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FORSCHUNGSZENTRUM

Initial Research of np Scattering with Polarized Deuterium Target at ANKE/COSY

Boxing Gou
for the ANKE-Collaboration

Spin2014

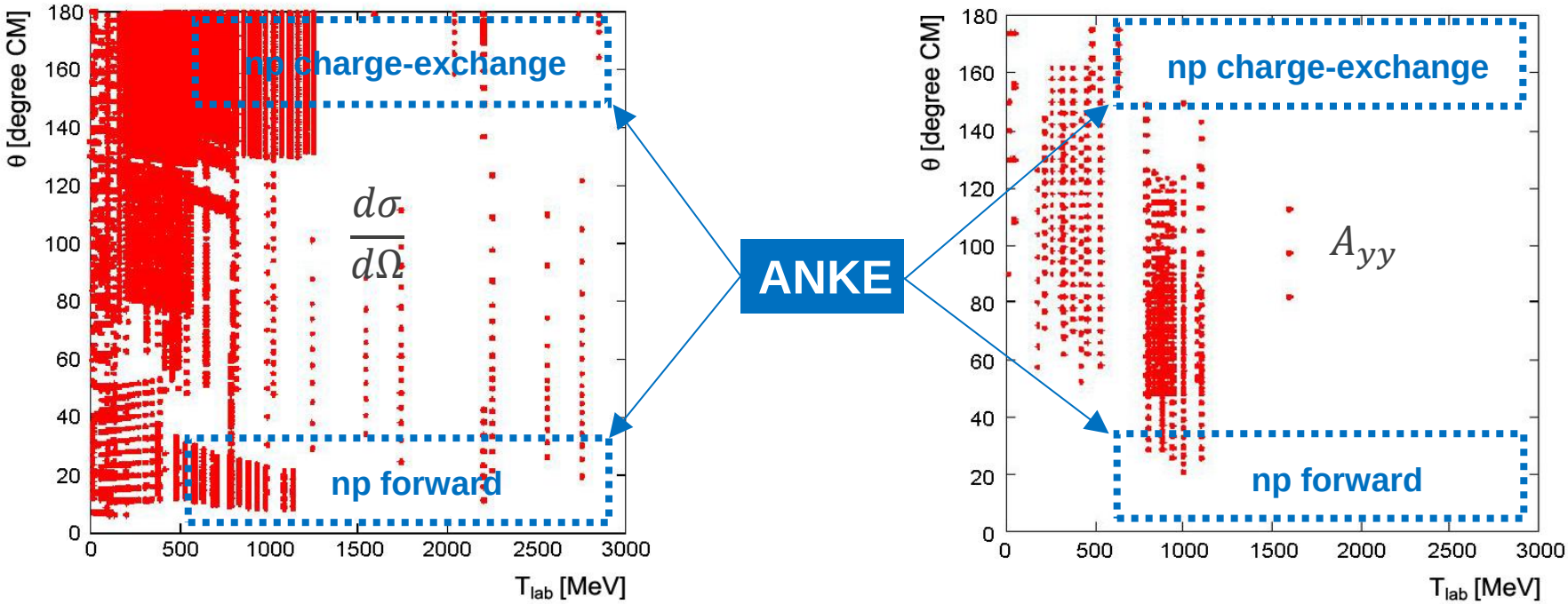
October 20, 2014

Outline

- Physics motivation
- Experimental facilities
- Initial research - commissioning experiment at $T_p = 600\ MeV$
- Polarimetry
  - $p\vec{d} \rightarrow pd$
  - $p\vec{d} \rightarrow d\pi^+ n_{sp}$
- Charge-Exchange deuteron breakup reaction $p\vec{d} \rightarrow \{pp\}n$
- Summary and outlook

Motivation – Investigate np system

np experimental data above 800 MeV are scarce

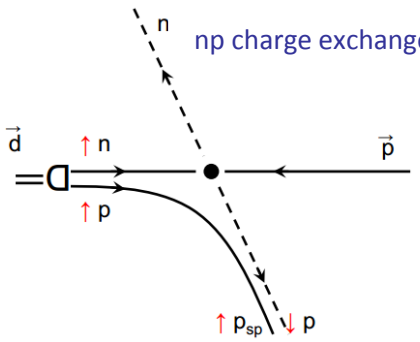


ANKE is able to explore the small-angle regions by studying the np charge-exchange and np-forward reactions thus can improve our understanding about np system.

Motivation – Investigate np system

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

Theory



dp CE observables:
$\frac{d\sigma}{d\Omega}, A_N, A_{NN}, C_{NN} \ldots\ldots$

{pp} in $^1S_0$

PSA

np elementary amplitudes:
$\gamma,\ \beta,\ \delta,\ \varepsilon \ldots\ldots$

D. V. Bugg, C. Wilkin, Nucl. Phys. A 467, 575

Achieved results

With deuteron beam, investigation has been done at COSY up to T_N=1.135GeV

D. Mchedlishvili et al. Eur. Phys. J. A 49, 49

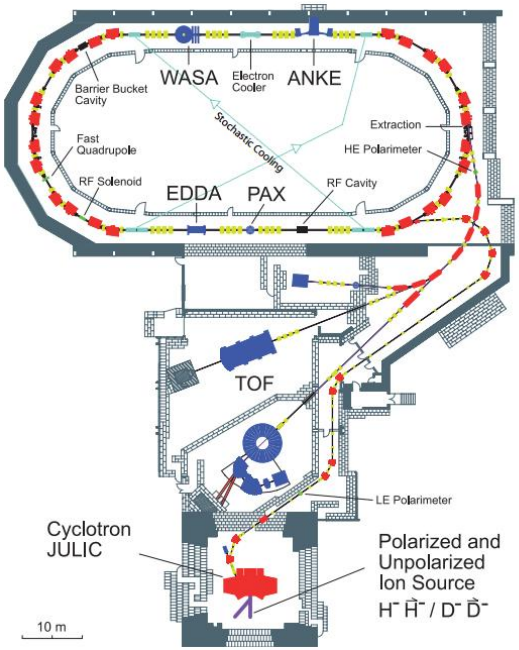
Extend np study

Use deuteron target, study up to T_P = 2.8 GeV

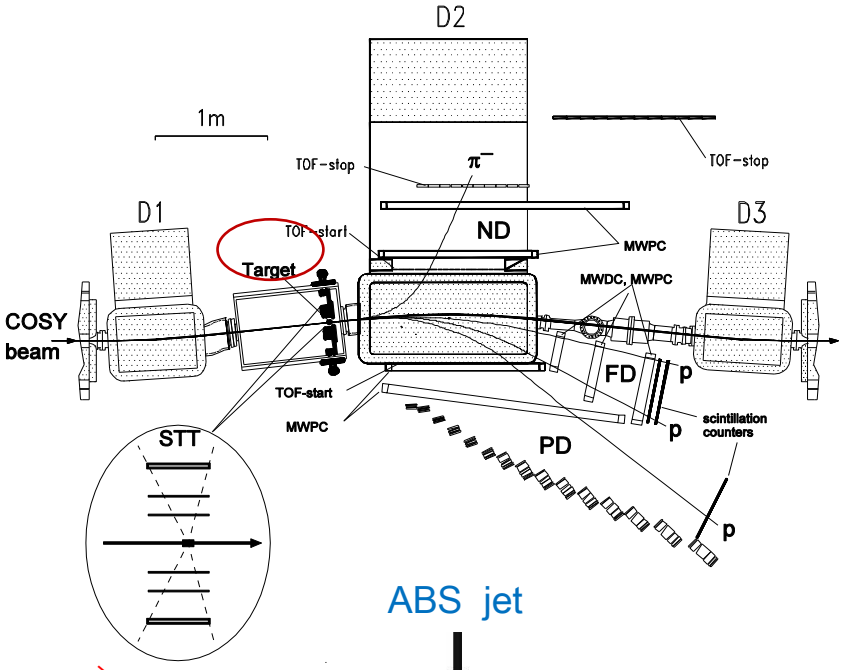
See talk A.Kacharava

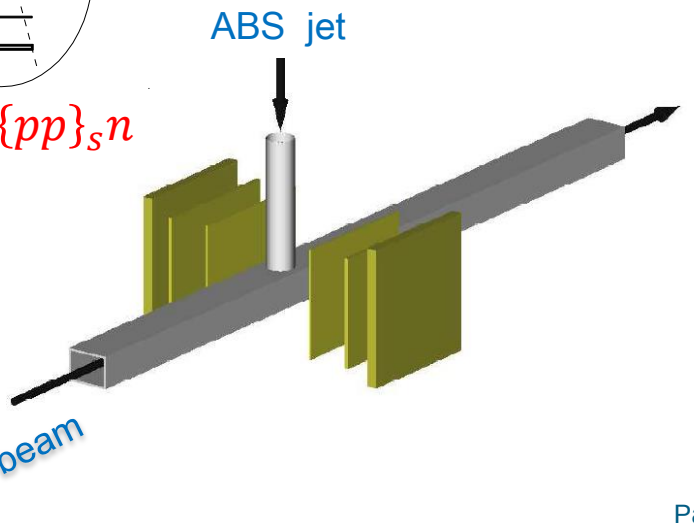
Experimental facilities – COSY and ANKE

COSY – COoler SYnchrotron

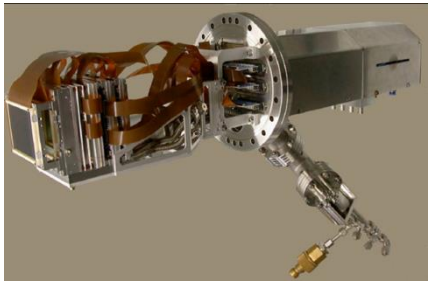


ANKE - Apparatus for Studies of Nucleon and Kaon Ejectiles





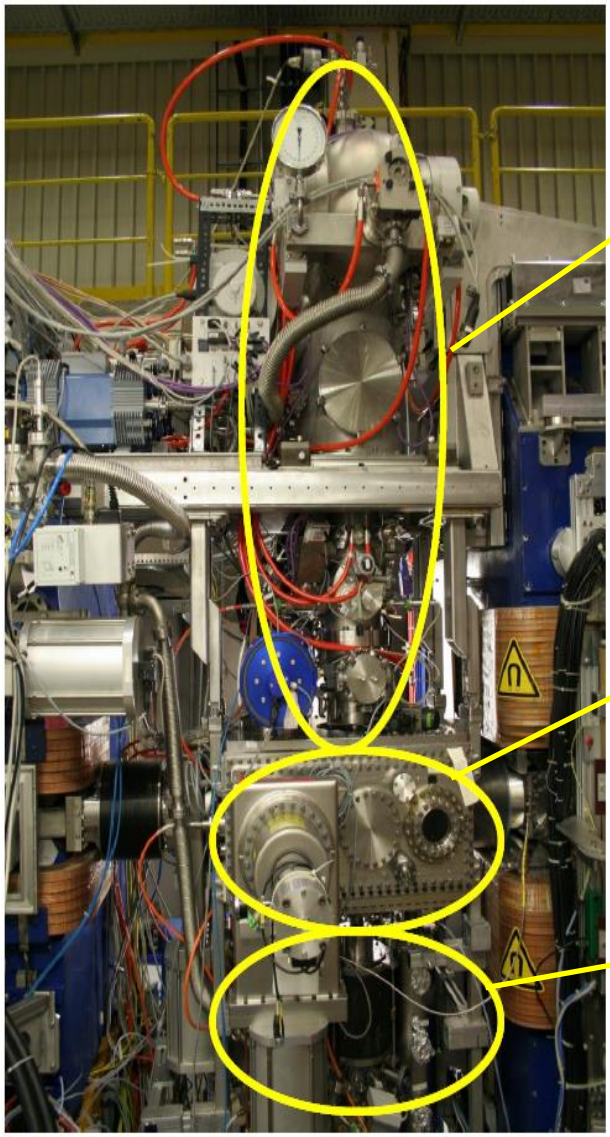
$p\vec{d} \rightarrow \{pp\}_s n$



Silicon **T**racking **T**elescope (**STT**)

- PID using ΔE.
- Event vertices reconstructed.
- $\{pp\}_s$ registered.

Experimental facilities – **P**olarized **I**nternal **T**arget (**PIT**)



Atomic **B**eam **S**ources **(ABS)**
- Polarized D beam
- Different modes
  (Qy, Qyy)
- High polarization
  Ideal value: (+1 +1)
  Lab value (~ 0.7, ~ 0.7)
- Beam size at IP
  σ = 2.85 ± 0.42 mm

Target **C**hamber **(TC)**
- STT
- **S**torage **C**ell (**SC**)
  15x20x370 mm^3
  To increase the target intensity
  (10^{13} cm^{-2})

Lamb-**S**hift **P**olarimeter **(LSP)**
- Tune the setting of ABS
- Fast on-line measurement

Initial research - Commissioning experiment

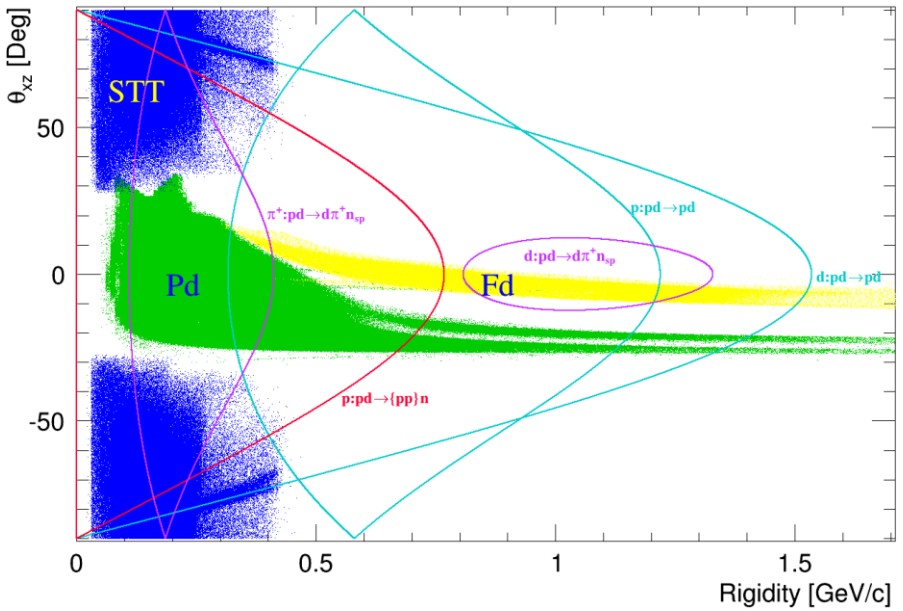
June 2012

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

Deuterium		
	Q_y	Q_{yy}
Pol.1	+1	+1
Pol.2	-1	+1
Pol.3	0	-2
Pol.4	0	+1
Unpol.	0	0
N_2: background simulation of cell wall		
Empty cell: generate background		

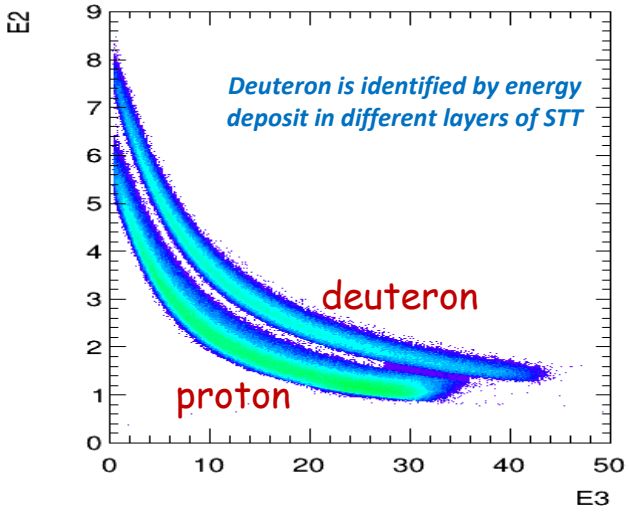
Reactions interested:

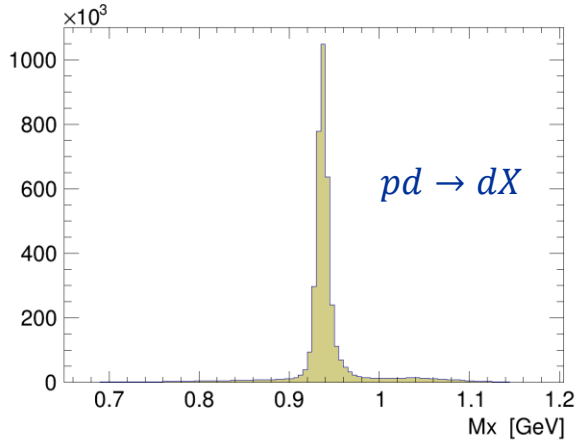
- ✓ $p\vec{d} \rightarrow \{pp\}n$ (CE: A_{yy} ...)
- ✓ $\vec{pd} \rightarrow pd$ (Polarimetry: Q_y & Q_{yy})
- ✓ $p\vec{d} \rightarrow d\pi^+ n_{sp}$ (Q_y cross check)



- ✓ **Pol. Target:**
  - Pol. 1 and pol. 2 switch between each other every 10 sec.
  - Pol. 3 and pol. 4 switch between each other every 10 sec.
- ✓ **N_2 target:** *to simulate the background* caused by cell

Polarimetry - $p\vec{d} \rightarrow pd$

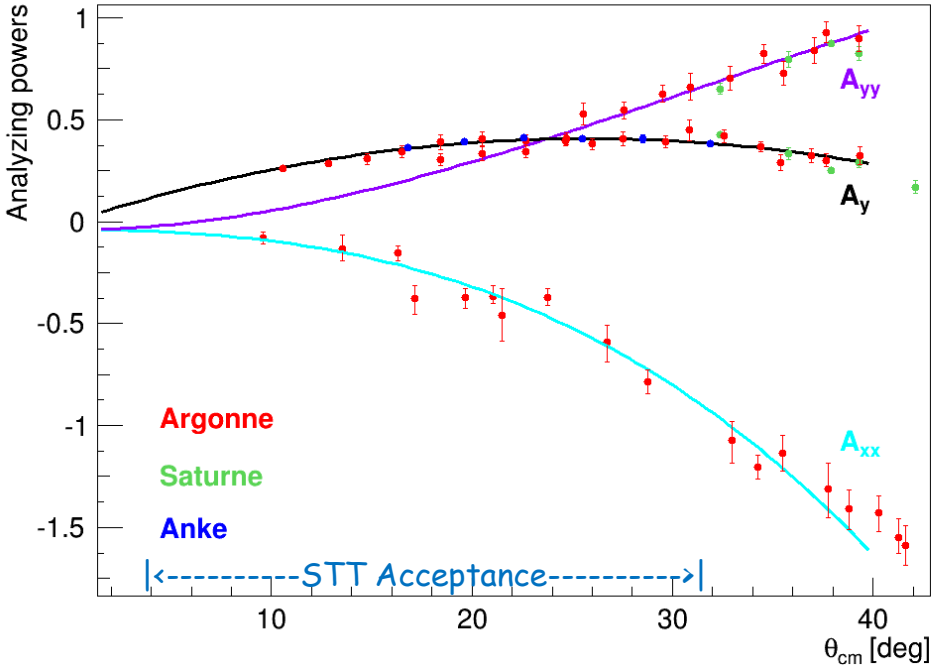




Very little background under the peak

Why $p\vec{d} \rightarrow pd$?

- ✓ High cross section.
- ✓ High and well-known analyzing powers (A_y & A_{yy}).
- ✓ Covered by the detectors (STT).



Polarimetry - Principle $\left(p\vec{d} \rightarrow pd\right)$

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

Observable

$$\varepsilon(\theta,\varphi) = \frac{N_a - N_b}{N_a + N_b}$$

$$\begin{cases} a = 1 \\ b = 2 \end{cases} OR \begin{cases} a = 3 \\ b = 4 \end{cases}$$

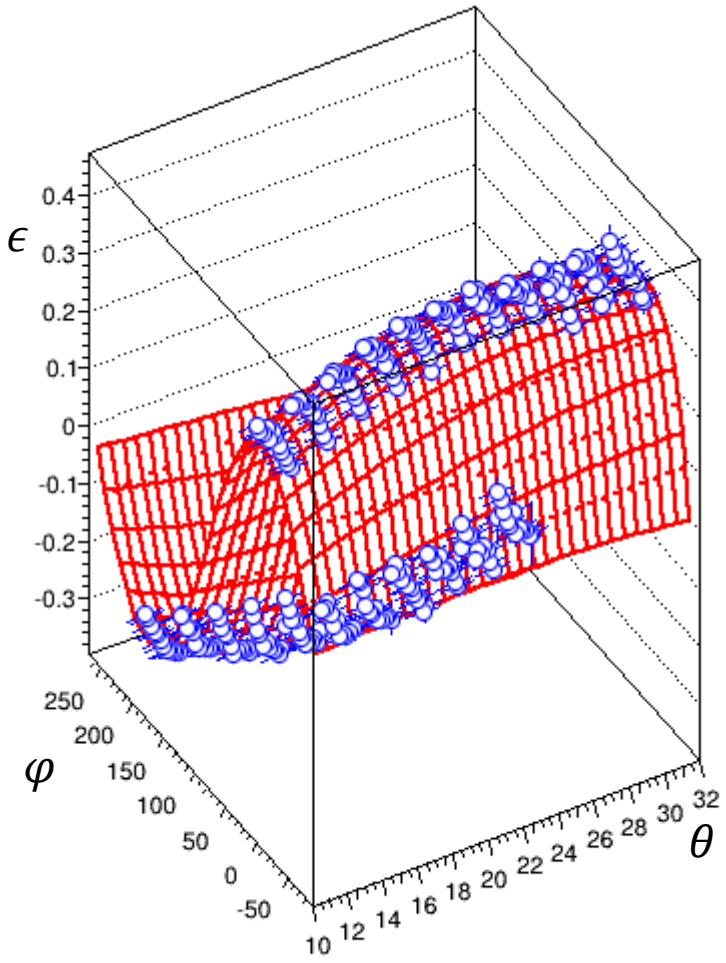
- Target densities of modes a and b equal
- Mode a and b switch every 10 sec
- ✓ Systematic errors minimized ☺

Fitting function

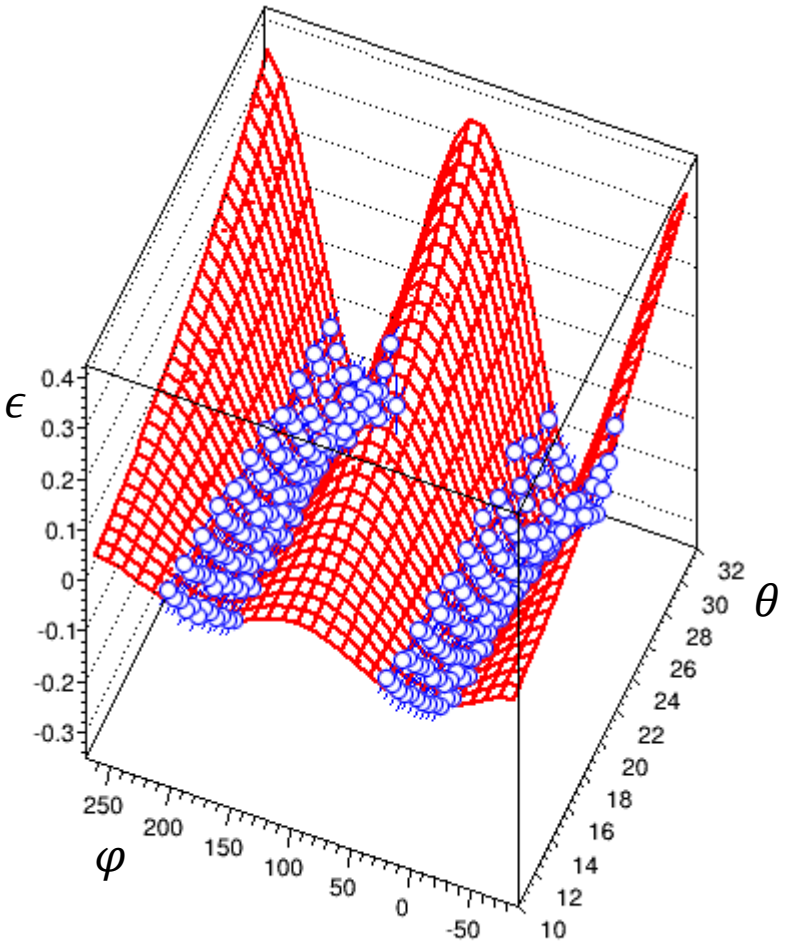
$$\epsilon(\theta,\varphi)\frac{\frac{3}{2}A_y(\theta)cos\varphi\left(Q_y^a - Q_y^b\right) + \frac{1}{4}[A_{yy}(\theta)(1+cos2\varphi) + A_{xx}(\theta)(1-cos2\varphi)](Q_{yy}^a - Q_{yy}^b)}{2 + \frac{3}{2}A_y(\theta)cos\varphi\left(Q_y^a + Q_y^b\right) + \frac{1}{4}[A_{yy}(\theta)(1+cos2\varphi) + A_{xx}(\theta)(1-cos2\varphi)](Q_{yy}^a + Q_{yy}^b)}$$

Polarimetry - 2-dimentional fit

Modes 1 and 2



Modes 3 and 4

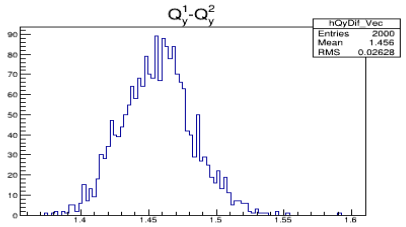


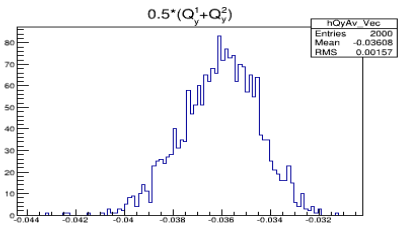
Polarimetry - Systematic error

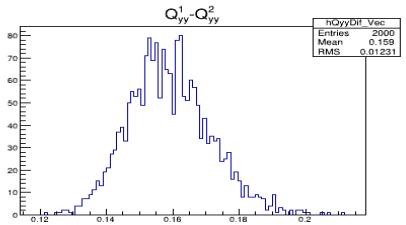
Change parameters of polynomial functions and repeat the fit procedure

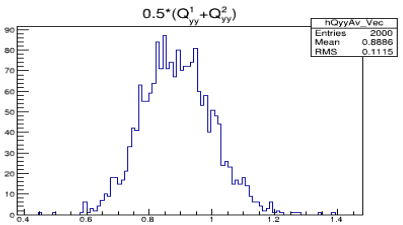
(Q_y, Q_{yy}): $(+1,+1), (-1,+1), (0,-2), (0,+1)$

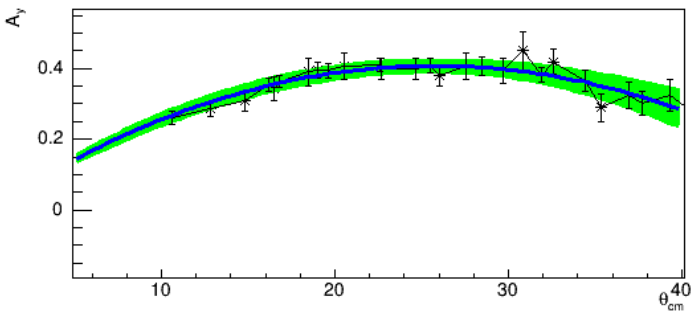
Pol.	Modes 1, 2			Modes 3, 4		
	Ideal	Measured	Sys. err.	Ideal	Measured	Sys. err.
ΔQ_y	+2	1.46 ± 0.01	0.03	0	-0.07 ± 0.01	0.01
$\langle Q_y \rangle$	0	-0.03 ± 0.01	0.01	0	-0.02 ± 0.02	0.01
ΔQ_{yy}	0	0.17 ± 0.02	0.01	-3	-1.68 ± 0.02	0.14
$\langle Q_{yy} \rangle$	+1	0.88 ± 0.03	0.11	-0.5	-0.13 ± 0.06	0.03

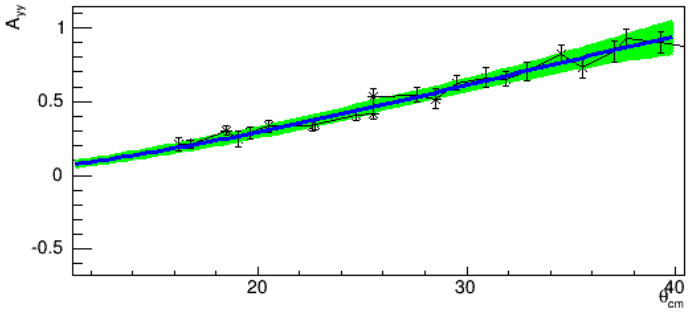


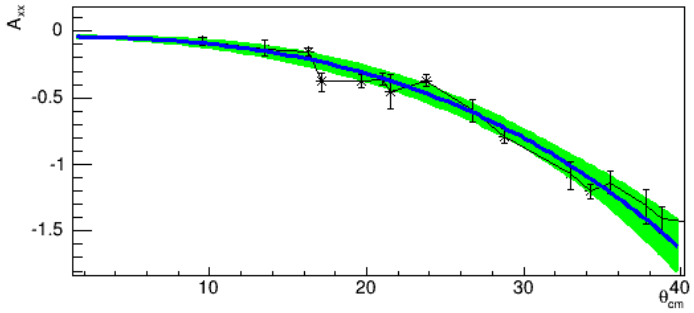








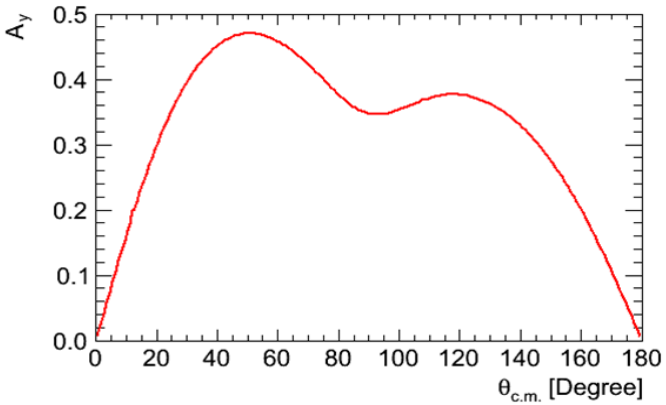




Polarimetry - $p\vec{d} \rightarrow d\pi^+ n_{sp}$

Quasi-free: $p\vec{p} \rightarrow d\pi^+$

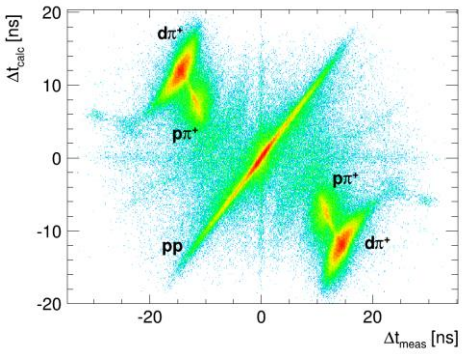
$$N(\theta,\varphi) = N_0(\theta)[1 + Q_y A_y(\theta) cos\varphi]$$

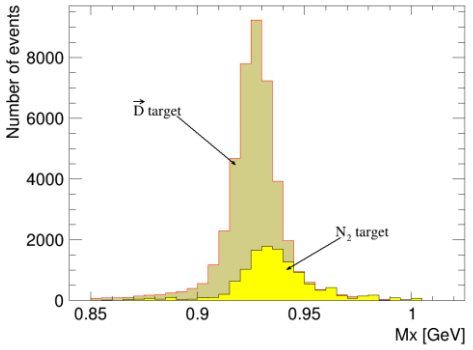


A_y *of* $\vec{p}p \rightarrow d\pi^+$ *from SAID*

$$|Q^{\uparrow}| = |Q^{\downarrow}| = Q_y$$

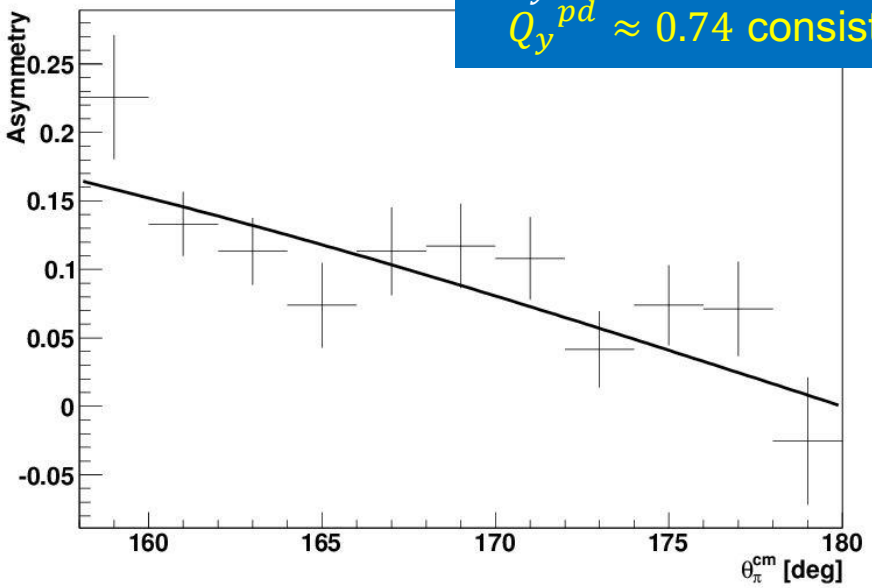
$$\frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}} = Q_y A_y(\theta) cos\varphi$$





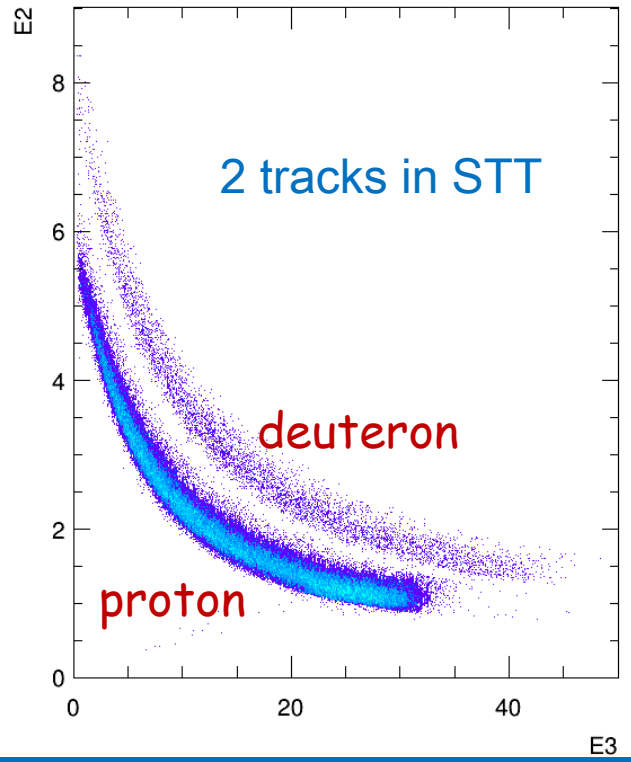
$Q_y = 0.7489 \pm 0.0668$

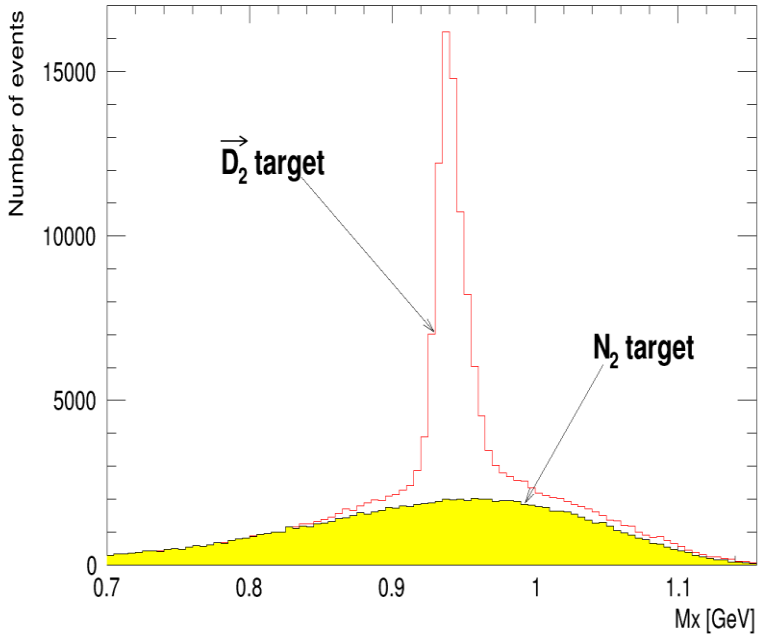
$Q_y{}^{pd} \approx 0.74$ consistent



Charge-Exchange $p\vec{d} \rightarrow \{pp\}n$ - Identification

Fewer deuterons in 2-track events





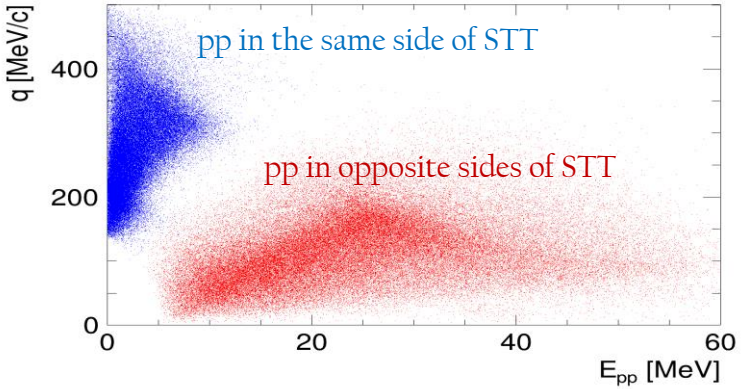
Shape of the background from the storage cell is simulated by nitrogen gas.

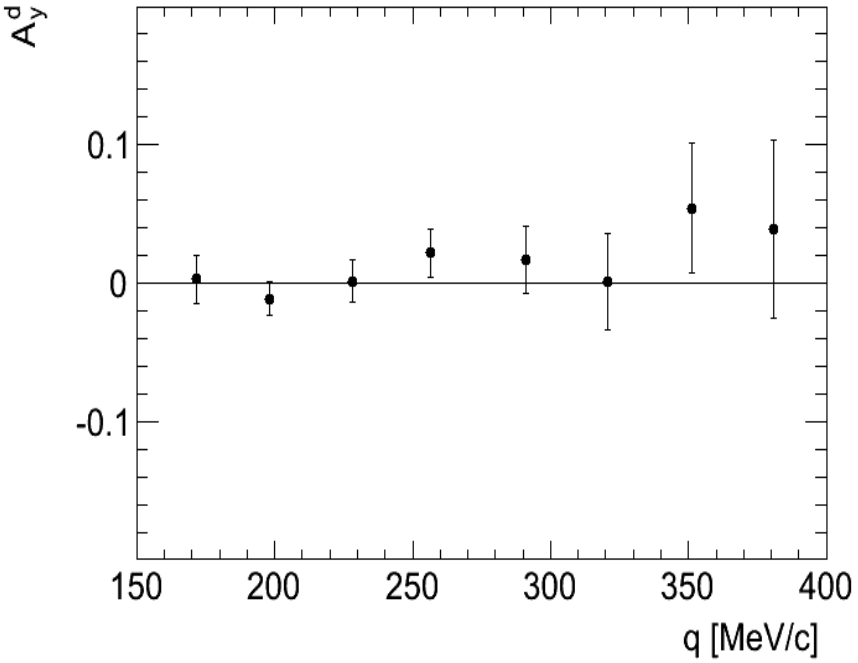
$p\vec{d} \rightarrow \{pp\}n$ is isolated by building missing mass spectrum for 2-track events in STT

Charge-Exchange $p\vec{d} \rightarrow \{pp\}n$ - A_{yy}

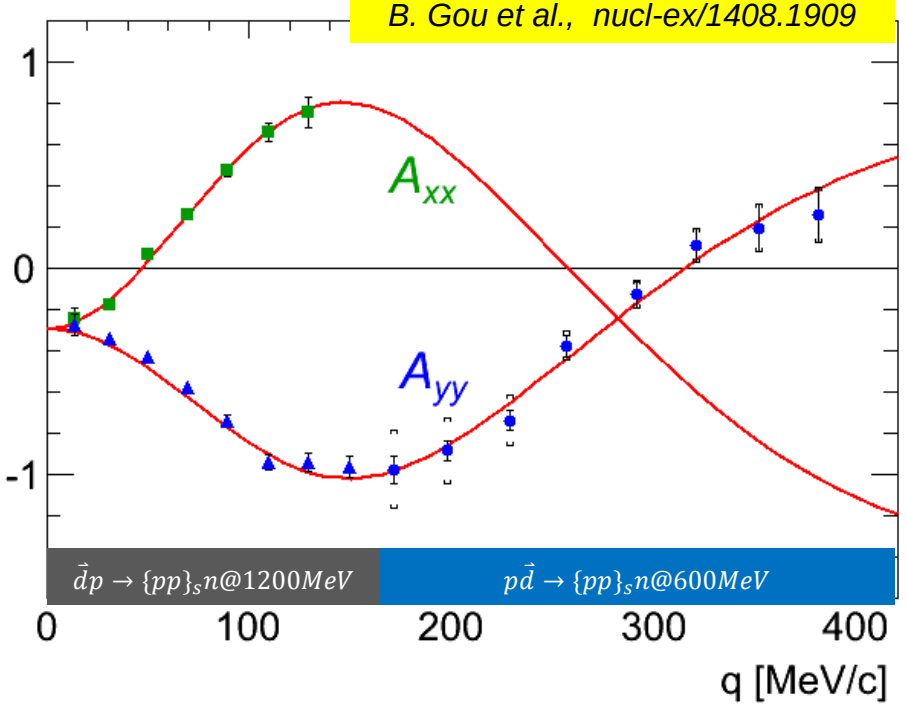
CE reaction is not sensitive to deuteron vector polarization if {pp} is in $^1S_0$ ($E_{\{pp\}} < 3MeV$)

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





B. Gou et al., nucl-ex/1408.1909



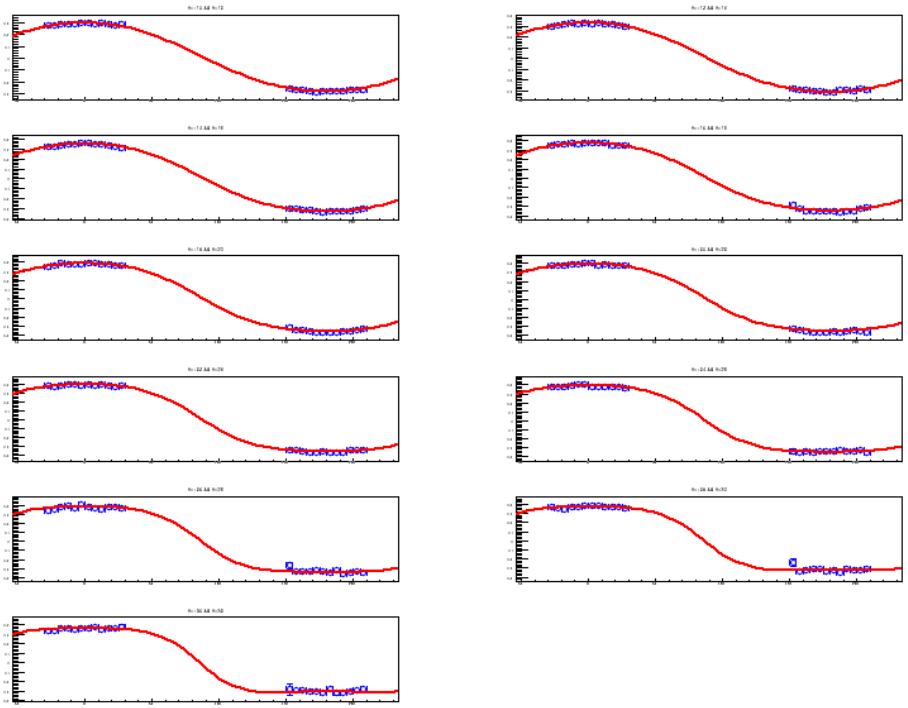
Summary and Outlook

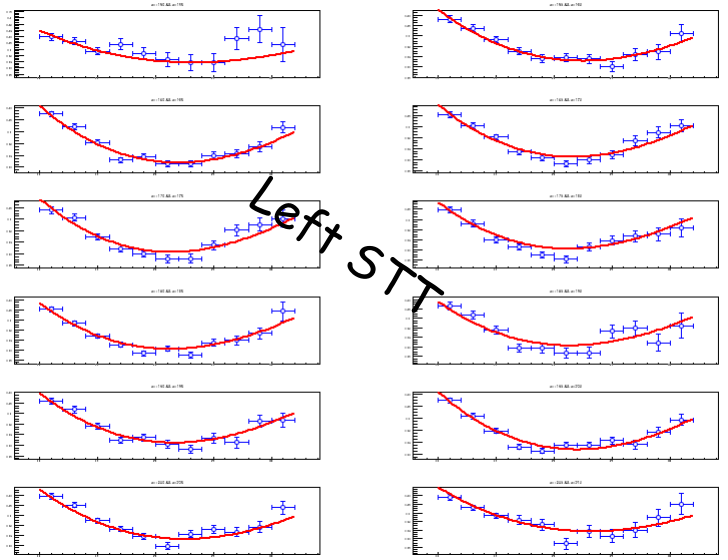
- Target commissioning experiment was successful
- High performance of the deuterium target was achieved (Q_y, Q_{yy} > 70%)
- Reliable polarimetry (STT, $p\vec{d} \rightarrow pd$ at 600 MeV)
- Initial np study carried out at 600 MeV
- Production experiment: next week

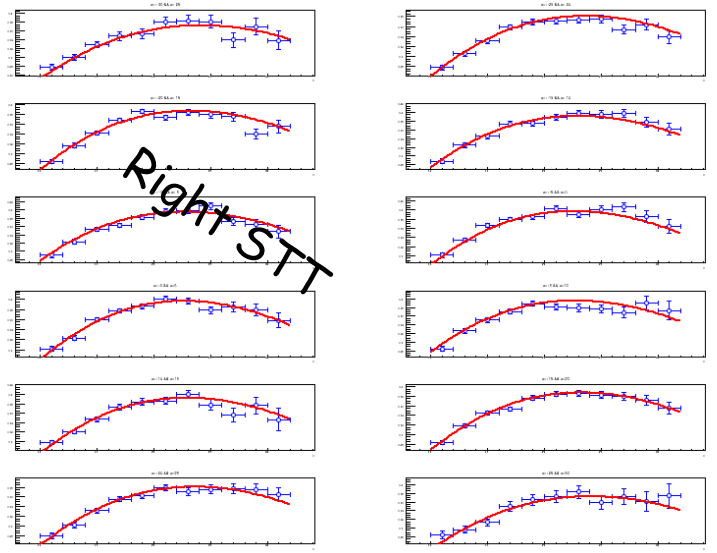
Thank you

Modes 1 and 2

1D

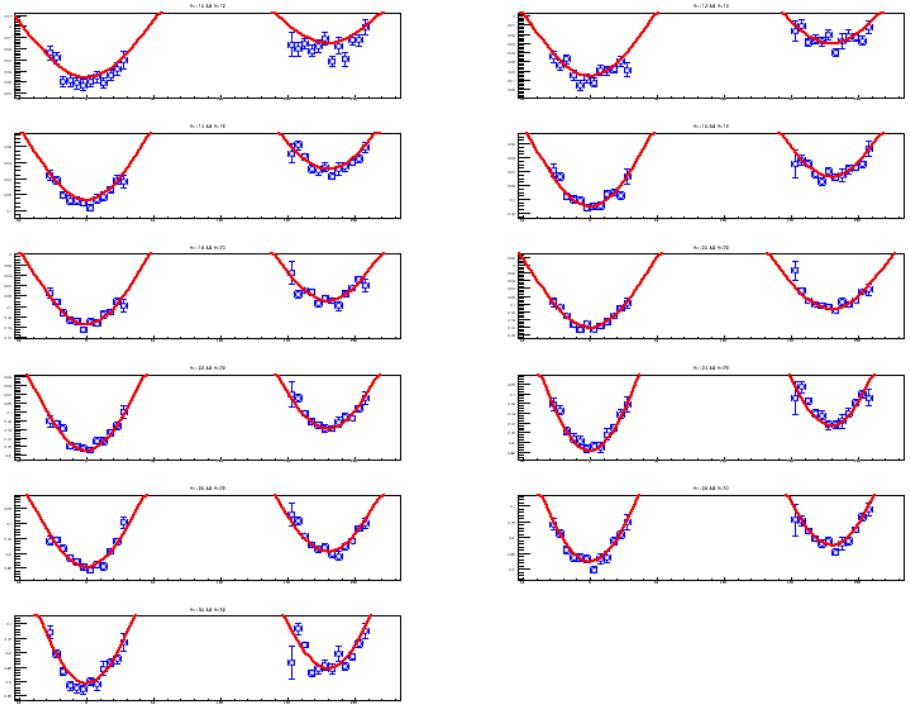


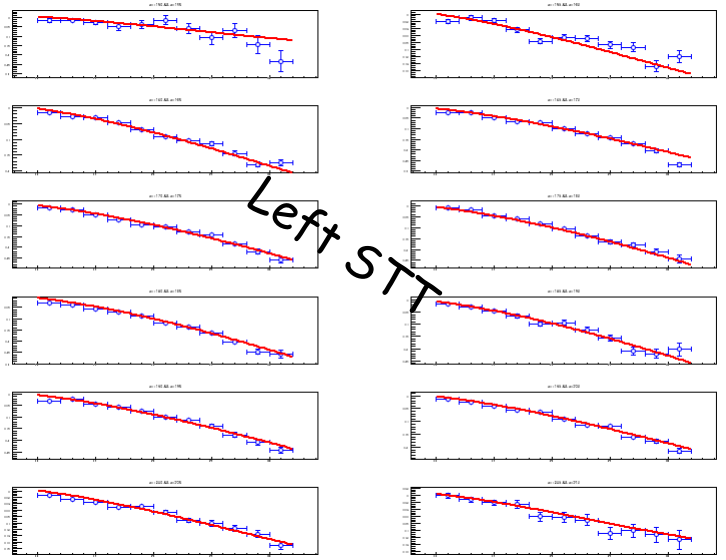


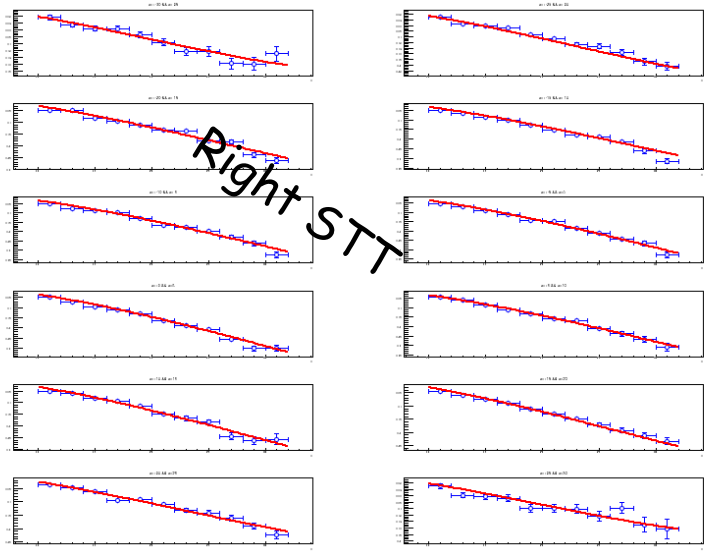


Modes 3 and 4

1D







Systematic error

Change parameters of polynomial functions and repeat the fit procedure