is still in puzzle
- A_N is crucial input for
 - **T**ransverse **M**omentum **D**ependent PDF
 - Polarization in fragmentation function
- RHICf collaboration measured two A_N
 - π^0 (*PRL 124 252501 (2020)*)
 - Neutron (*Preliminary result*)

$$A_N = \frac{\sigma_L^\uparrow - \sigma_R^\uparrow}{\sigma_L^\uparrow + \sigma_R^\uparrow}$$





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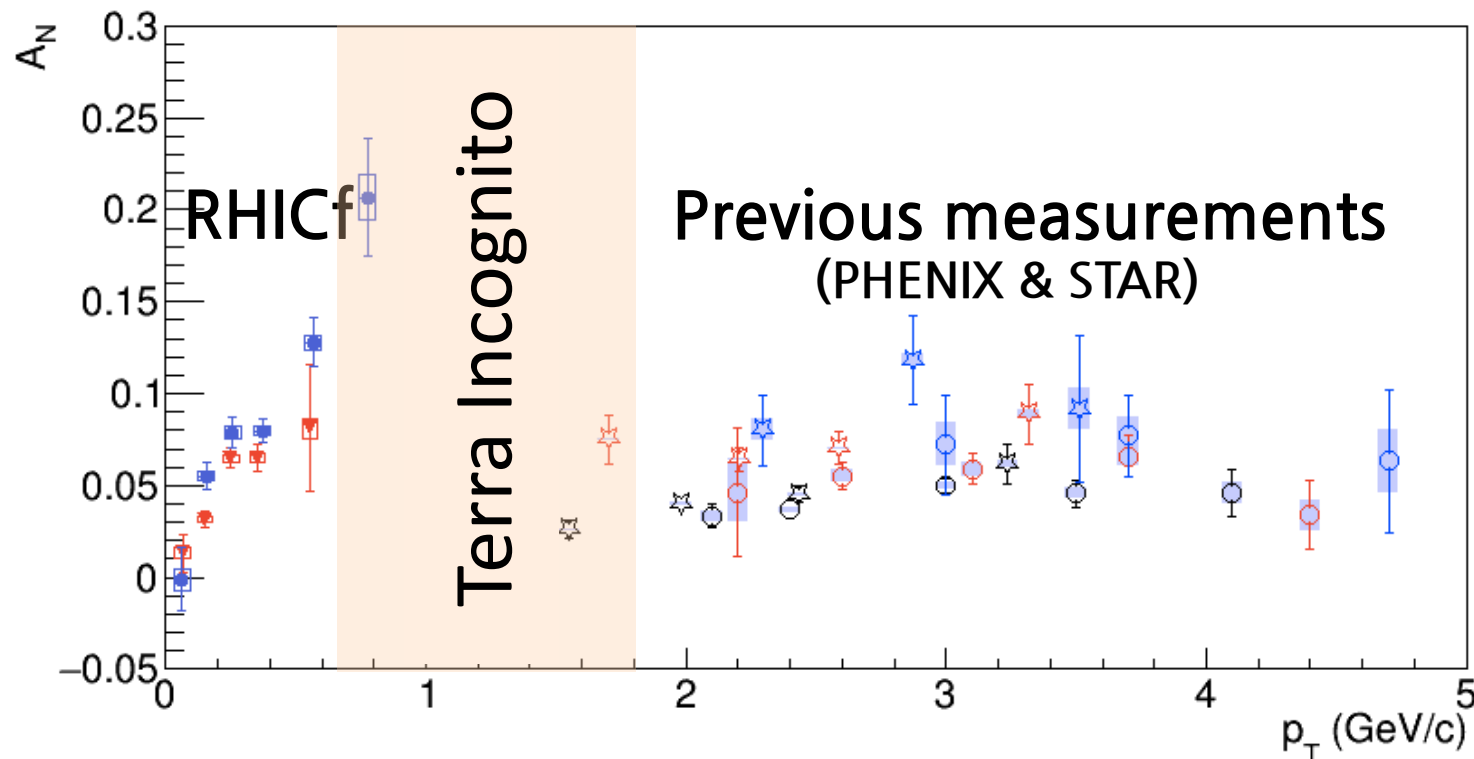


RHICf measured very forward π^0 at $\sqrt{s} = 510$ GeV

- $p_T < 1$ GeV and $0.25 < x_F < 1.0$
- Diffractive hadronic process is dominant in this region
- Observed non-zero A_N as much as measured at less forward regions (PHENIX, STAR)
- A_N is consistent with zero only at very low $p_T < 0.7$ GeV

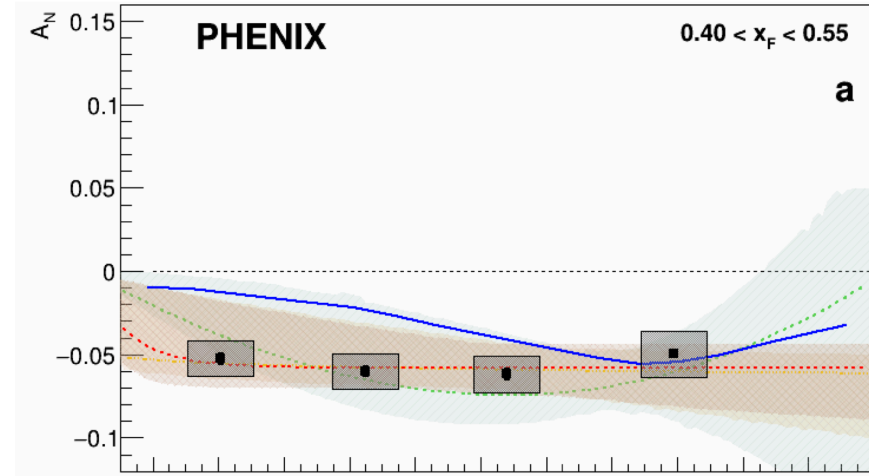
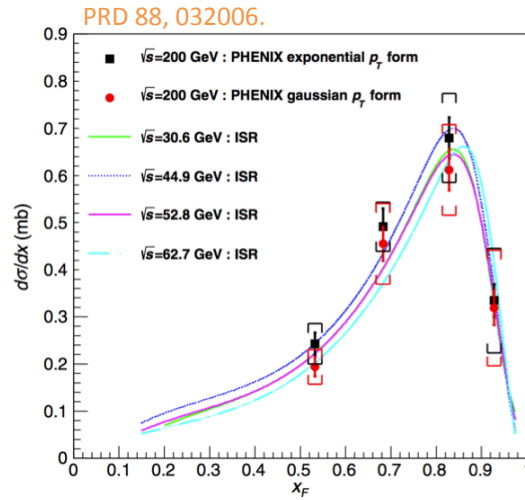
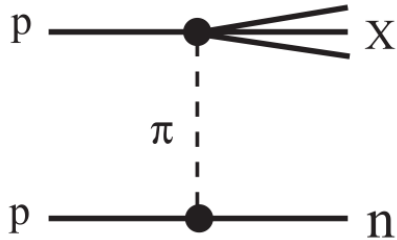
Diffractive

Non-diffractive (partonic)



- A_N of π^0 may come from both diff. and non-diff process
- Similarity of magnitude of A_N in the wide p_T range suggests a common underlying production mechanism for diffractive and non-diffractive process

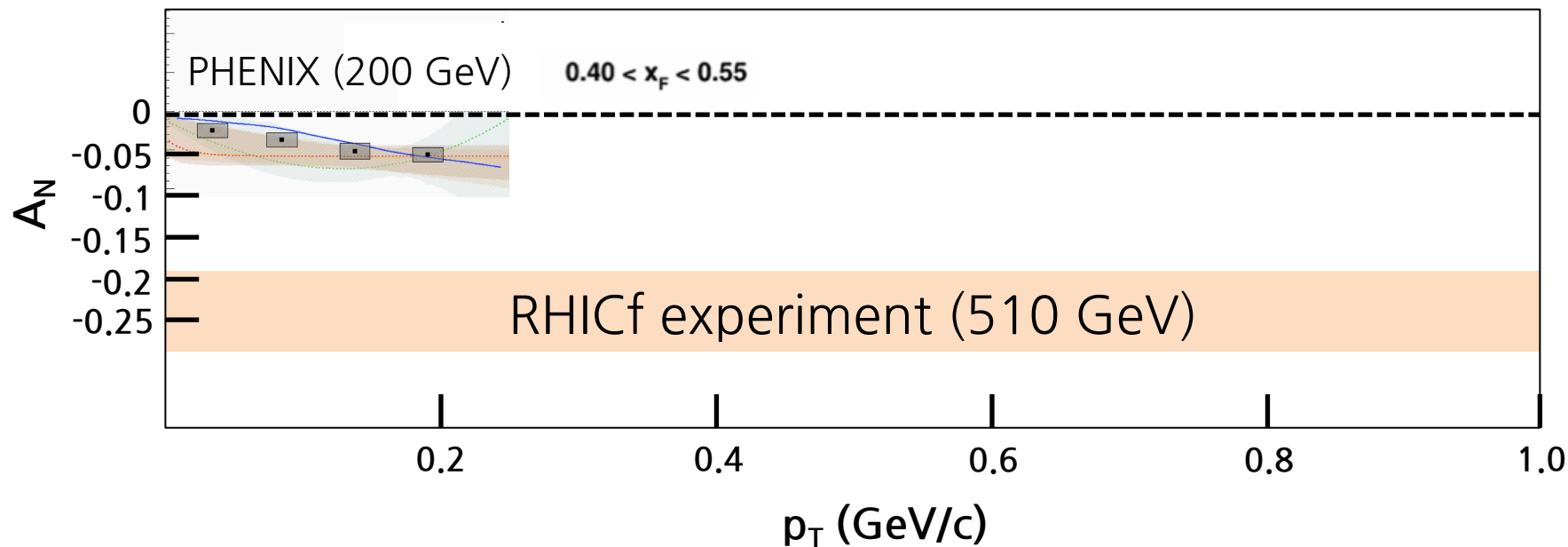
Neutron A_N



Neutron production at forward region

- One Pion Exchange (OPE) model explains x_T differential cross section well in which $p \rightarrow n$ process is dominant
- Yet, A_N was not reproduced quantitatively
- Adding a_1 exchange made up this gap and now can reproduce the data at least qualitatively in the PHENIX measurement range

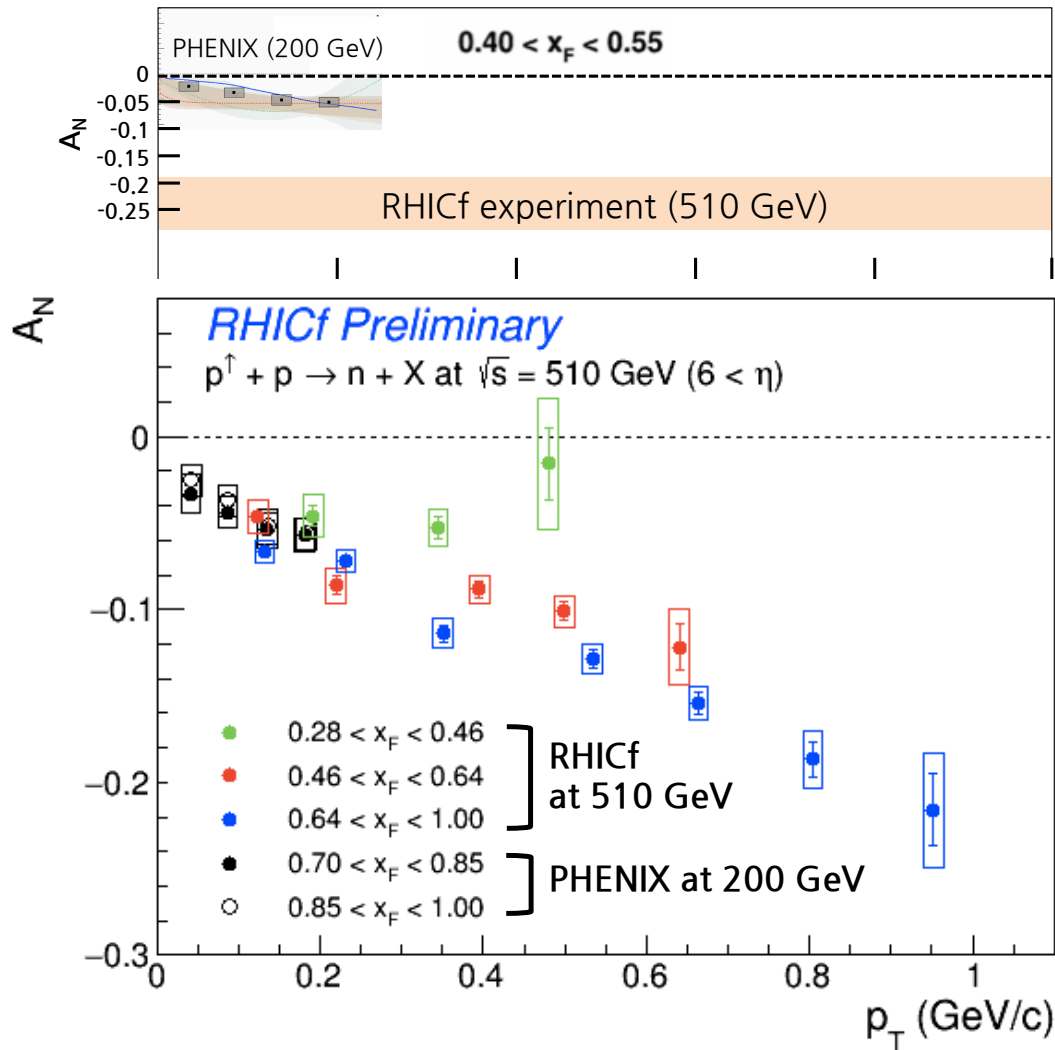
Neutron A_N



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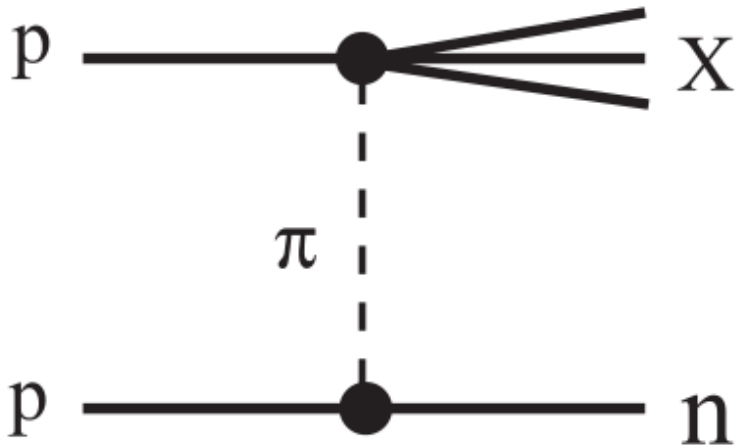
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Neutron A_N



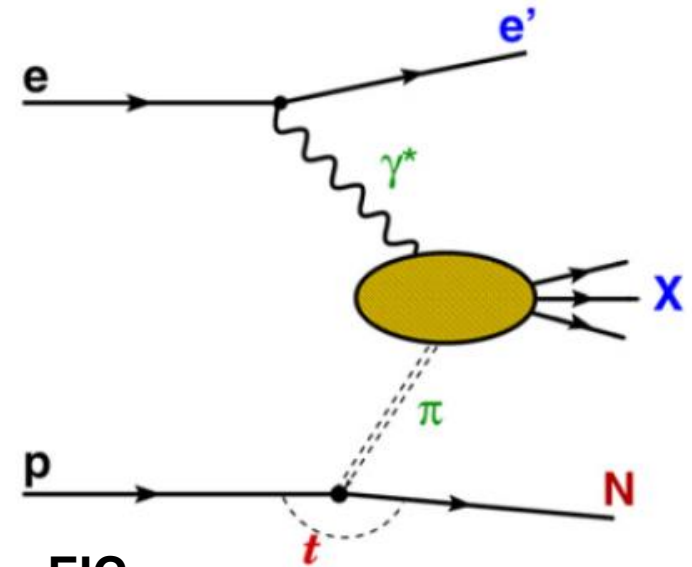
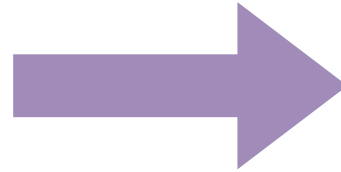
- $p_T < 0.25$ GeV
 - No dependence on x_F
 - Consistent with PHENIX result
- $p_T > 0.25$ GeV
 - Monotonic increase of A_N magnitude
 - Data indicates finite x_F dependence
- Final result will be reported soon

Diffraction process at EIC



RHIC & RHICf

- $p\uparrow + p$
- $p\uparrow + A$



EIC

- $e\uparrow + p$
- $e\uparrow + A$

- EIC can shed light on meson structure function more clearly
 - Tagging scattered electron
 - Tagging X -> exclusive measurement
 - Measurement of forward photon, π^0 , and neutron is highly appreciated

Outlook for forward ZDC R&D

- **Participation in far-forward calorimeter**

- Rich physics in the structure of p/A and diffraction interaction
 - Tagger for the many processes, e.g. DVCS, exclusive VM production, etc
 - Direct observables, e.g. spin asymmetry of neutron production
- Related to other fields, e.g. astroparticle physics

- **Detector R&D**

- Participation in the ZDC-h design and performance study
- The final designs for ZDC will be converged by the ePIC collaboration soon
- We are considering various aspects for contribution, including the tower construction and the readout chip development

backup