ZARA BAGDASARIAN

Master's Student
Iv. Javakhishvili Tbilisi State University
Exact and Natural Science Faculty
Fundamental Physics

Physics in the LHC era

17-21 October, 2011

RECENT RESULTS OF SPIN FILTERING EXPERIMENT AT COSY

JÜLICH
FORSCHUNGSZENTRUM

Physics in the LHC era
18 October 2011

Polarized Antiproton eXperiments

18/10/2011

ZARA BAGDASARIAN

e-mail:zara_bagdasarian@hotmail.com

Short CV

EDUCATION:

- Master's Student in Atomic, Nuclear, Particle Physics
- Deutsches Electronen Synchrotron (DESY) Summer Student Program 2009
- Hadron Physics Summer School 2010 in Bad Honnef
- ISTC-CERN-JINR Summer School on High Energy Physics and Accelerator Physics 2011
- Summer student at Juelich Research Center in 2010 and 2011

SCHOLARSHIPS:

- Presidential scholarship
- WORLD FEDERATION OF SCIENTISTS' scholarship
- Estate Khmaladze (Victoria University of Wellington) Scholarship

OUTLINE

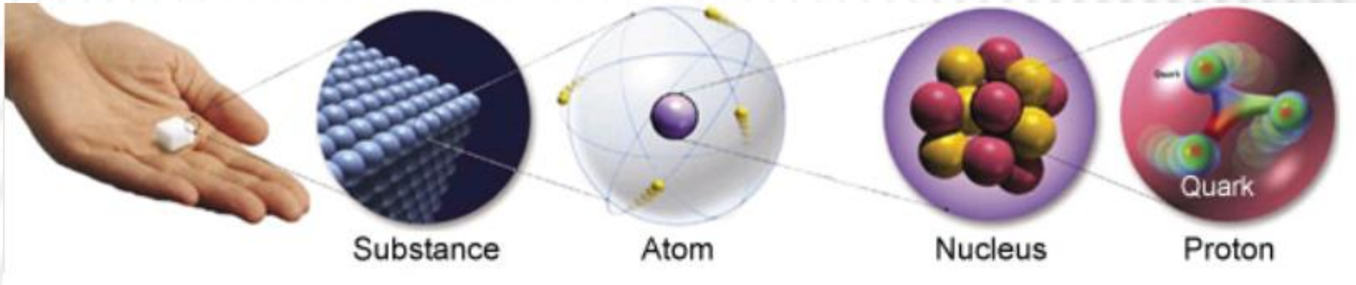
- Motivation of PAX
- General Idea of Spin Filtering
- Current Results and Further Plans

PAX

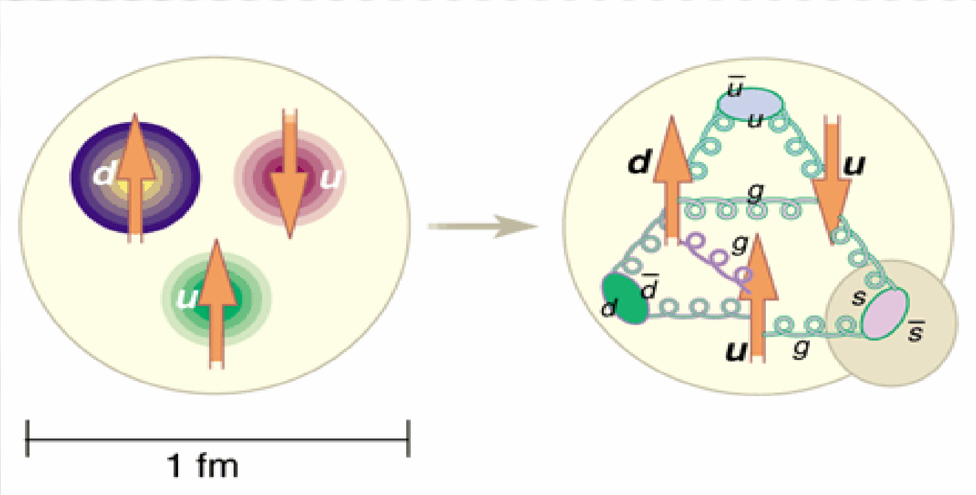
Polarized Antiproton eXperiments

HADRON PHYSICS

- Understanding of all matter comprised of quarks and gluons

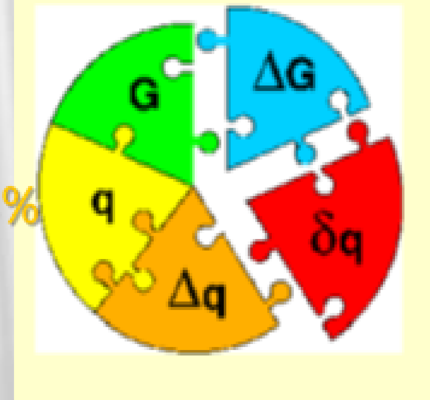


QCD has not yet provided complete explanation on structure of hadrons

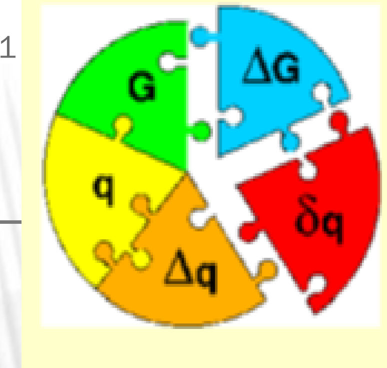


~14% ÷23%

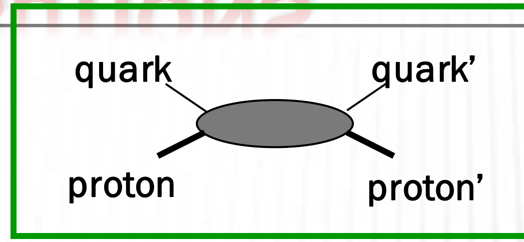
Proton spin



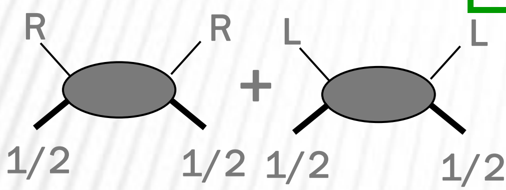
"Spin Crisis"

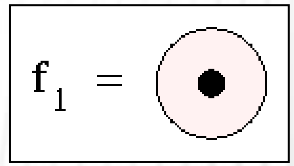


QUARK DISTRIBUTIONS



$f_1(x)$

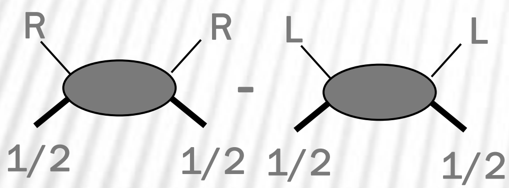


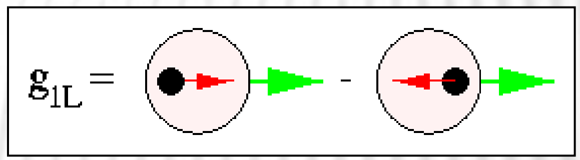


Very well known

$q(x) = q_+(x) + q_-(x)$

$g_1(x)$

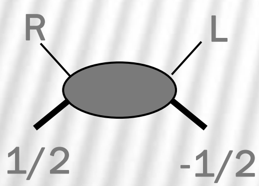


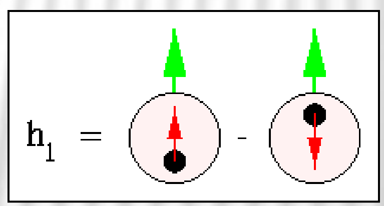


Helicity:Well know

$\Delta q(x) = q_+(x) - q_-(x)$

$h_1(x)$

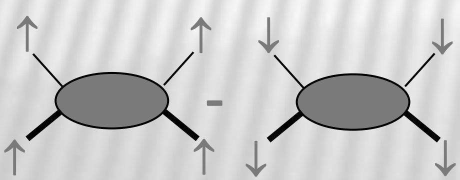




Transversity:

Largely unknown

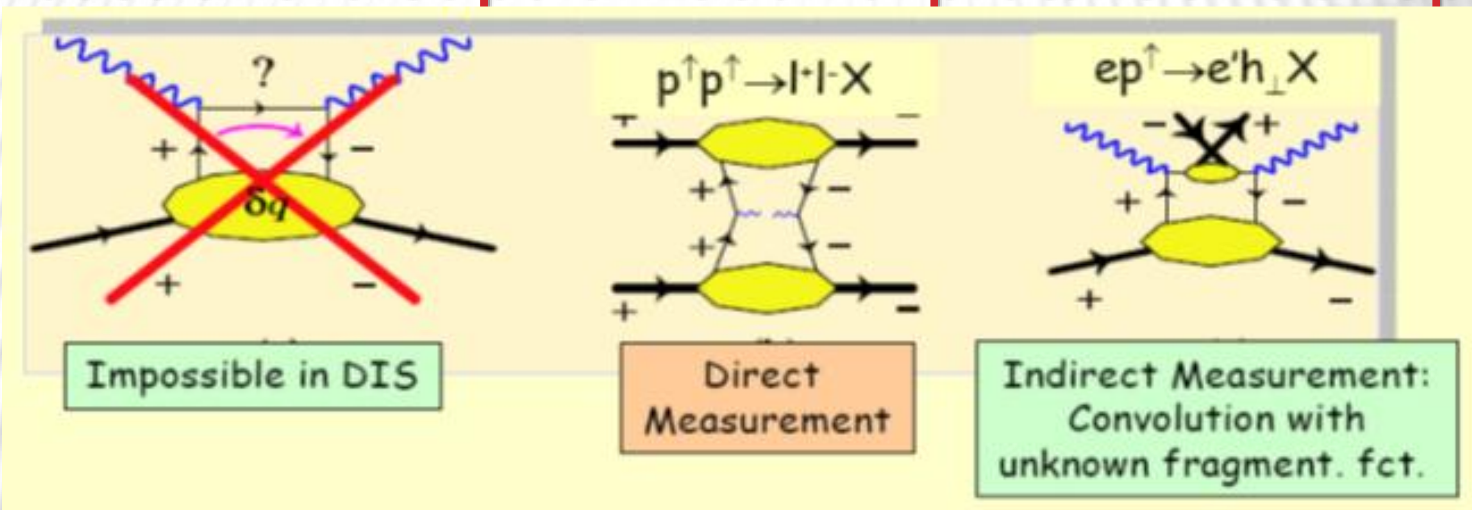
Chirality Odd nature

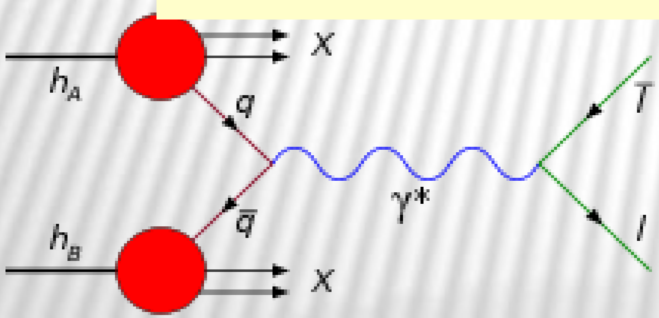


Soffer inequality: $q(x) + \Delta q(x) \geq 2|\delta q(x)|$

MOTIVATION

New Fundamental Observables (which can't be studied without transverse polarization of protons and antiprotons)





Drell-Yann Process

$$A_{TT} \equiv \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \hat{a}_{TT} \frac{\sum_q e_q^2 h_1^q(x_1, M^2) h_1^{\bar{q}}(x_2, M^2)}{\sum_q e_q^2 q(x_1, M^2) \bar{q}(x_2, M^2)}$$

pp: $\frac{A_{TT}}{a_{TT}} \sim 1\%$

Very restircted x region

$p\bar{p}\ \frac{A_{TT}}{a_{TT}} \sim 0.2$

Wide x region

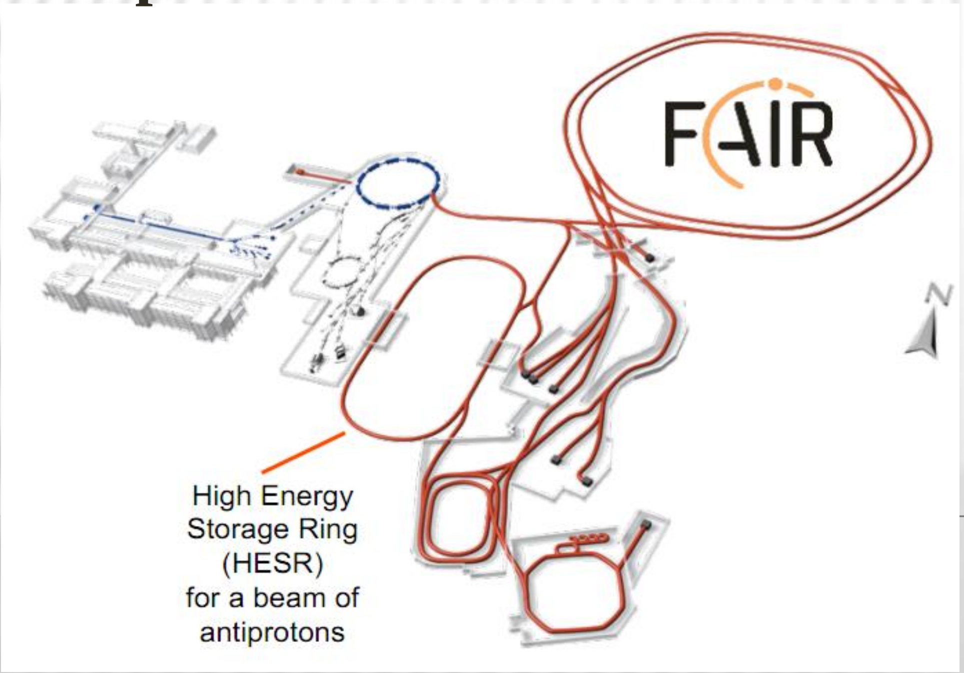
Golden channel

POLARISED ANTIPROTON EXPERIMENTS

Polarized Antiproton eXperiments

2010-2012: Spin Filtering Studies for protons at COSY

- 2012-2015: Spin-Filtering Studies for antiprotons at CERN AD



- After 2015: PAX at FAIR:

Collide polarized protons and polarized antiprotons

CAN WE POLARIZE ANTIPROTONS?

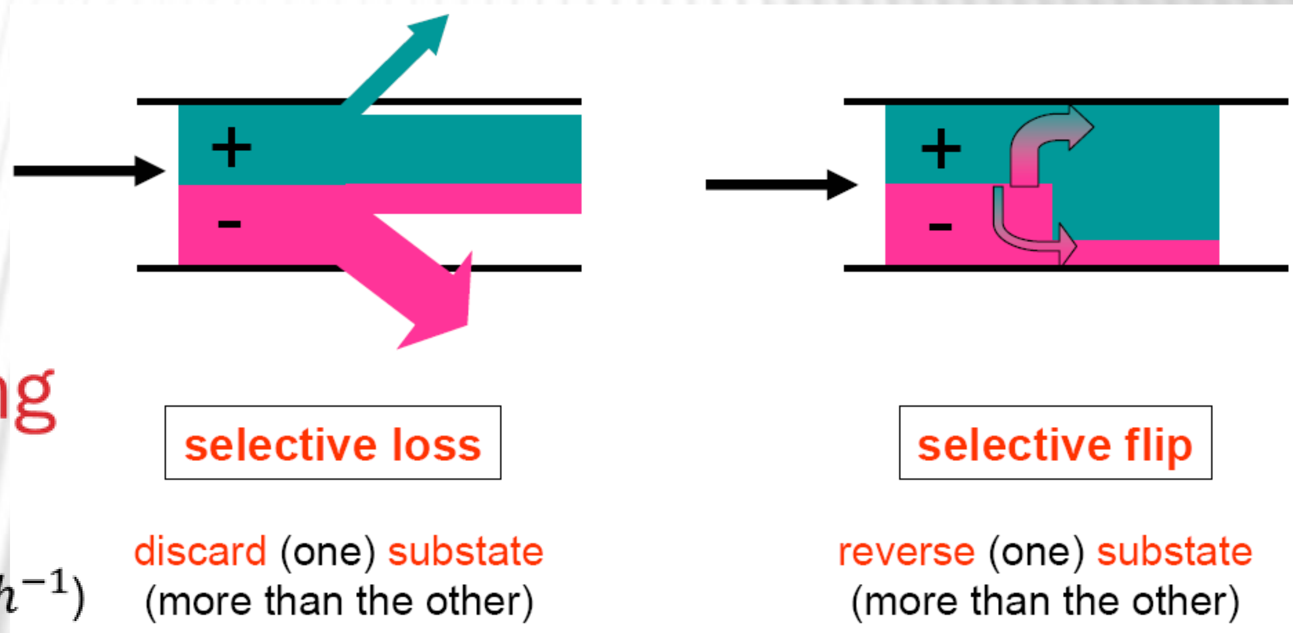
- From polarized ion sources (No)
- **From polarized antihyperons (low intesnities)**
- **By stochastic method (No)**
- By Spin Flip

(showed small cross sections $4 \cdot 10^6$ b and $7 \cdot 10^6$b)

- By Spin Filtering

demonstrated by FILTEX

$$\frac{\Delta P}{\Delta t} = \pm(1.24 \pm 0.06)10^{-2}h^{-1})$$



Interesting experiments on the spin dependence should be possible, even if the achievable polarization of the stored antiproton beam is a few percent.

HOW DO WE SPIN FILTER?

Unpolarized beam starts circulating in the ring

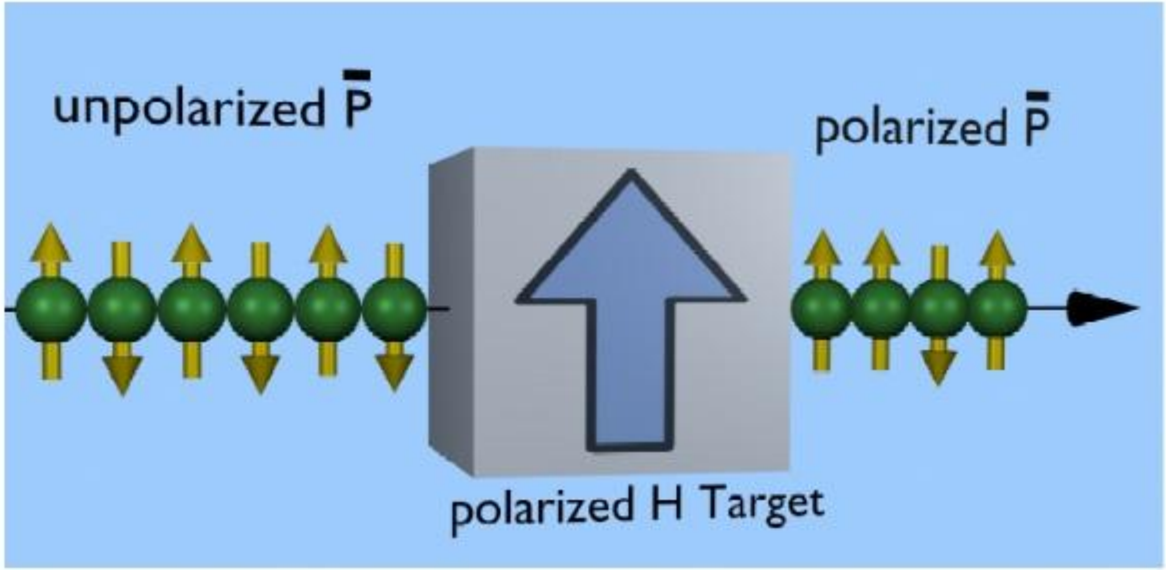
- Hits polarized target

$$P(t) = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow}$$

- $\sigma(\uparrow\uparrow) \neq \sigma(\uparrow\downarrow)$
- One spin direction depleted more than the other

- A fraction of beam is lost

- BUT: the left beam is polarized



$$\sigma_{tot} = \sigma_0 + \sigma_\perp \cdot \vec{P} \cdot \vec{Q} + \sigma_{||} \cdot (\vec{P} \cdot \vec{k})(\vec{Q} \cdot \vec{k})$$

P beam polarization
Q target polarization
k || beam direction

- **In other words: more protons with spin in direction parrallel to the one of the target**

POLARIZATION BUILD-UP

$$\tau_b = \frac{1}{(\sigma_0 + \sigma_c) d_t f}$$

the spin-independent part of the cross section and the loss of particles by small-angle Coulomb scattering

$$\tau_p = \frac{1}{\sigma_p P_t d_t f}$$

the polarization build up time constant

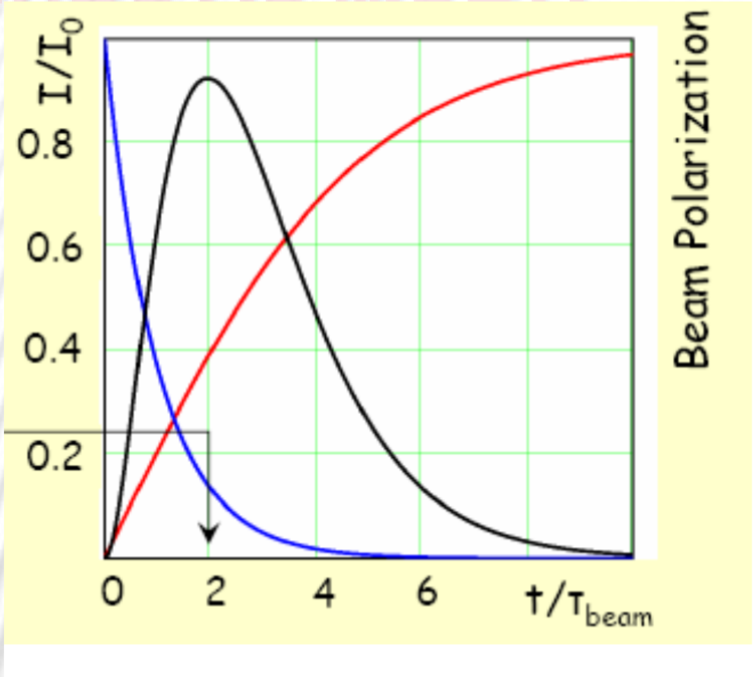
$$I_{\uparrow}(t) = \frac{I_0}{2} e^{-\frac{t}{\tau_b}} e^{(\frac{t}{\tau_p})}$$

$$I_{\downarrow}(t) = \frac{I_0}{2} e^{-\frac{t}{\tau_b}} e^{-(\frac{t}{\tau_p})}$$

$$P(t) = \frac{I_{\uparrow}(t) - I_{\downarrow}(t)}{I_{\uparrow}(t) + I_{\downarrow}(t)} = tanh\left(\frac{t}{\tau_p}\right)$$

$$I(t) = I_{\uparrow}(t) + I_{\downarrow}(t) = I_0 e^{-\frac{t}{\tau_b}} cosh\left(\frac{t}{\tau_p}\right)$$

FIGURE OF MERIT



$$t \sim FOM = P^2 I$$

Optimum time for Polarization Build-up,
given by maximum of FOM(t)

$$t_{filter} = 2\tau_{beam}$$

AS SMALL AS POSSIBLE FILTER TIMES:

- ***The maximum target density*** d_t
- ***Maximum spin-dependent cross section*** σ_p ***(corresponding energy of the beam)***
- *minimize the Coulomb beam losses*

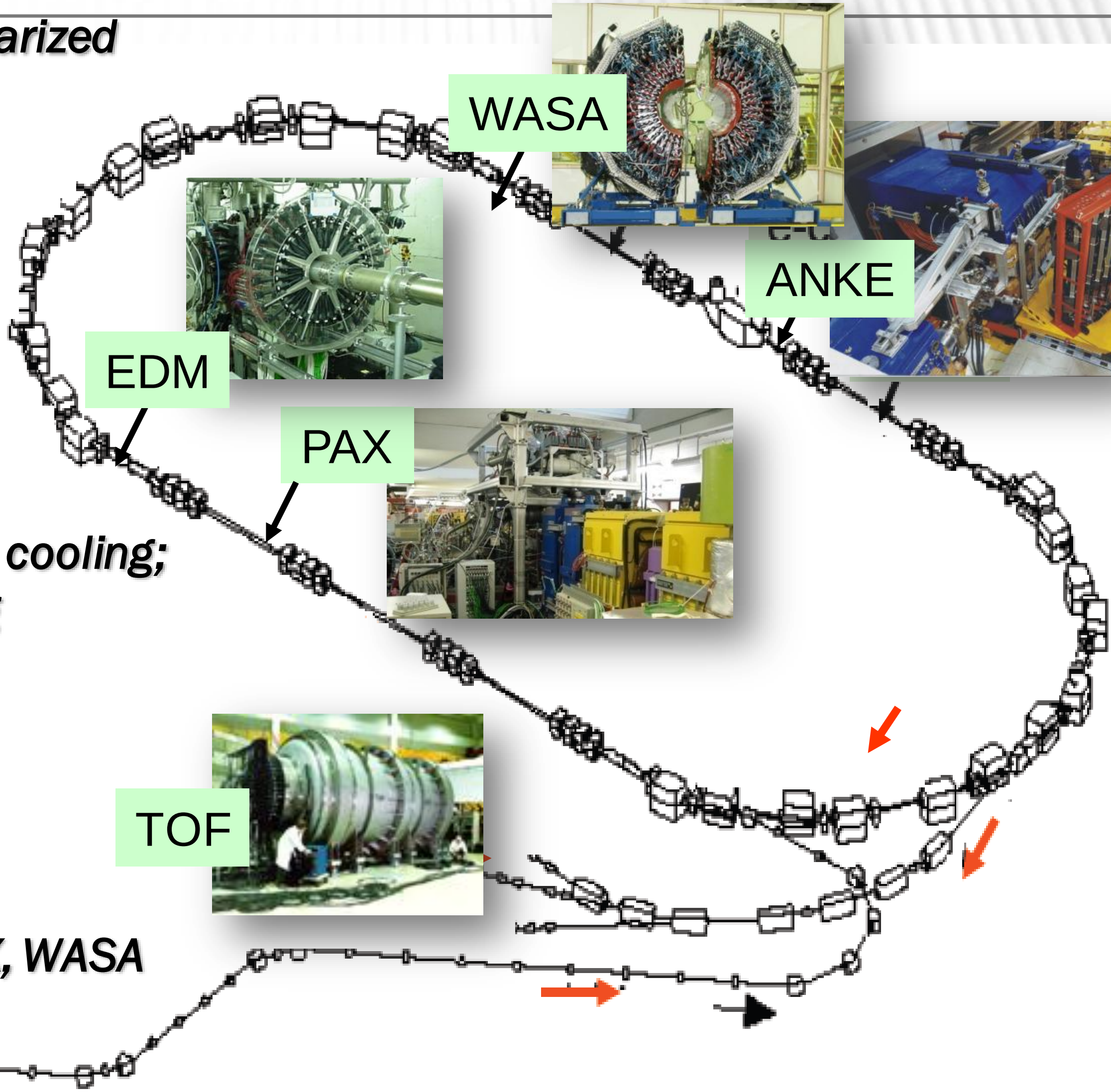
HIGHEST POSSIBLE BEAM POLARIZATION:

- *Elimination of the effects of depolariziation*
- *Increase of the beam lifetime*

(Minimal for spin-filtering at COSY is 5000 s)
In 09.2011 average 8000

COSY (COOLER SYNCHROTRON)

- *Unpolarised and transversely polarized proton and deuteron beams*
- *Momentum range:*
  300MeV/c - 3.7 GeV/c
- *183 m circumference, including two 40m straight sections*
- *For 300-600MeV range: electron cooling; for higher energy: stochastic cooling*
- *Ring Acceptance:*
  27.0 ± 3.4 7.7 ± 1.2π mm mrad
  17.4 ± 2.2 3.4 ± 0.6 π mm mrad
- *Internal experiments: ANKE, PAX, WASA COSY-11, EDDA;*
- *External: TOF, JESSICA and etc.*

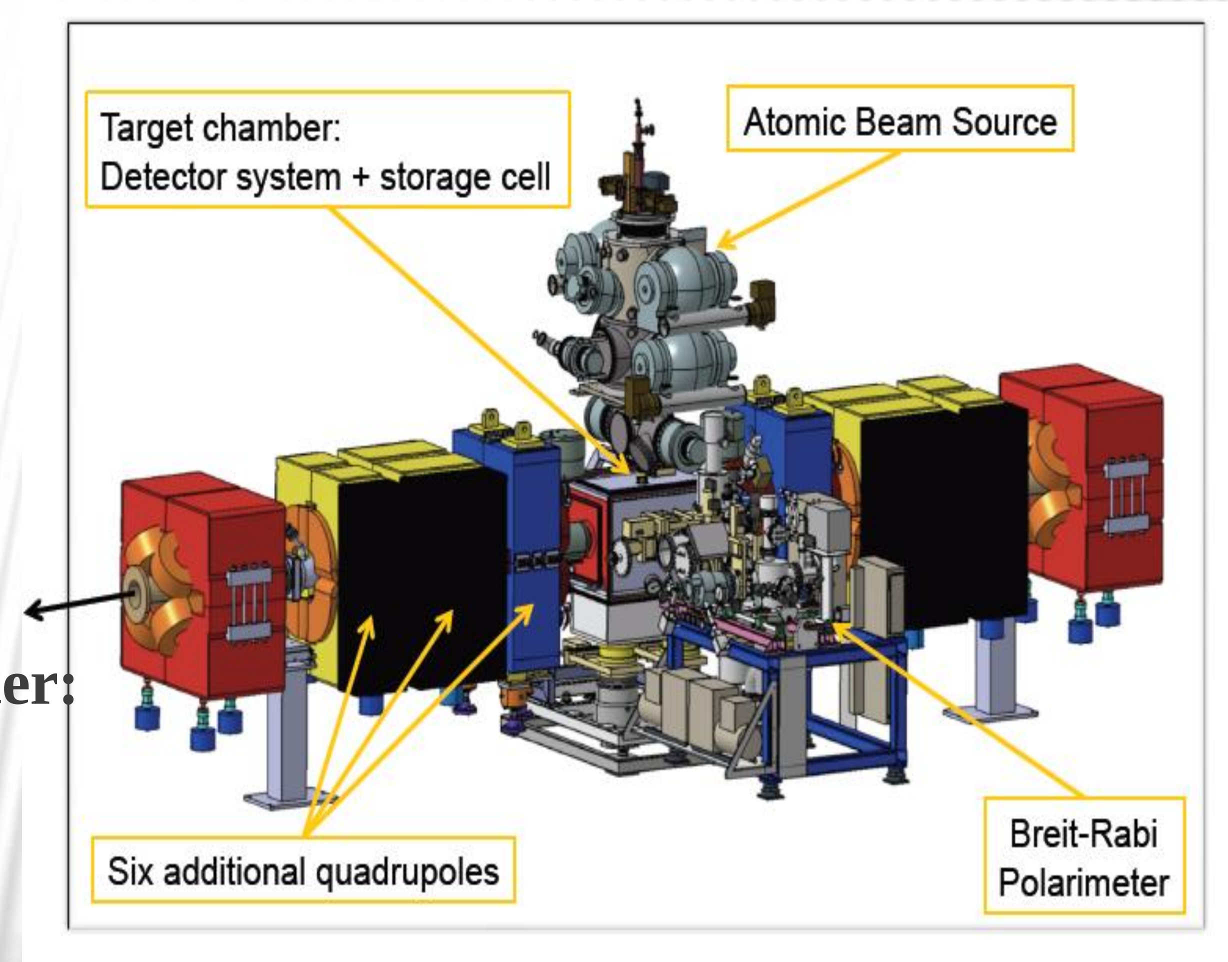


PAX SECTION HARDWARE

- Atomic Beam Source (ABS):
polarized atoms (H, D);

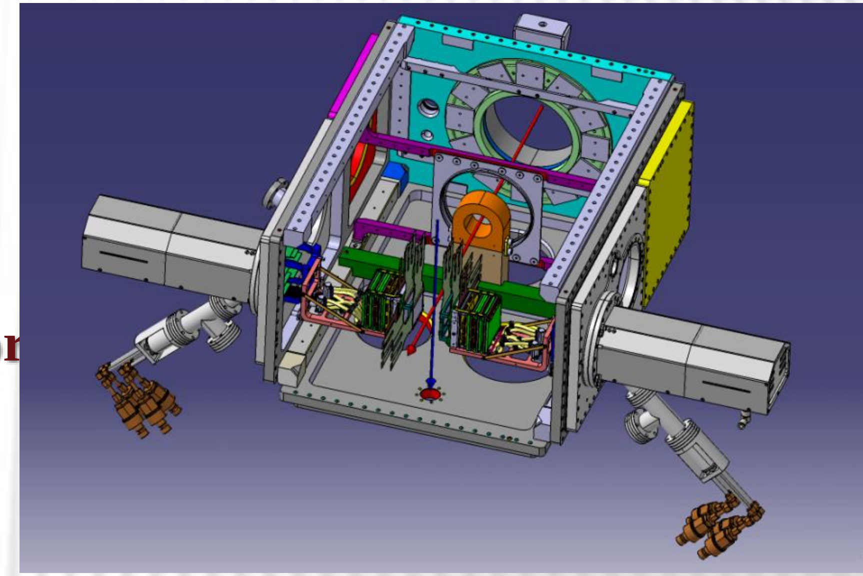
- Storage cell to
increase target density;

- Breit-Rabi Polarimeter:
Monitoring of target polarization;

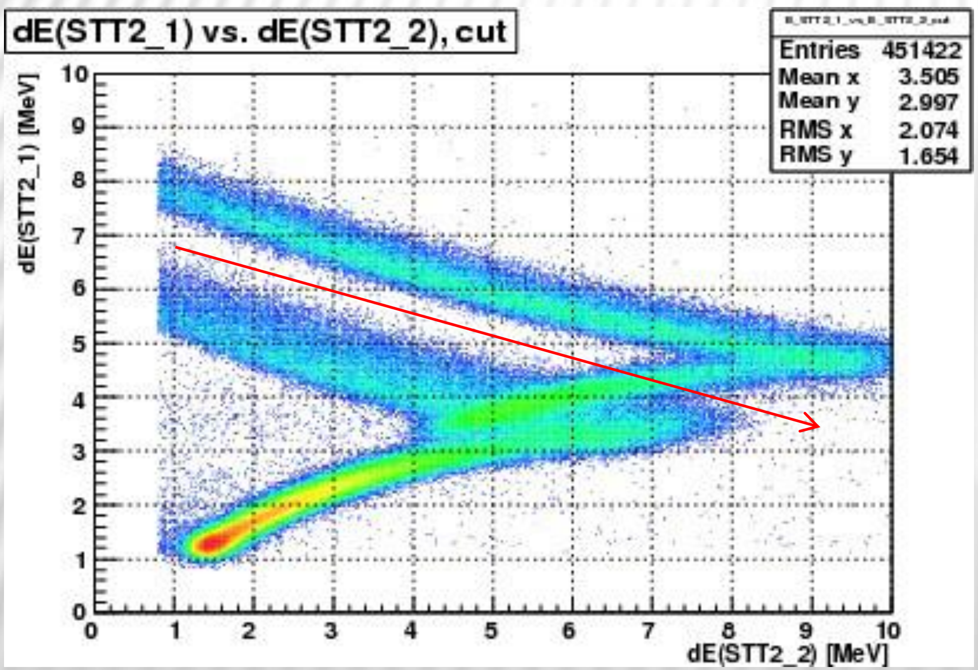


ANKE SECTION

- Unpolarized deuteron cluster target
- Silicon Tracking Telescope



3 layers of double – sided silicon-strip detector
Surround target from 2 sides



Particle tracking -> Vertex

Stopping particle -> Total energy

Distinguishing protons and deuterons

POLARIZATION MEASUREMENT

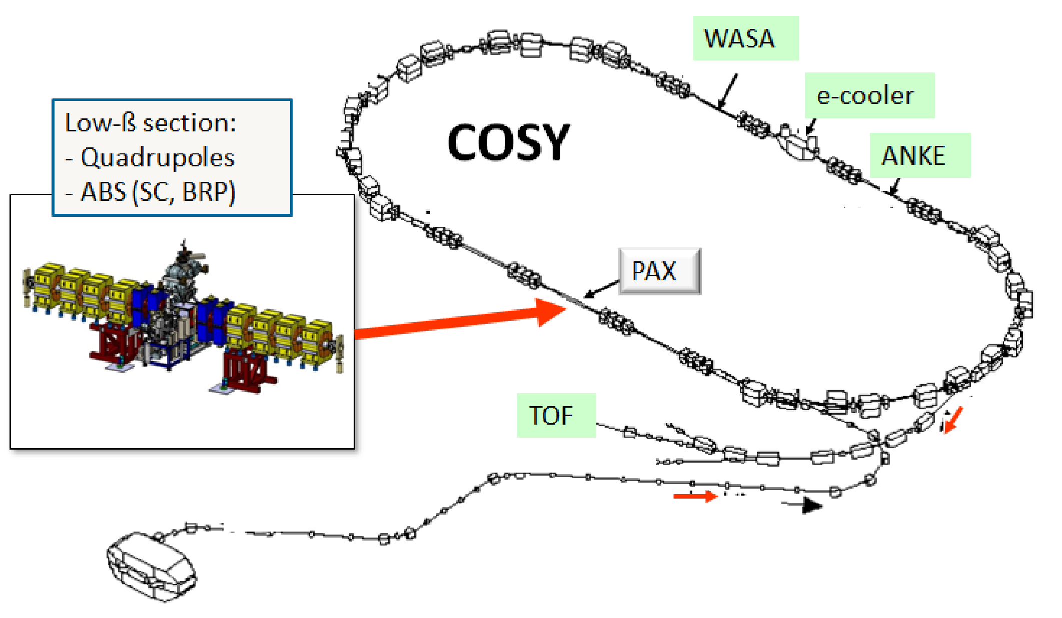
After 4.5 hours of polarization PAX polarized target is turned off and ANKE unpolarized deuteron target turns on

$$\frac{d\sigma}{d(\theta,\varphi)} = \frac{d\sigma_0}{d(\theta)}[1 + PA_y(\theta)cos\varphi]$$

- For pd-pd A_y Analyzing Power is well known

$$N(\theta,\varphi) = nd_t\Delta\Omega E\frac{d\sigma}{d\Omega}(\theta, \varphi)\text{-}$$

actual number of counts in detector



$$\delta = \frac{L}{R} = \frac{1+PA_y(\theta)}{1-PA_y(\theta)}$$

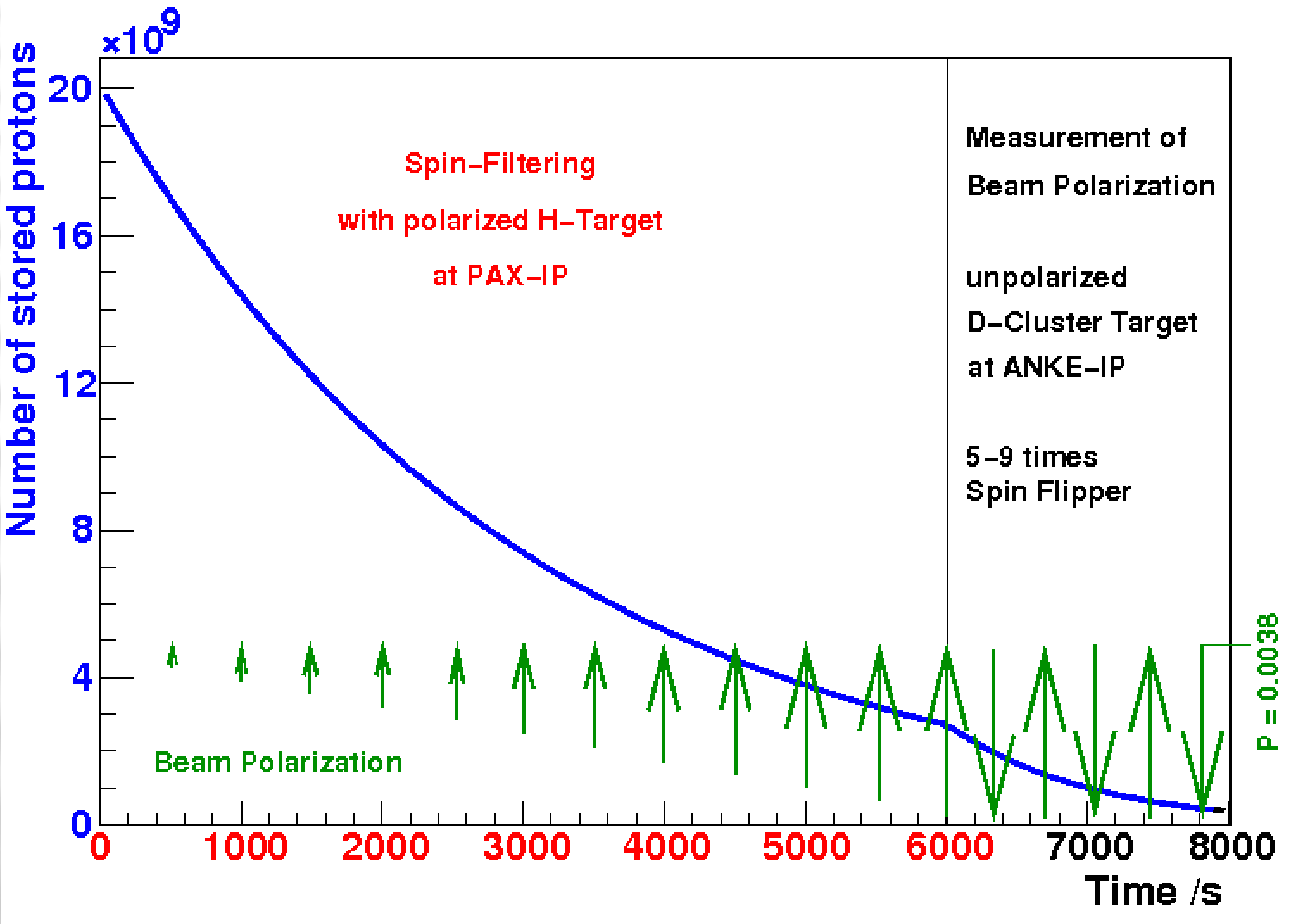
the ratio of counts in Left and Right detectors

- $\varepsilon = \frac{\delta-1}{\delta+1} = PA_y(\theta)$

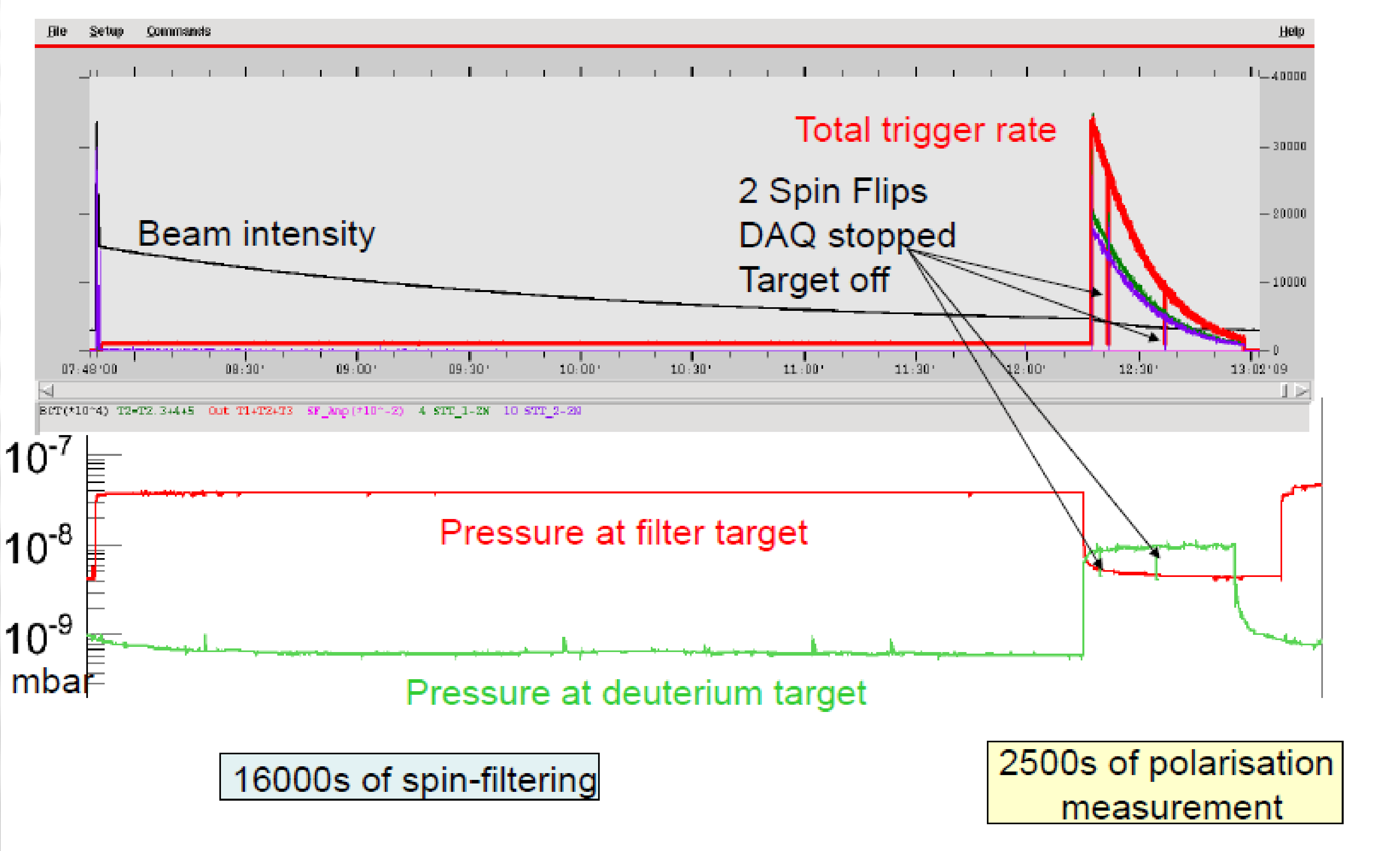
count-rate-asymmetry

- $P = \frac{\varepsilon}{A_y(\theta)\langle cos\varphi\rangle}$

SPIN FILTERING CYCLE



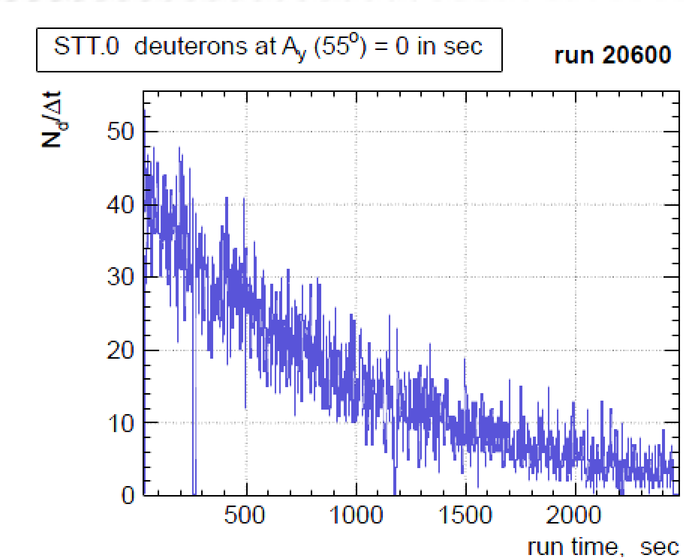
CYCLE STRUCTURE PICTURES FROM DATA

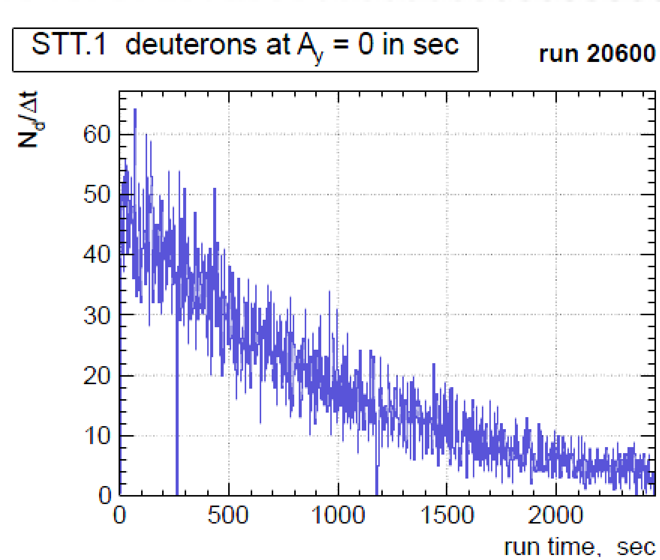


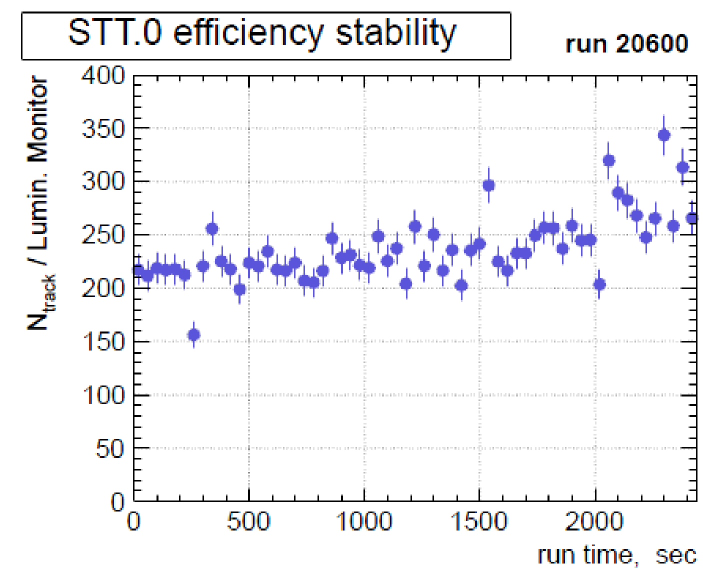
FULL DATA ANALYSIS

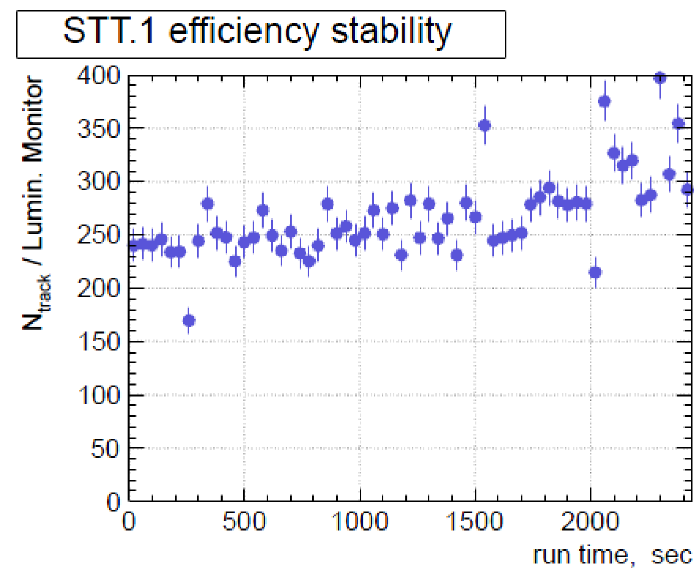
- *the detector stability should be checked*
- *the reaction independent track reconstruction should be performed, various cuts should be applied to identify protons and deuterons and reactions they came from*
- *and finally the polarization (count-rate asymmetry is determined, additionally error estimation should be done.*

DETECTOR STABILITY









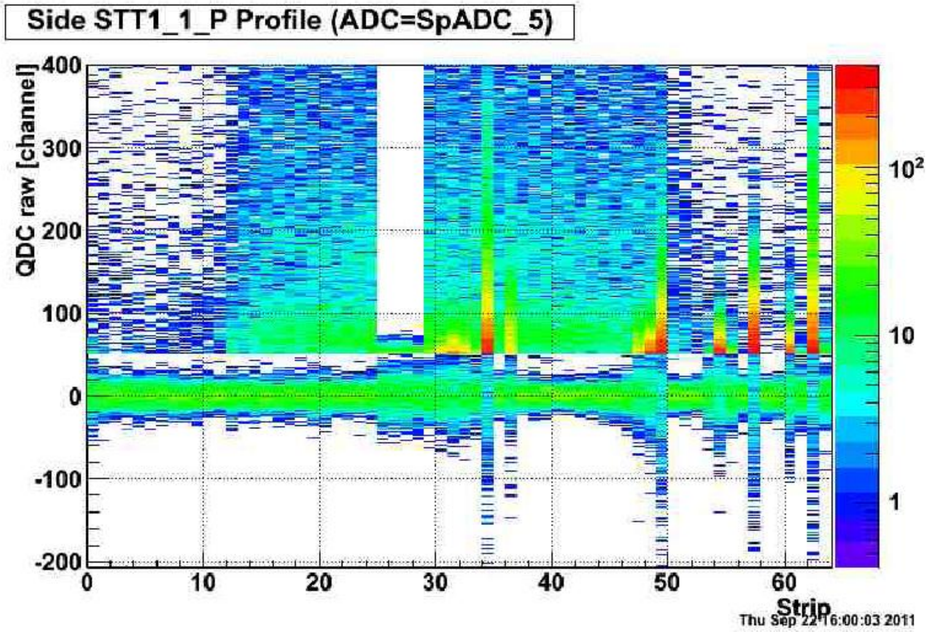
Number of detected deuterons around the $A_y = 0$ point

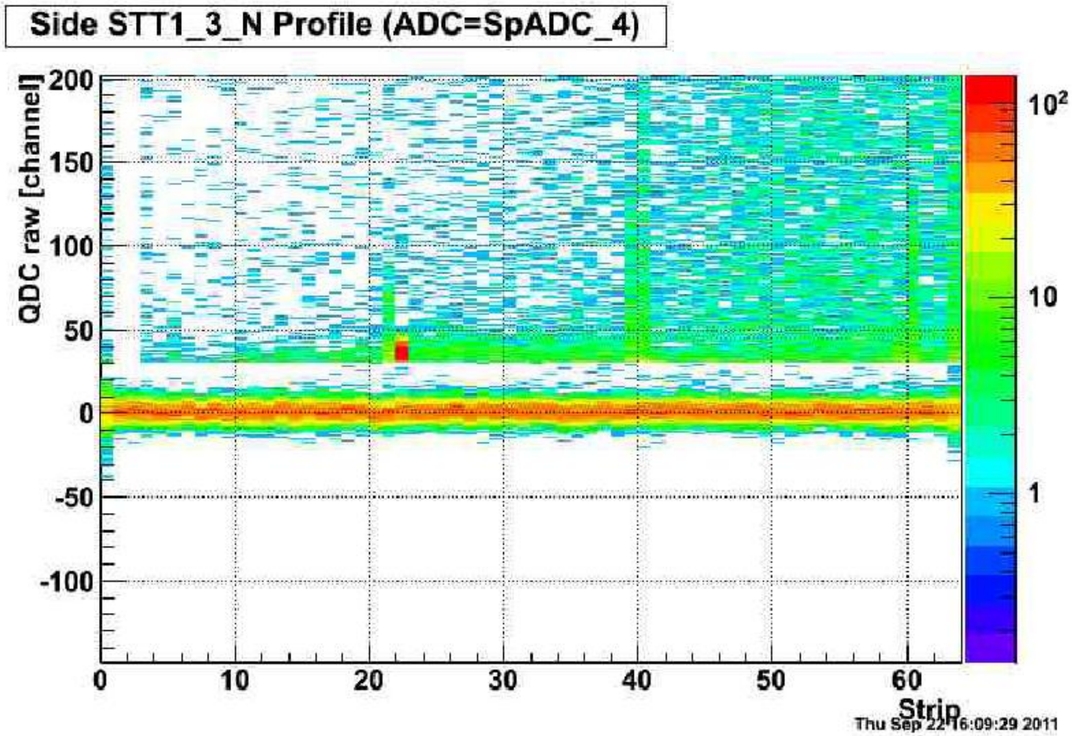
The left and right telescope efficiencies:

Number of recorded tracks normalized to the beam intensity

PEDESTAL STABILITY

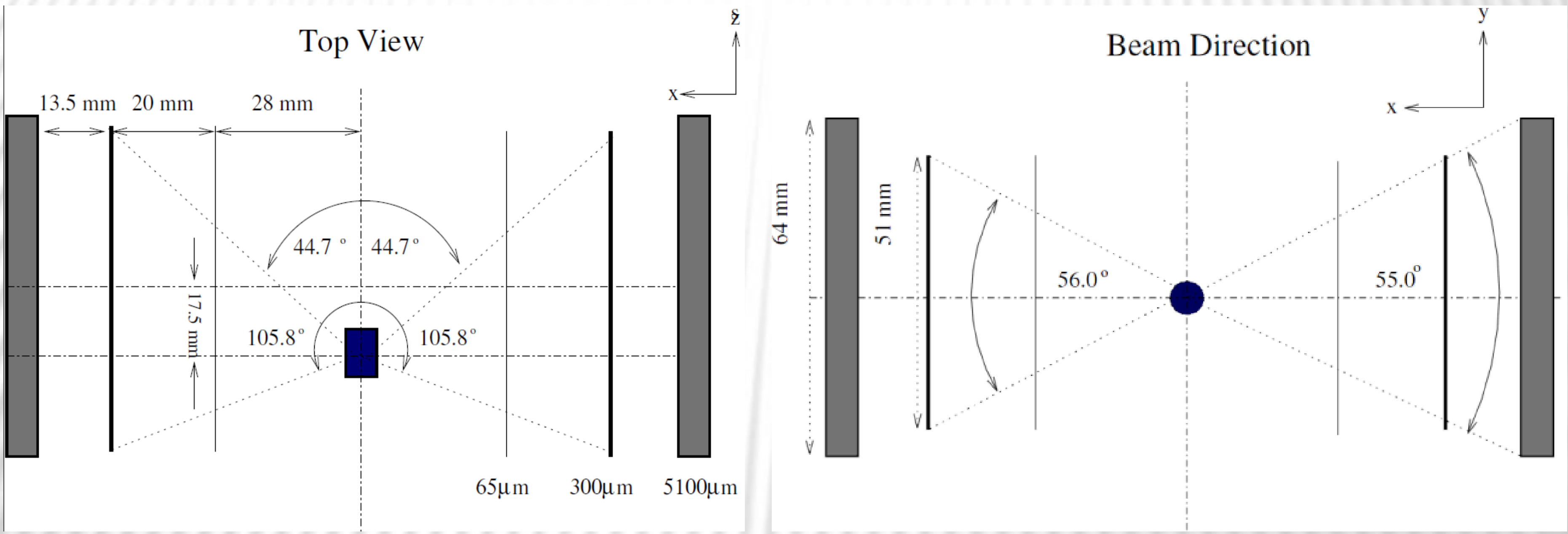
- On each stripe small signal (pedestal) is given to test detector stability





GEANT4 SIMULATION

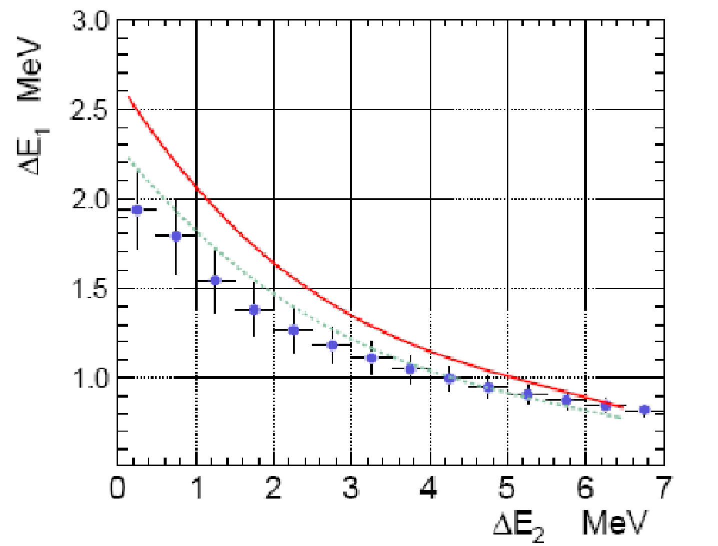
Tracking of particles through a current experimental setup geometry



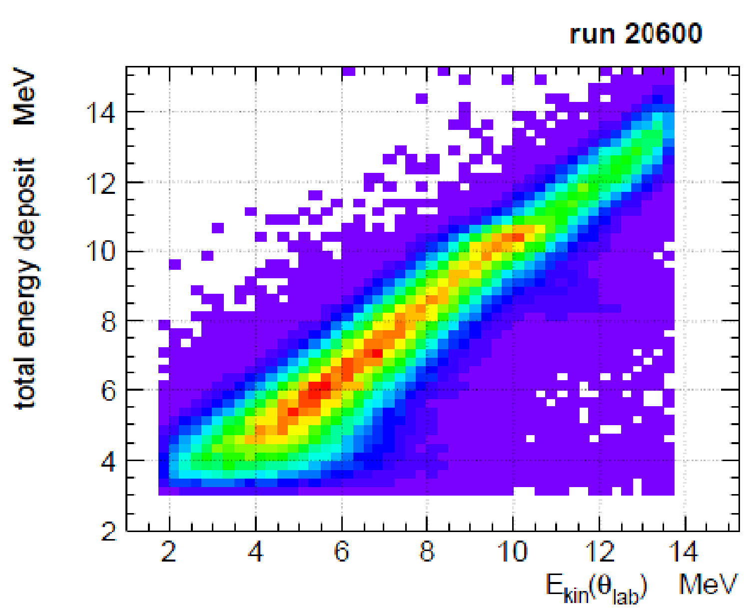
- **Hits: coordinates, energy deposits in layers**
- Tracks: θ, φ
- Particle type, kinetic energy, stopped or not
- Not isotropically (crossections from experiment at 46.3 MeV were used to fit)

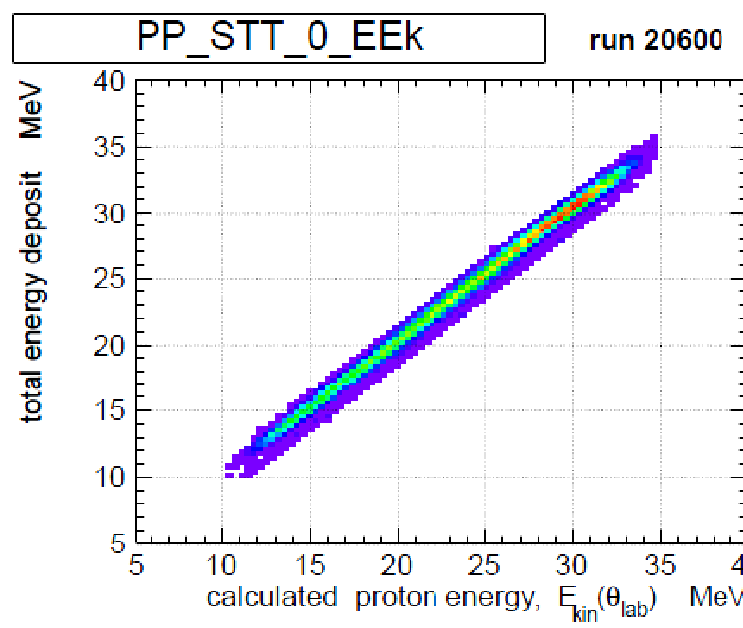
STT CALIBRATION QUALITY

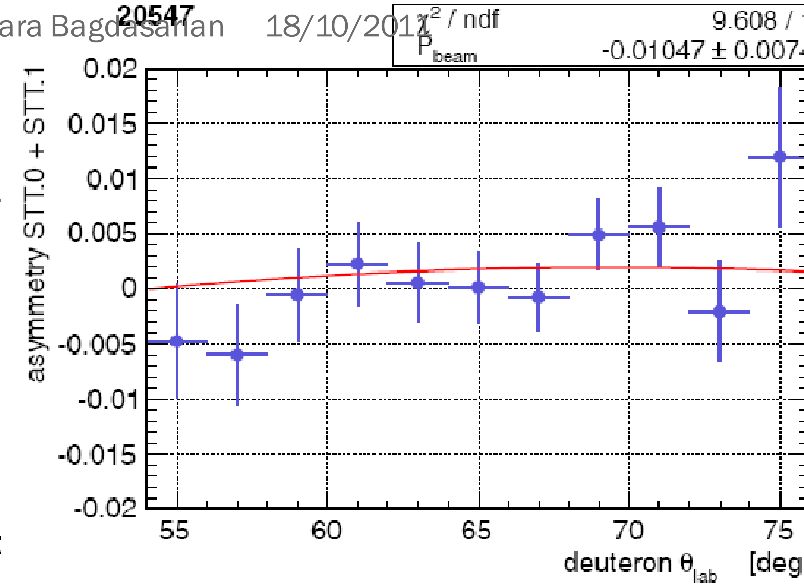
Energy deposits in first and second layer (red line- simulation by GEANT4 , blue crosses- experimental data)



Total energy deposit and reconstructed kinetic energy correlation for stopped deuterons and stopped in the 3rd layer protons

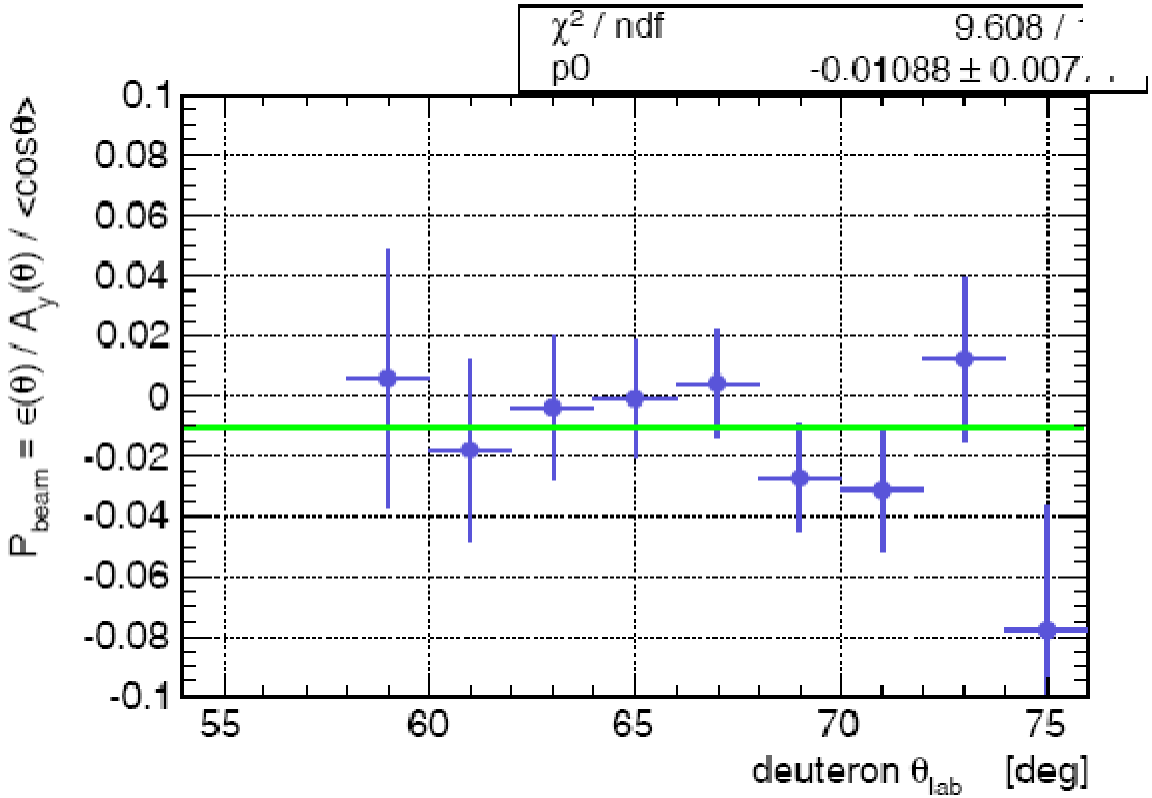






PRELIMINARY RESULTS

$$\delta = \frac{L}{R} = \frac{1 + PA_y(\theta)}{1 - PA_y(\theta)}$$



- $$P = \frac{\varepsilon}{A_y(\theta)\langle cos\varphi \rangle}$$

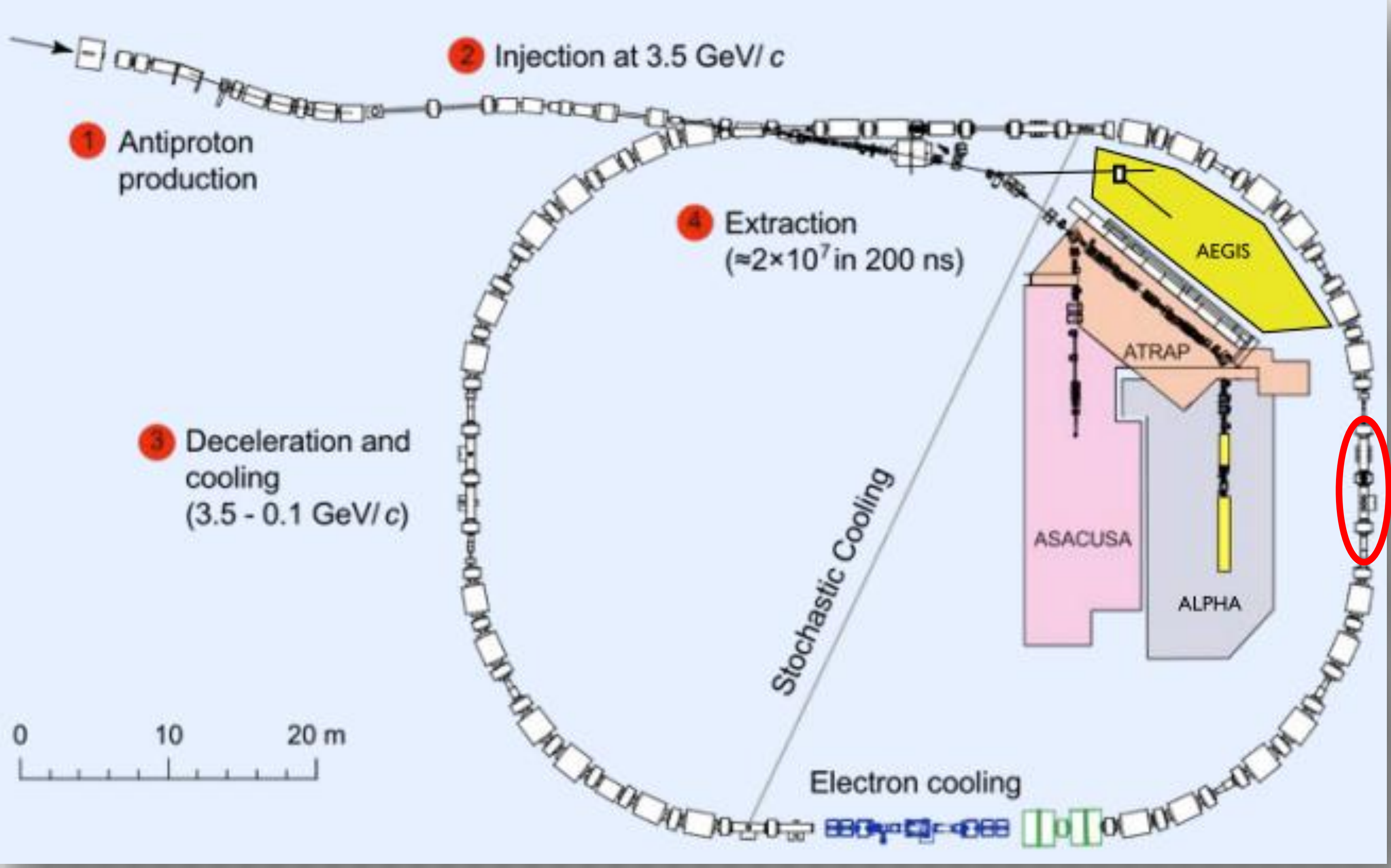
WORK IN PROGRESS

- Calibrate analysis using data with unpolarized beam. (precise measurement of zero)
- Run analysis using data with high polarized beam
- Check and handle dead time
- Optimize energy calibration
- Identification of protons from pd-elastic to increase statistics (background from break-up reactions)

CONCLUSIONS

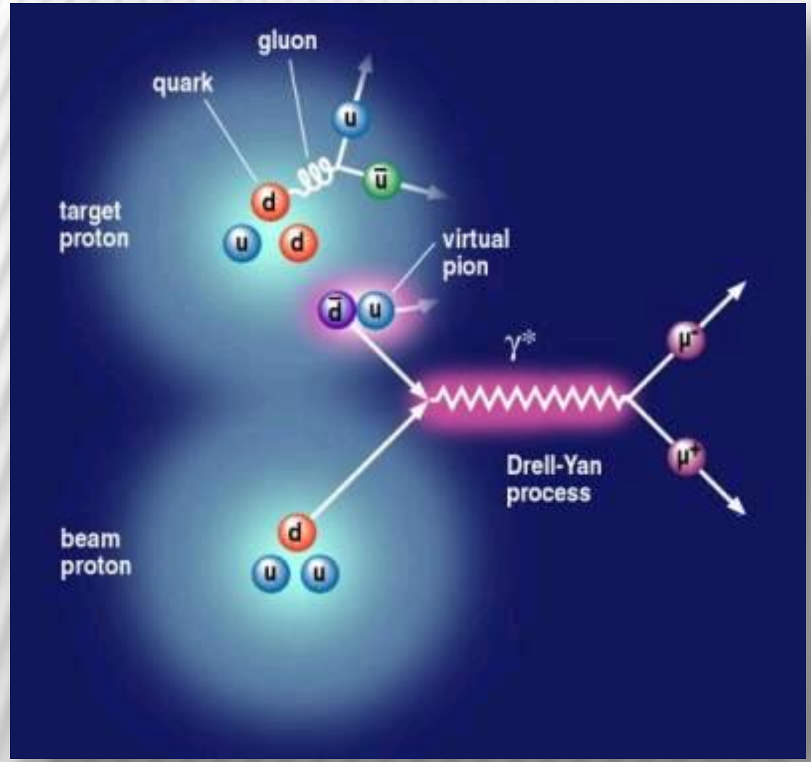
- Spin Filtering Experiment successful performance at COSY
- Necessary subsystems work as expected or even better
(eg the vacuum system resulting in very long beam lifetimes)
- Sufficient data for statistical significant result
- Collected data to gain experience in high precision experiments
- Preliminary result (holding field up) is close to expected 0.006+-0.00015
- If PAX goes to CERN with AD ring acceptance 220 π mm mrad antiproton polarization of several percent is expected

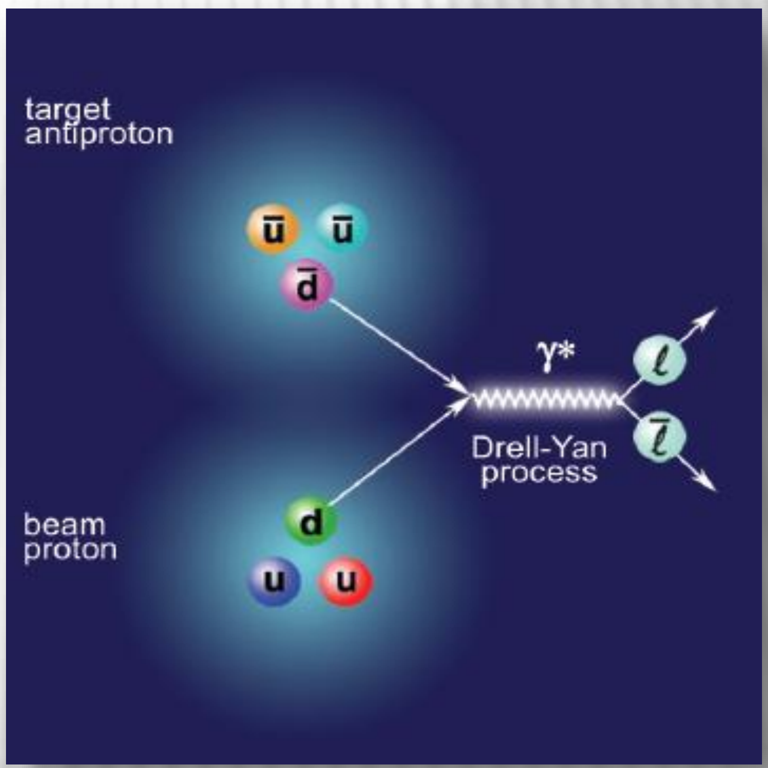
PAX AT CERN



Proposed place for PAX set-up

PROTON-PROTON VS PROTON-ANTIPROTON





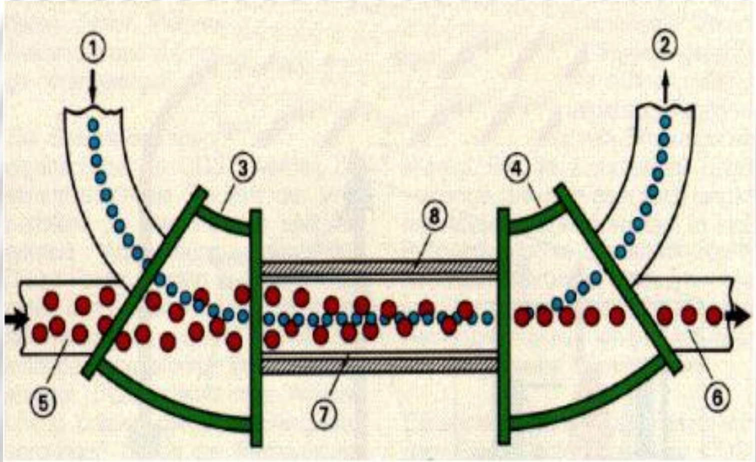
EXPECTED BUILD-UP RATE

- **Input parameters:**
- target density: ~ 5.5 * 1013/cm2
- target polarization: ~ 0.75
- cross section: σ1 = -26.9 mb
- (at T=49.3MeV, Θacc = 7mrad)
- ⇨ ΔPexpected ~ 0.002/h
- **Long filtering time necessary**
- ⇨ high beam lifetime
- ⇨ highest possible target density
- ⇨ best possible vacuum

WHY COSY IS SO COOL?

ELECTRON COOLING

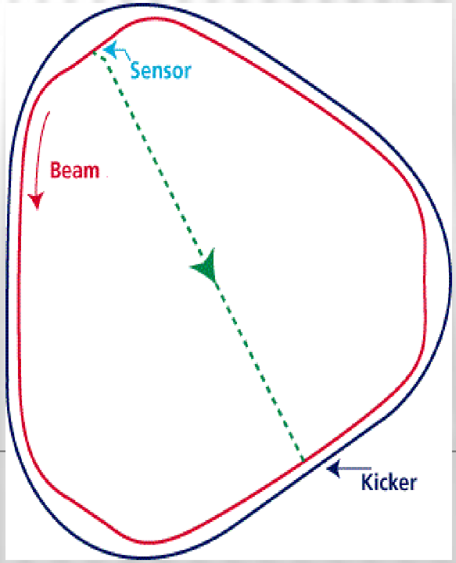
- High quality electron beam injected into the straight section
- Electrons velocities spread: 1/100 000 of the average velocity
- Average V(el)=V(pr)
- Electron Beam Current >>Proton BC



☹: Difficult to accelerate an intense beam of electrons by more than ~100 KV

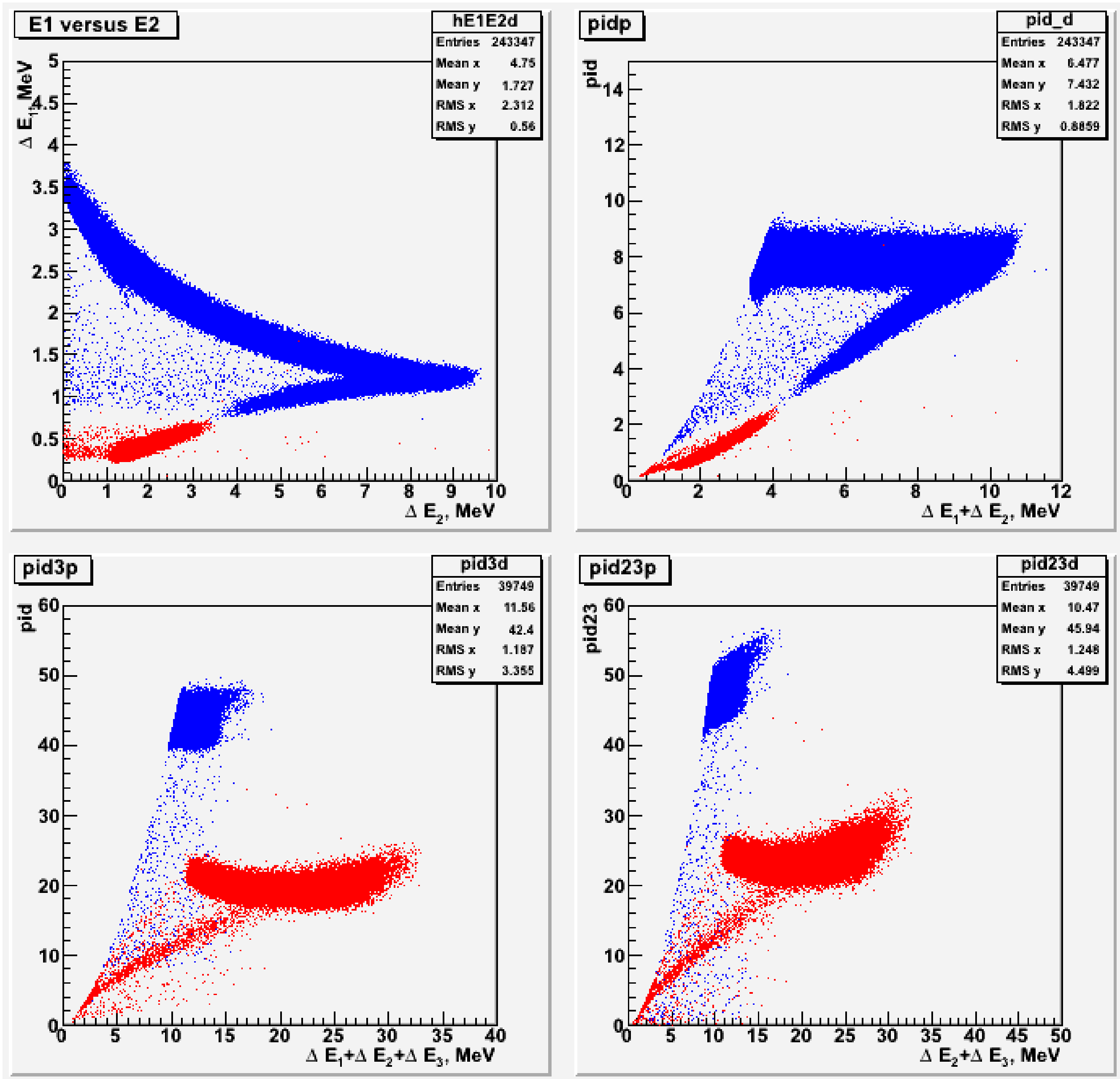
STOCHASTIC COOLING

- Sensor: the average position of circulating particles with respect to a central orbit
- Signal proportional to the displacement sent to another point
- Corrective pulse forces the particle to approach the central orbit



- Obvious for one particle
- Shown that works for many particles as well

VARIOUS DISTRIBUTIONS



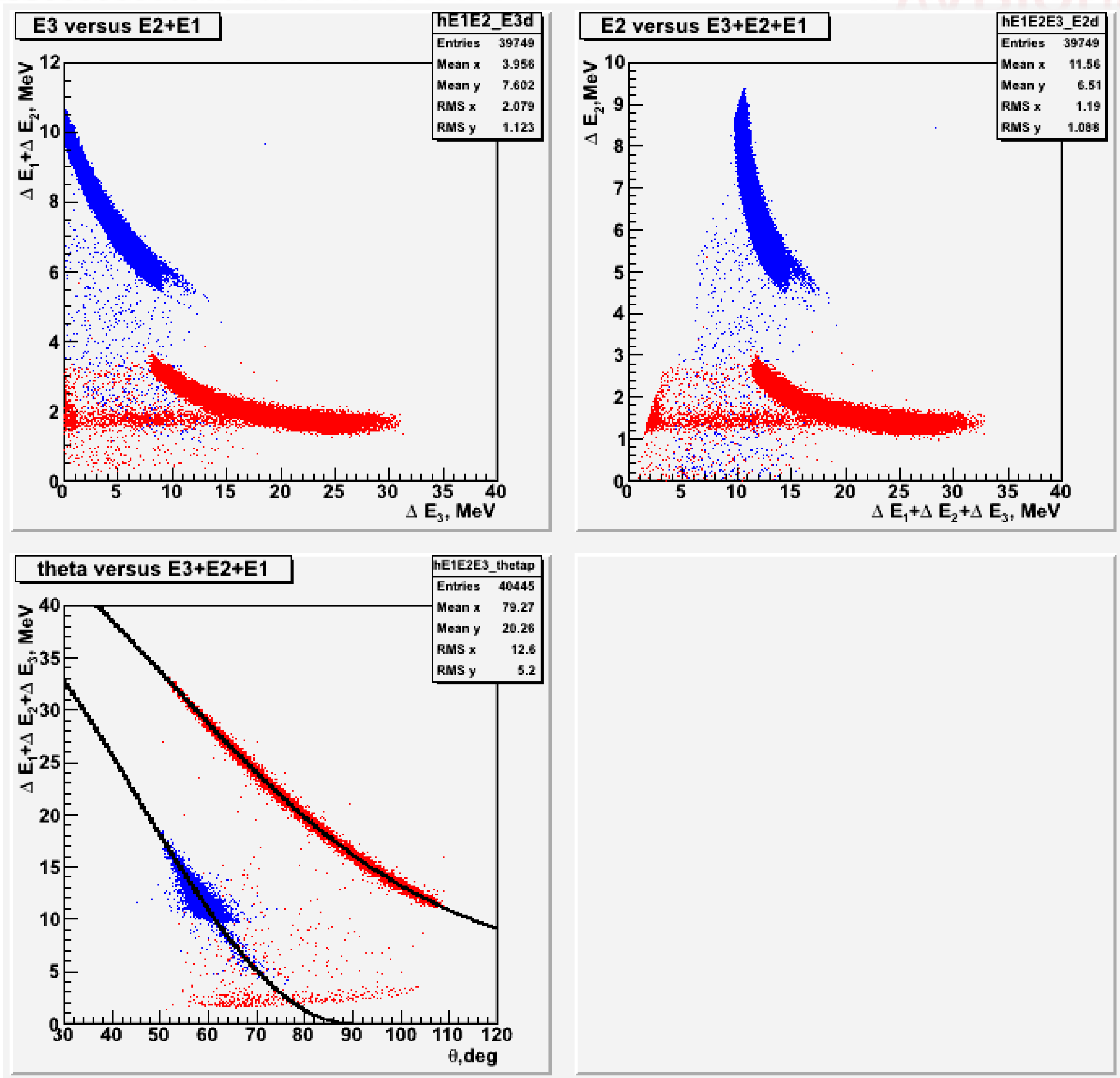
(1 TRACK DETECTED)

Pd elastic

Blue- deutrons

Red-Protons

VARIOUS DISTRIBUTIONS



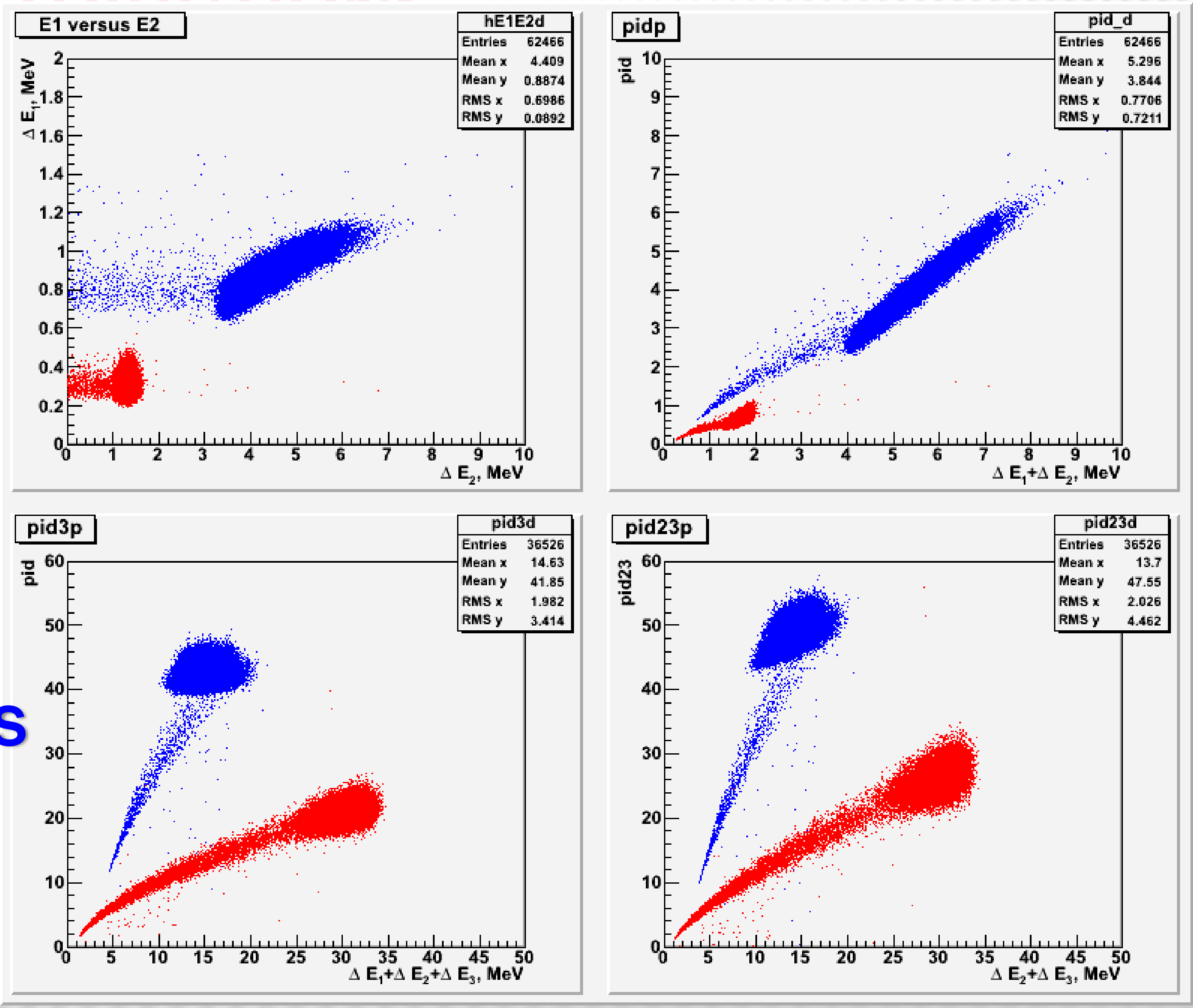
(1 TRACK DETECTED)

- Pd elastic
- Blue- deutrons
- Red-Protons

VARIOUS DISTRIBUTIONS

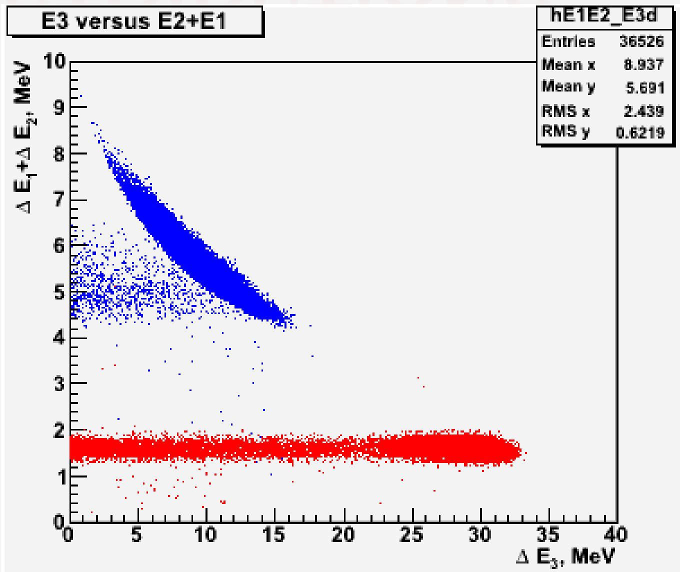
(2 TRACKS DETECTED)

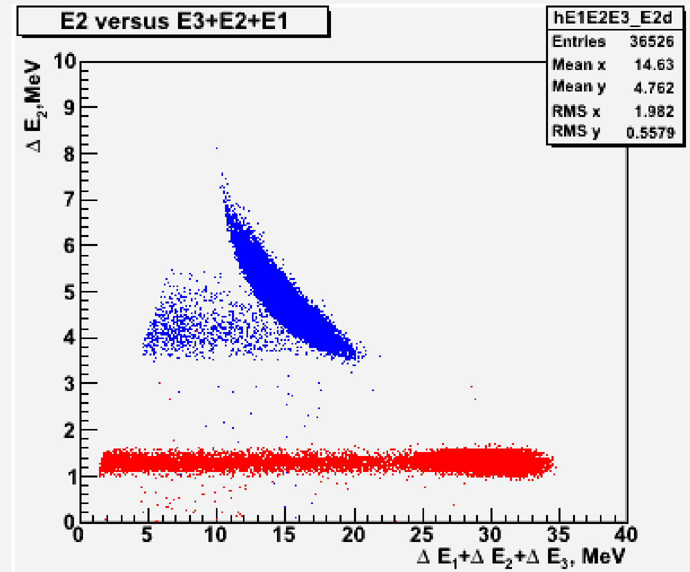
- Pd elastic
- Blue- deutrons
- Red-Protons

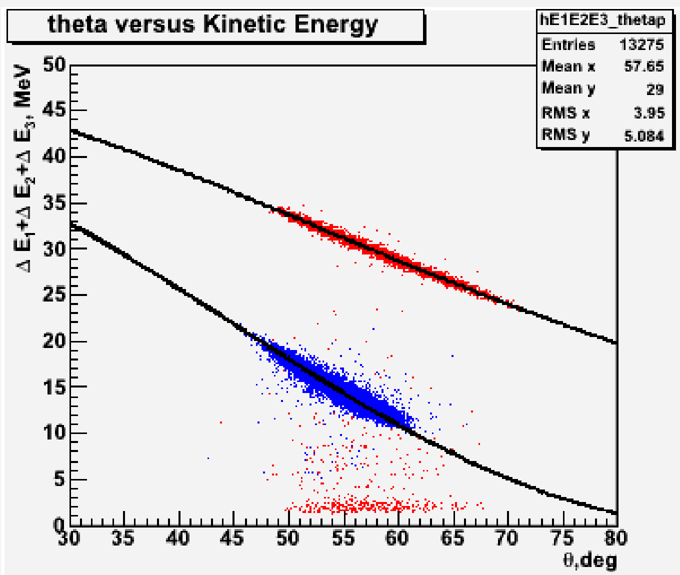


VARIOUS DISTRIBUTIONS

(2 TRACKS DETECTED)







- Pd elastic
- Blue- deutrons
- Red-Protons