中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

JÜLICH
FORSCHUNGSZENTRUM

Polarimetry for the polarized deuterium target at ANKE/COSY

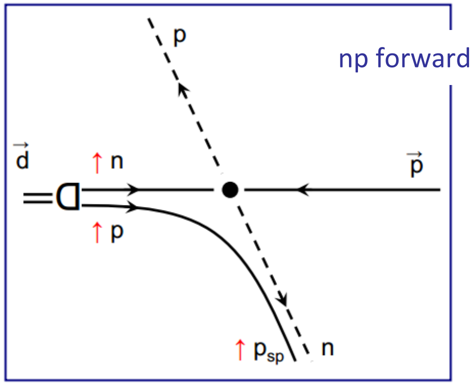
Boxing Gou
for the ANKE-Collaboration

PSTP2013

September 09-13, 2013

Motivation – Investigate np system at higher energies

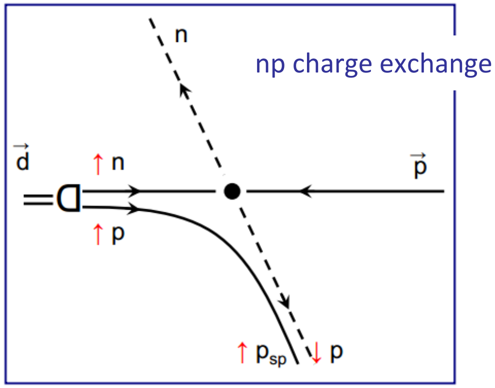
Deuteron is used as source for quasi free polarized neutron for np program at ANKE



dp observables: $d\sigma/d\Omega$, T_{20}, T_{22}, $A_{y,y}$, ...

leads to measurements of

np observables: $d\sigma/d\Omega$, A_{xx}, A_{yy}, $A_{xy,y}$,...



With deuteron beam, experiments have been done at COSY up to T_n=1.135GeV

With deuteron target, study can be extended up to T_n = 2.8GeV

Polarized Internal Gas Target at ANKE

PIT main components:

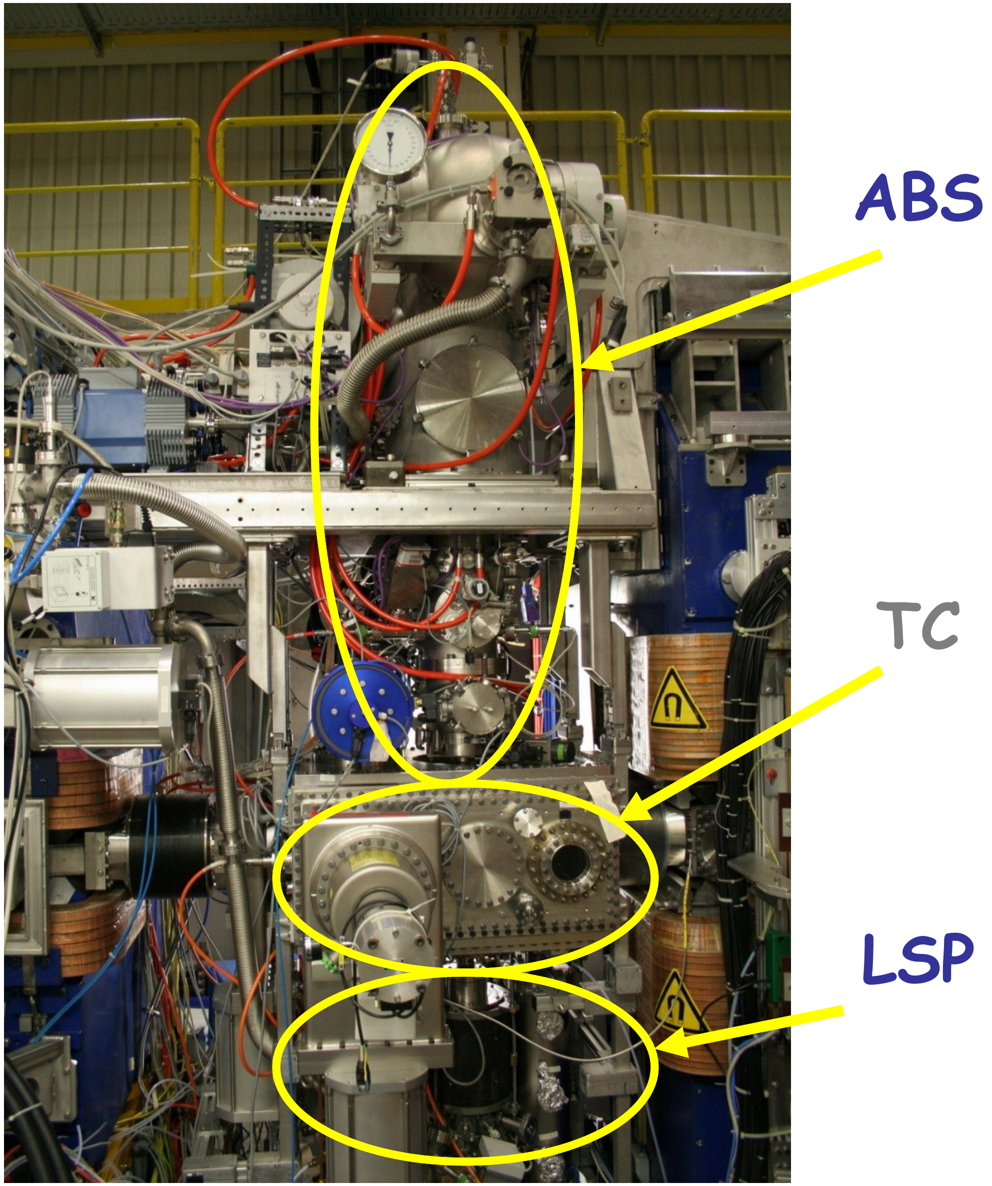
- Atomic Beam Source (ABS)
  - **H** or **D**
  - H beam intensity (2 HFS)

    $I = 8.2 \cdot 10^{16}$ atoms/s
  - Beam size at the IP

    $\sigma = 2.85 \pm 0.42$ mm
  - Polarization for deuterium

    $Q_y \approx 70\%$

    $Q_{yy} \approx 70\%$
- Lamb-Shift Polarimeter (LSP)
- Target Chamber with Storage Cell (SC) (15x20x370 mm^3) to increase the target density

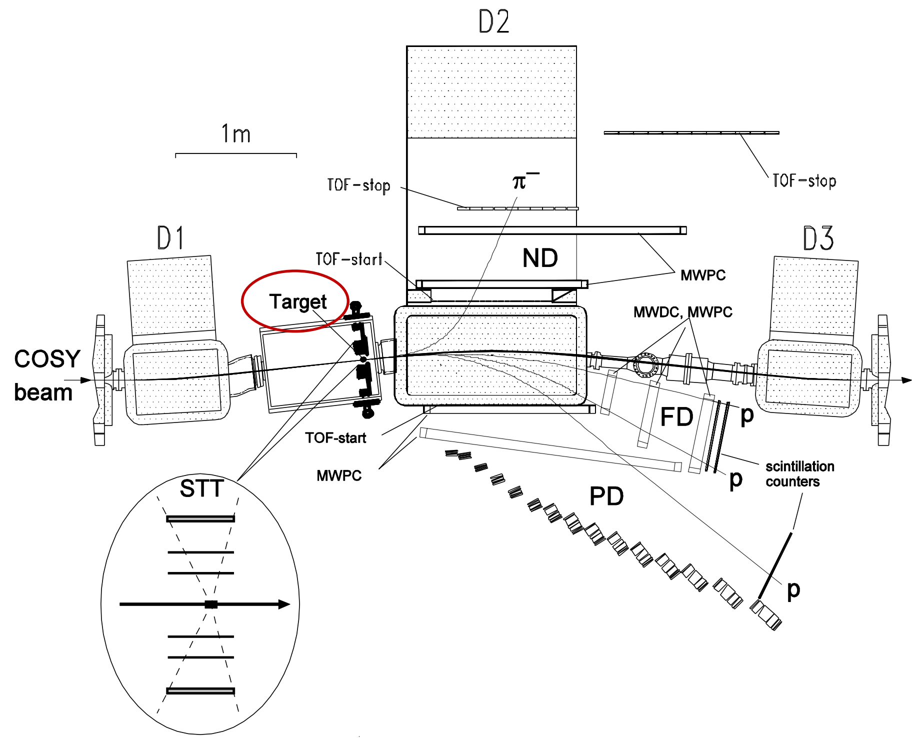


Setup of the experiment

June 2012

- **Beam:** Unpolarized proton beam (T_p = 600MeV)
- **Target:**

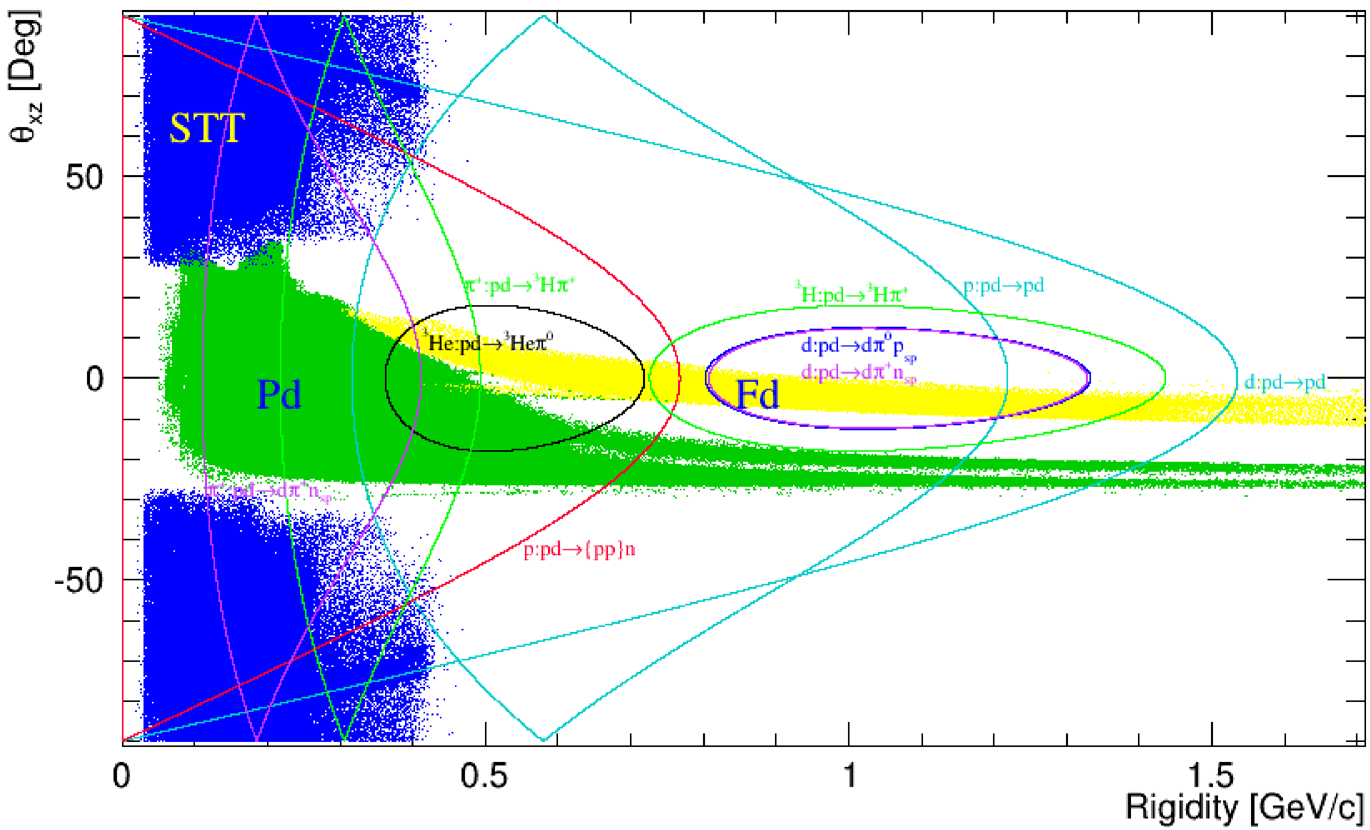
Deuterium		
	Q_y	Q_{yy}
Vector	+1	+1
	-1	+1
Tensor	0	-2
	0	+1
Unpol.	0	0
N_2: background simulation of cell wall		
Empty cell: generate background		



- **Detectors**
  - **Fd: F**orward **d**etector
  - **Pd: P**ositive **d**etector
  - **STT: S**ilicon **T**racking **T**elescope

Polarimetry reactions

Polarization is measured with nuclear reactions with high cross section and analyzing power which fall in ANKE acceptance



Vector polarization measurement:

$p\vec{d} \rightarrow d\pi^+ n_{sp}$ $\quad$ $p\vec{d} \rightarrow pd$

$p\vec{d} \rightarrow d\pi^0 p_{sp}$

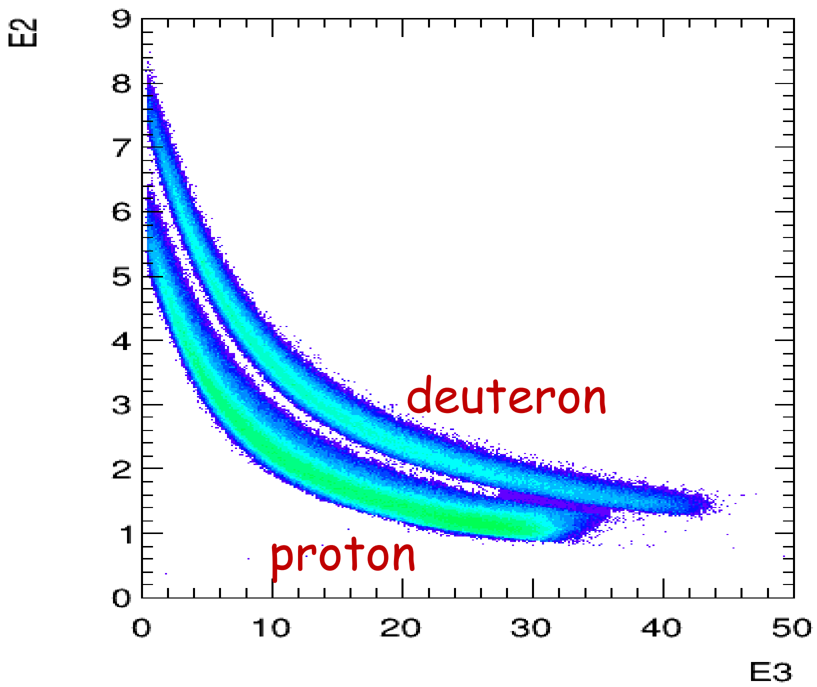
Tensor polarization measurement:

$p\vec{d} \rightarrow pd$

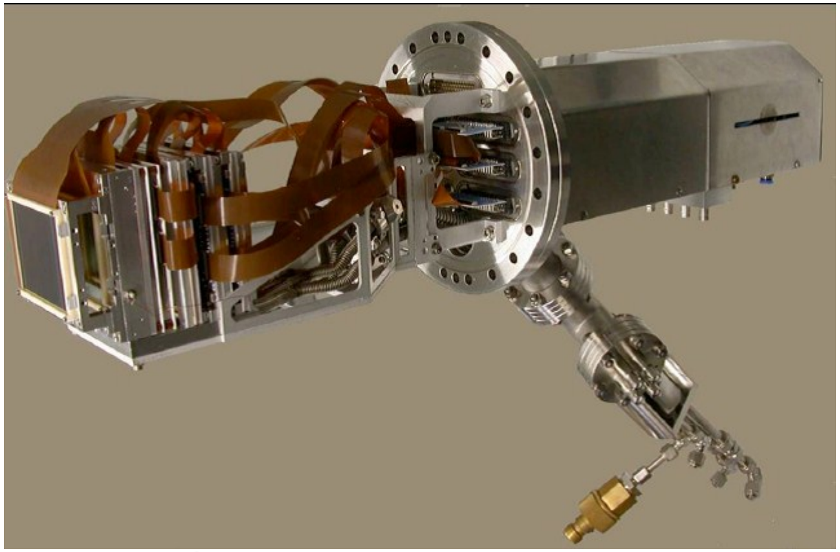
$p\vec{d} \rightarrow {}^3H\pi^+$

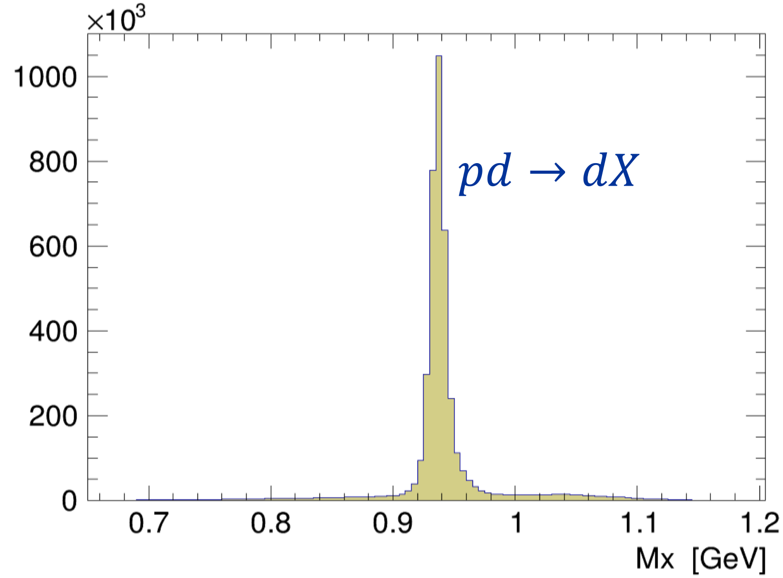
Reaction identification for $\vec{pd} \to$ pd

Deuteron is identified by energy deposit in different layers of STT



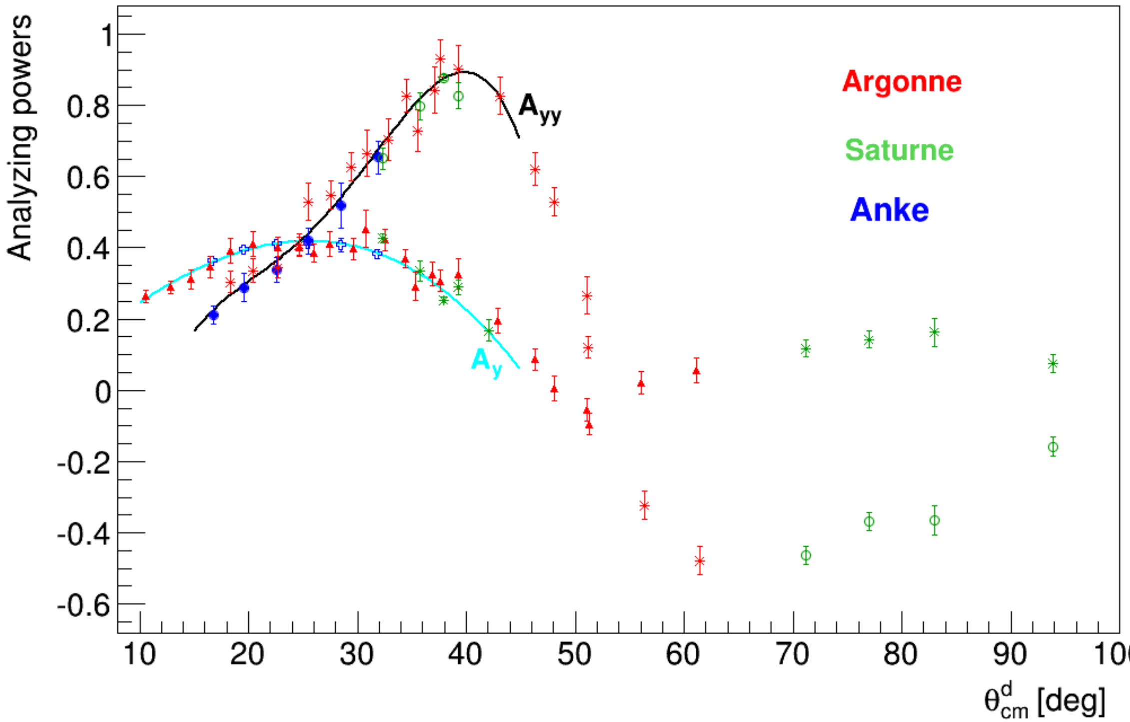
STT detection system



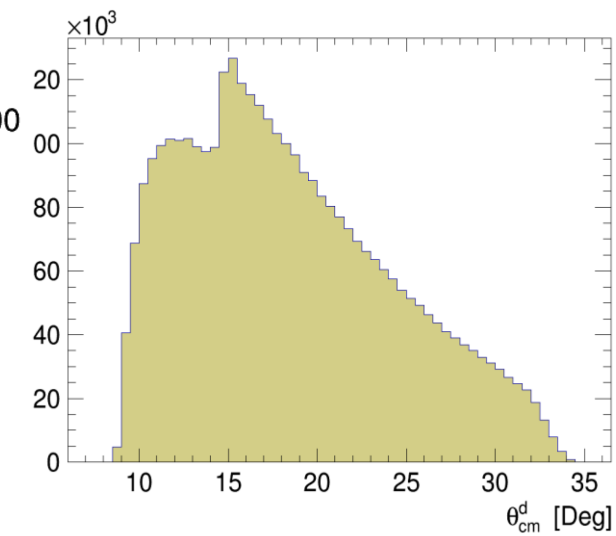


Reaction pd → pd is selected by missing mass method, there is very low background under the peak.

$p\vec{d} \to pd$ used as a polarimetry



Cross section is large, and detector acceptance covers the region where A_y and A_{yy} are known



Both vector and tensor analyzing powers large and well-known

Polarimetry principle $(p\vec{d} \rightarrow pd)$

$$\frac{d\sigma}{d\Omega}(\theta,\phi) = \left(\frac{d\sigma}{d\Omega}\right)_0(\theta)\left\{1 + \underbrace{\tfrac{3}{2}Q_y A_y(\theta)\cos\phi}_{\mathcal{A}_\mathcal{V}} + \underbrace{\tfrac{1}{4}Q_{yy}\left[A_{yy}(\theta)(1+\ \cos 2\phi) +\ A_{xx}(\theta)(1\ -\ \cos 2\phi)\right]}_{\mathcal{A}_\mathcal{T}}\right\}$$

$$\boxed{CR = \frac{N_L^{\mathrm{p}} \cdot N_R^0 - N_R^{\mathrm{p}} \cdot N_L^0}{N_L^{\mathrm{p}} \cdot N_R^0 + N_R^{\mathrm{p}} \cdot N_L^0}}$$

$$= \frac{\cancel{\left(\frac{\varepsilon_L^P}{\varepsilon_R^P}\Big/\frac{\varepsilon_L^0}{\varepsilon_R^0}\right)}\cdot(1-\mathcal{A}_\mathcal{V}+\mathcal{A}_\mathcal{T})-(1+\mathcal{A}_\mathcal{V}+\mathcal{A}_\mathcal{T})}{\cancel{\left(\frac{\varepsilon_L^P}{\varepsilon_R^P}\Big/\frac{\varepsilon_L^0}{\varepsilon_R^0}\right)}\cdot(1-\mathcal{A}_\mathcal{V}+\mathcal{A}_\mathcal{T})-(1+\mathcal{A}_\mathcal{V}+\mathcal{A}_\mathcal{T})}$$

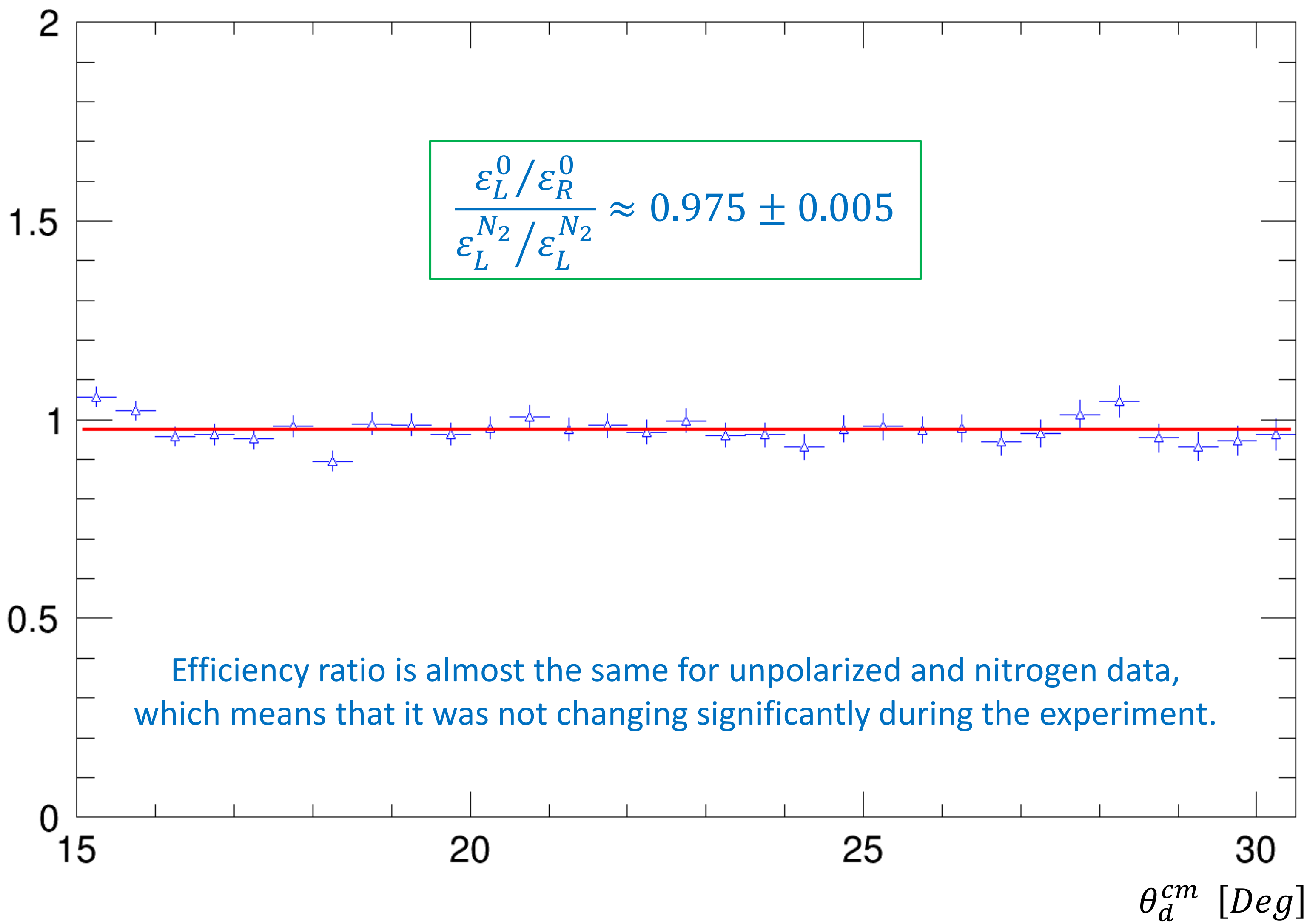
If the ratio of the left and right detector efficiency $\frac{\varepsilon_L}{\varepsilon_R}$ does not change, Qy and Qyy can be determined by fitting the CR obtained from the measurement.

$$= \frac{-\frac{3}{2}\cdot Q_y \cdot A_y(\theta)}{1+\frac{1}{4}\cdot Q_{yy}\cdot\left[A_{yy}(\theta)\cdot(1+\cos 2\phi)+A_{xx}(\theta)\cdot(1-\cos 2\phi)\right]}$$

$$\boxed{\approx \frac{-\frac{3}{2}\cdot Q_y \cdot A_y(\theta)}{1+\frac{1}{2}\cdot Q_{yy}\cdot A_{yy}(\theta)}}$$

$$\phi \rightarrow 0^\circ, 180^\circ$$

Check consistency of $\frac{\varepsilon_L}{\varepsilon_R}$



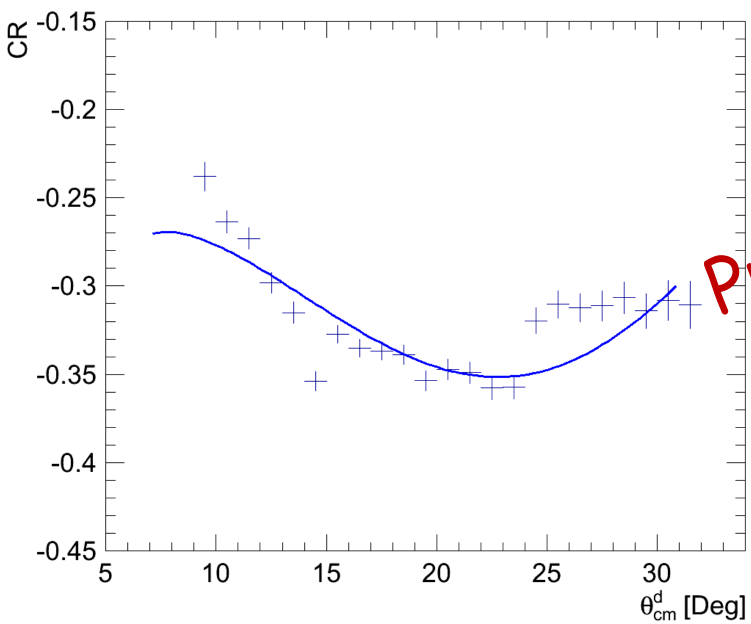
Result of polarization measurement $(p\vec{d} \rightarrow pd)$

1st State (1, 1)

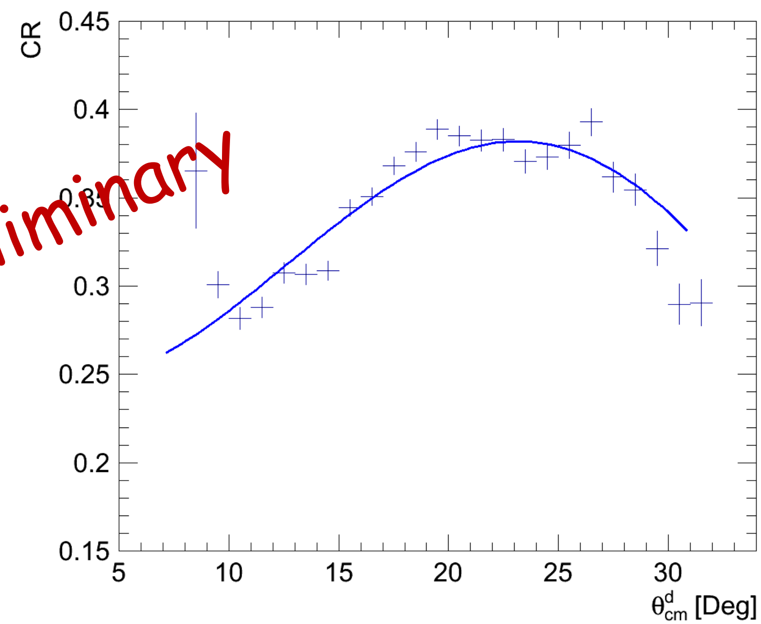
Measured polarization:
Q_y = 0.719+/-0.005
Q_{yy} = 0.951+/-0.054

2nd State (-1, 1)

Measured polarization:
Q_y = 0.716+/-0.007
Q_{yy} = 0.738+/-0.068



Preliminary



Result of polarization measurement $(p\vec{d} \to pd)$

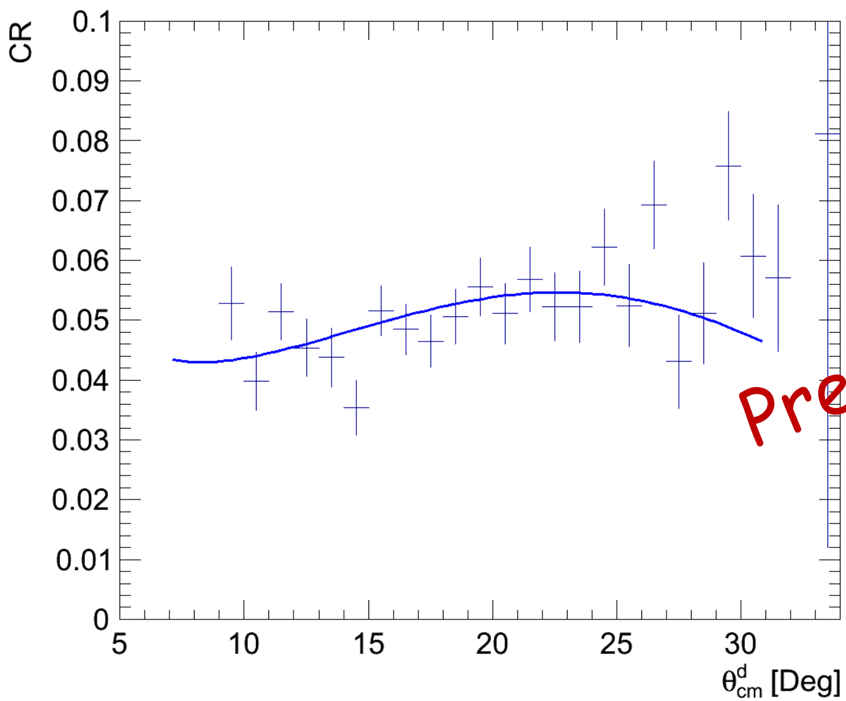
3rd State (0, -2)

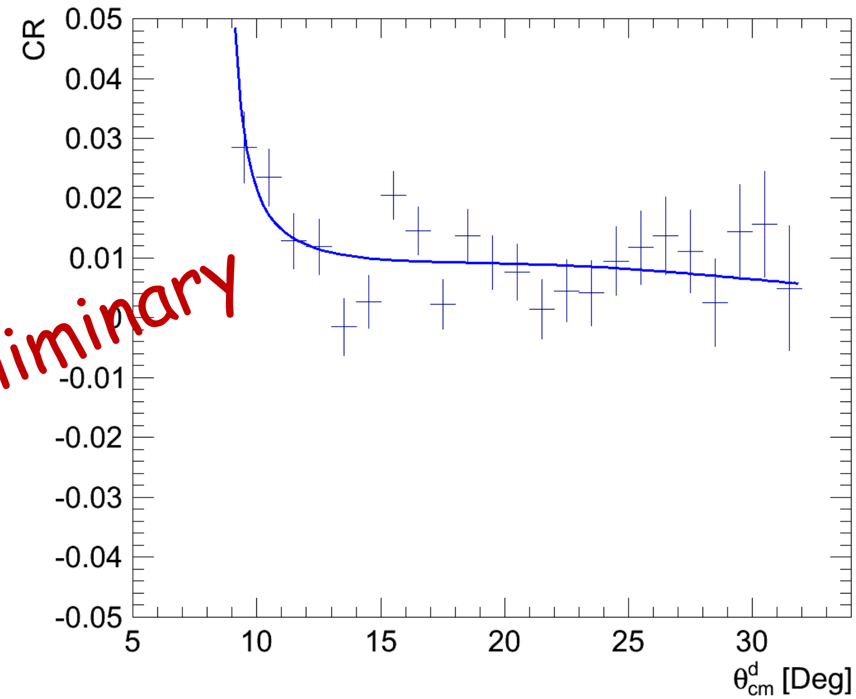
Measured polarization:
Qy =-0.101+/-0.003

4th State (0, 1)

Measured polarization:
Qy =-0.014+/-0.003

Tensor polarization Q_{yy} cannot be determined due to reduced signal caused by small value of Q_y ☹

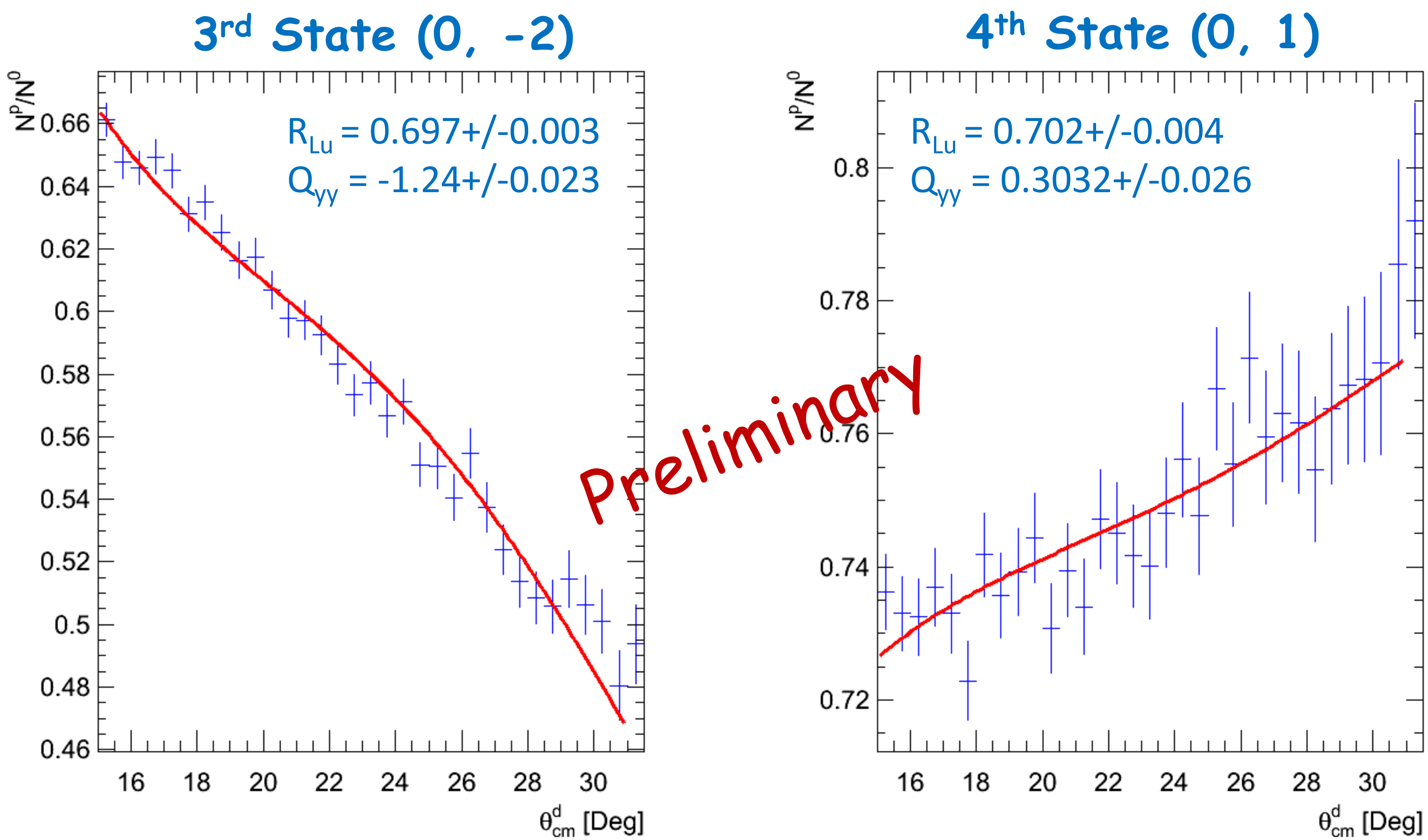




Result of polarization measurement $(p\vec{d} \rightarrow pd)$

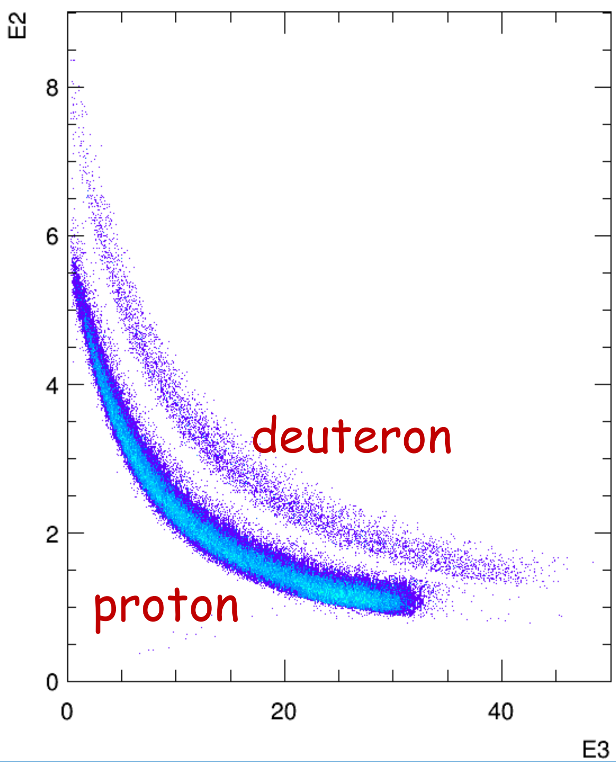
If vector polarization Q_y is closed to 0
luminosity ratio R_{Lu} and tensor polarization Q_{yy} can be determined by fitting

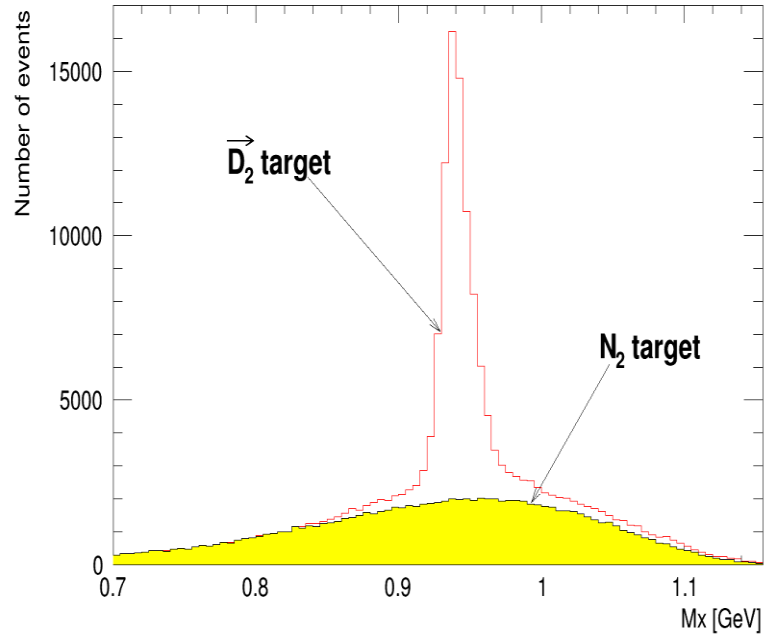
$$\frac{N^p(\theta,\,\phi)}{N^0(\theta)} = R_{Lu}\left[1 + \tfrac{1}{4}Q_{yy}A_{yy}(\theta)(1+ < \cos 2\phi >)\right]$$



Identification of $p\vec{d} \rightarrow \{pp\}n$ reaction.

Fewer deuterons in 2-track events

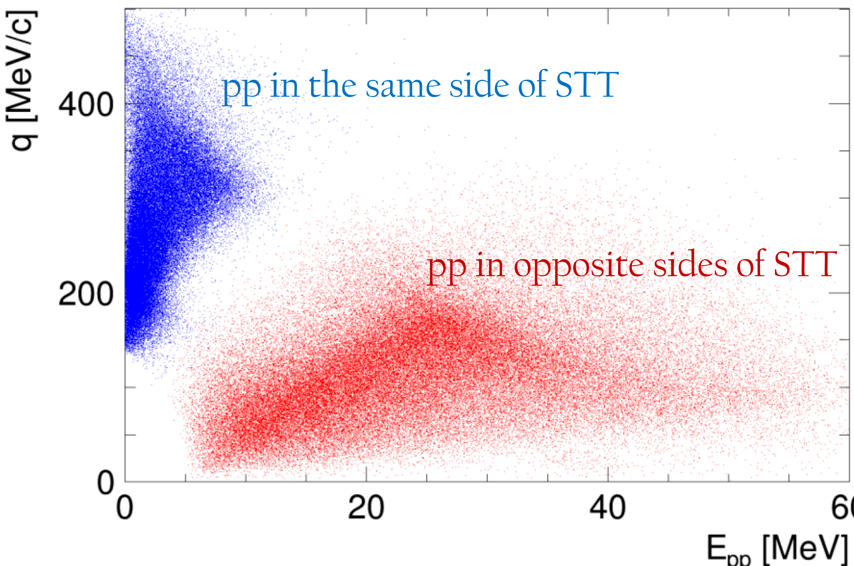




Shape of the background from the storage cell is simulated by nitrogen gas.

$p\vec{d} \rightarrow pd$ is isolated by building missing mass spectrum for 2-track events in STT

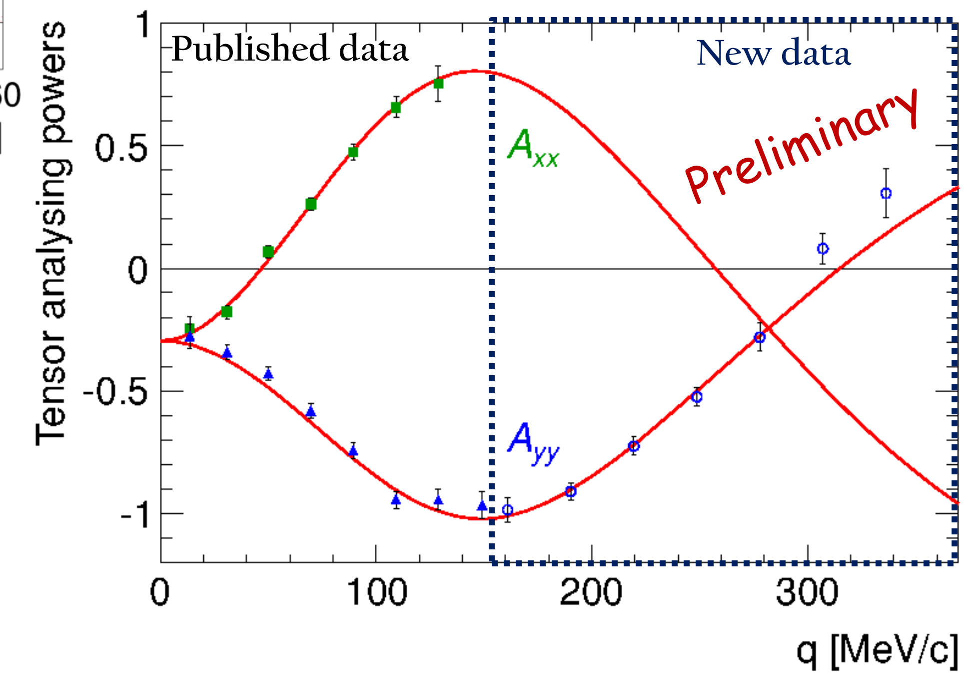
Preliminary result of A_{yy} measurment for $p\vec{d} \rightarrow \{pp\}n$



CE reaction is not sensitive to deuteron vector polarization if {pp} is in $^1S_0$ ($E_{\{pp\}}$ < 3MeV)

$$\frac{N^p(\theta,\ q)}{N^0(q)} = R_{Lu}\left[1 + \tfrac{1}{4}Q_{yy}A_{yy}(q)(1 + < \cos 2\phi >)\right]$$

Ayy of CE reaction is measured using the tensor polarization extracted from $p\vec{d} \rightarrow pd$, which is in a good agreement with the theoretical prediction.



Summary and Outlook

- Target commissioning experiment was successful.
- High performance of the target was achieved.
- Preliminary measurements of CE analysis powers are in good agreement with the theory.
- Production experiment was approved by COSY-PAC.
- Good physics results are expected.

Thank you