JÜLICH
FORSCHUNGSZENTRUM

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Bachelor Degree in Physics

On the Road from Bachelor ‘s to Master’s

6 weeks spent in Forschungzentrum Juelich IKP

August, 20 2010
Forschungzentrum Juelich, IKP

How it all began:

Georgian - German School and Workshop in Basic Science :

Before talk:

-Dr. Gela Devidze: "opportunity to give a talk"

-Me: "Of course!"

My talk: "Geometry Design Study for CTA 12m telescope" (DESY Summer School 2009)

After talk:

-Dr. Hans Stroeher: "I would like to invite you for 6 weeks in FZJ"

–Me: "I'd love to come!"

After 2 months: **between the exams for applying to Master's Program:**

I'm in Forschungszentrum Juelich!!!

IKP (Institute fuer KernPhysiks) & COSY

- Dr. Andro Kacharava was very helpful, gave me a great introduction excursion on COSY, and guided me during my whole stay in IKP

- IKP's very friendly people: wishes for pleasant stay came true

❖ Georgians' great support

WHAT I SAW

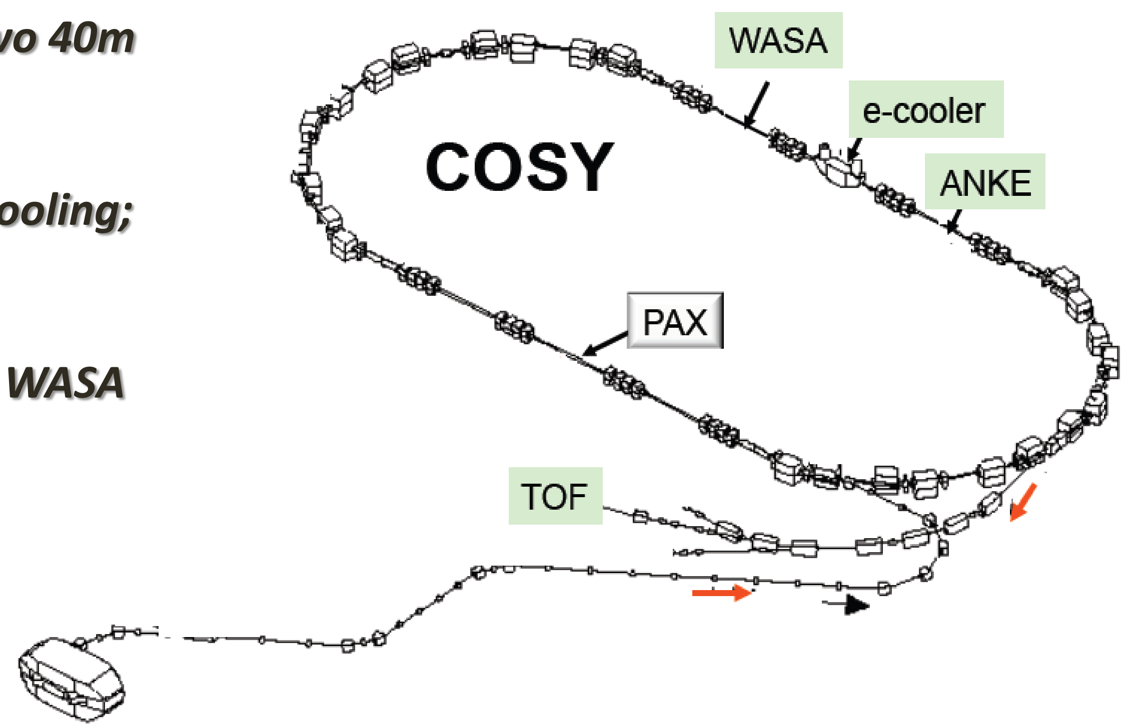
Thanks for guided tours to COSY:

Andro Kacharava, Alex Nass, *Valerie Serduk.*
Christian Weidemann, Kirill Grigoriev,
and excursion from Bad Honnef

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*
- *Internal experiments: ANKE, PAX, WASA COSY-11, EDDA;*
- *External: TOF, JESSICA and etc.*

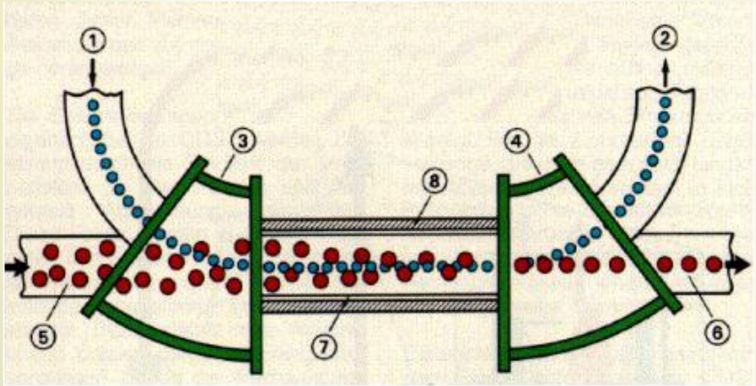
I have been on COSY 7-8 times (much better than one 4 hour excursion on HERA)



Why COSY is so Cool?

Electron cooling

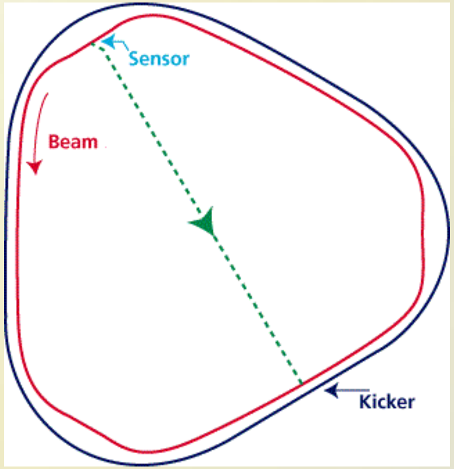
- High quality electron beam injected into the straight section
- Electrons velocities spread: 1/100 000 of the average velocity
- Average V(el)=V(pr)
- Electron Beam Current >>Proton BC



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

Stochastic cooling

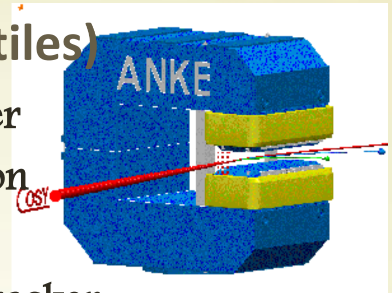
- Sensor: the average position of circulating particles with respect to a central orbit
- Signal proportional to the displacement sent to another point
- Correcting pulse forces the particle to approach the central orbit



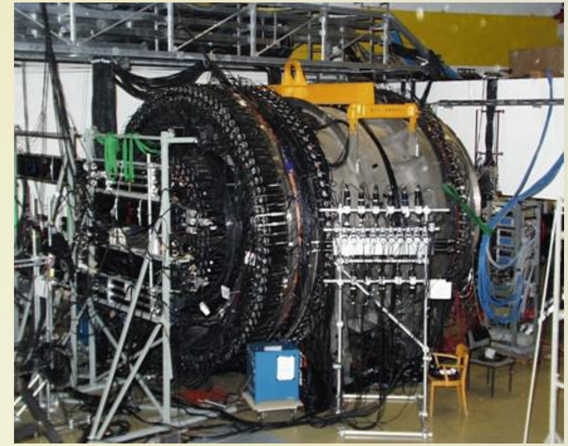
- Obvious for one particle
- Shown that works for many particles as well

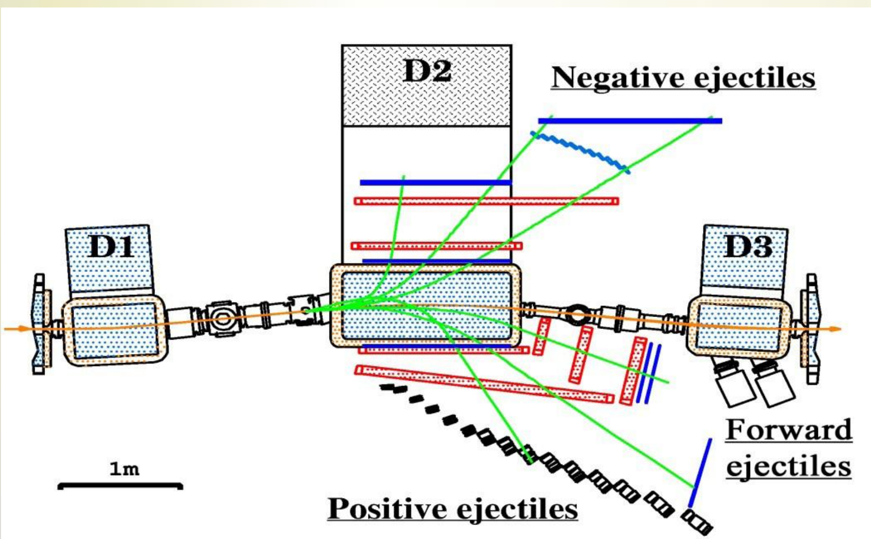
EXPERIMENTS

ANKE (Apparatus for Studies of Nucleon and Kaon Ejectiles)



- Internal magnetic spectrometer
- Excellent momentum resolution
- Limited solid angle coverage
- Optimized kaon ID, Si recoil tracker
- Targets: polarized („PIT“) or unpolarized (cluster)





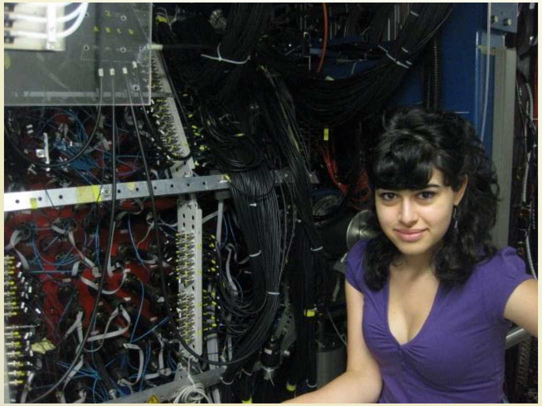
TOF (Time Of Flight)

- Large angle (non magnetic) spectrometer: external exp. at COSY
- 4π geometrical coverage
- Particle Identification from Time-Of-Flight, (dE/dx)
- Target: liquid hydrogen, deuterium

EXPERIMENTS

WASA
(*W*ide *A*ngle *S*hower *A*pparatus)

- A large-acceptance detector for charged and neutral particles.
- Pellet target
- very good momentum resolution
- No acceptance at 0°



PAX Project
(Polarised Antiproton eXperiment)

2010-2012: Spin Filtering Studies for protons at COSY

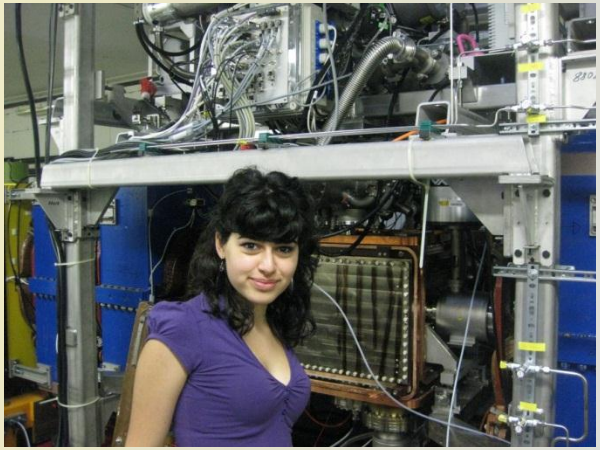
- 2012-2015: Spin-Filtering Studies for antiprotons at CERN AD

- After 2015:

PAX at FAIR:
Collide polarised protons and polarised antiprotons

- Motivation:

Transversity distribution,
Filling in gaps of QCD



Me, visiting PAX, earlier than many IKP scientists

WHAT I'VE LEARNED

Insight into PAX project

Thanks to Dr. Andro Kacharava, Dr. Nodar Lomidze for great help

Spin-Filtering Principle:

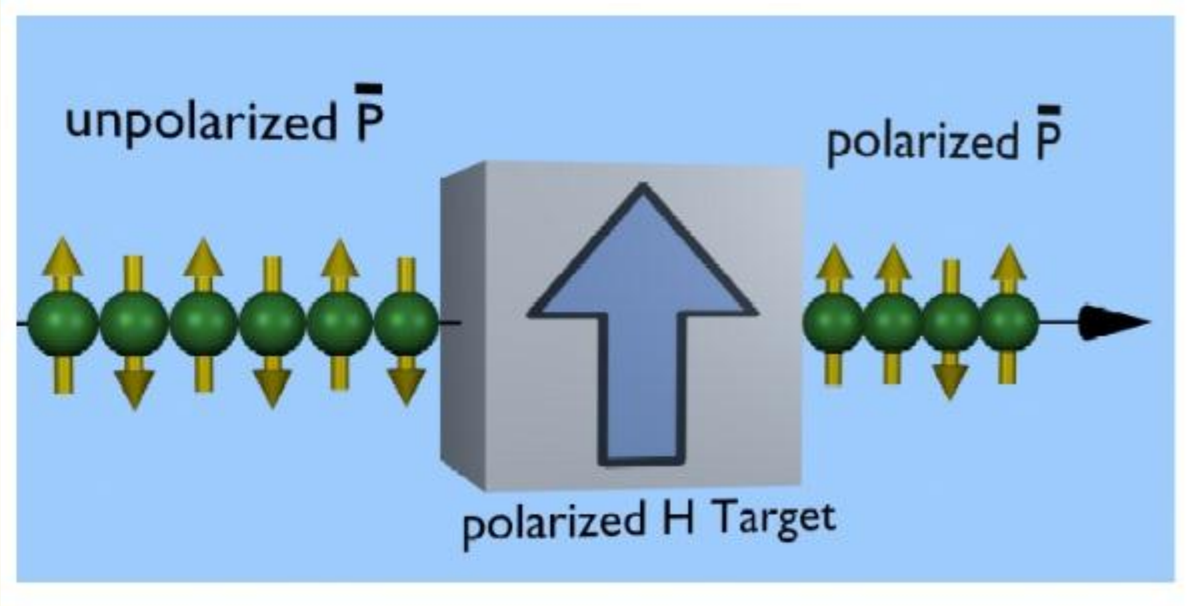
Unpolarized beam starts circulating in the ring

- Hits polarised target

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

- A fraction of beam is lost

- BUT: the left beam is polarised



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

P beam polarization
Q target polarization
k || beam direction

- In other words: more protons with spin in particular direction.

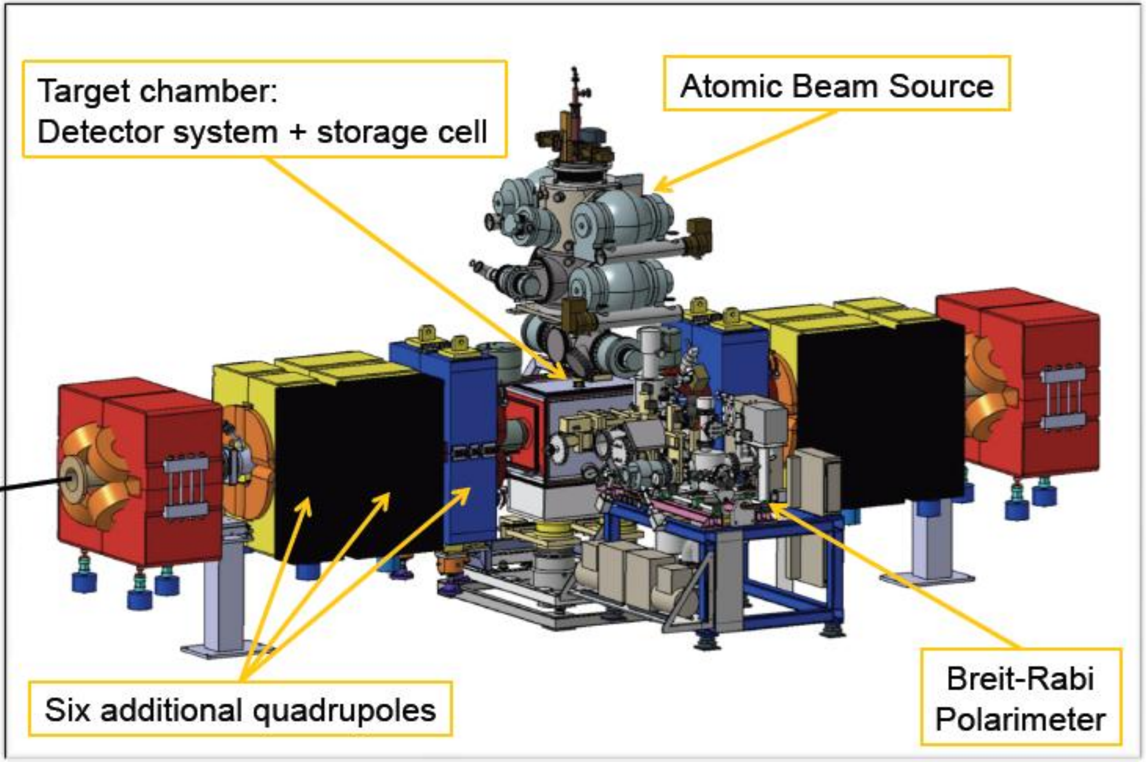
PAX hardware

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

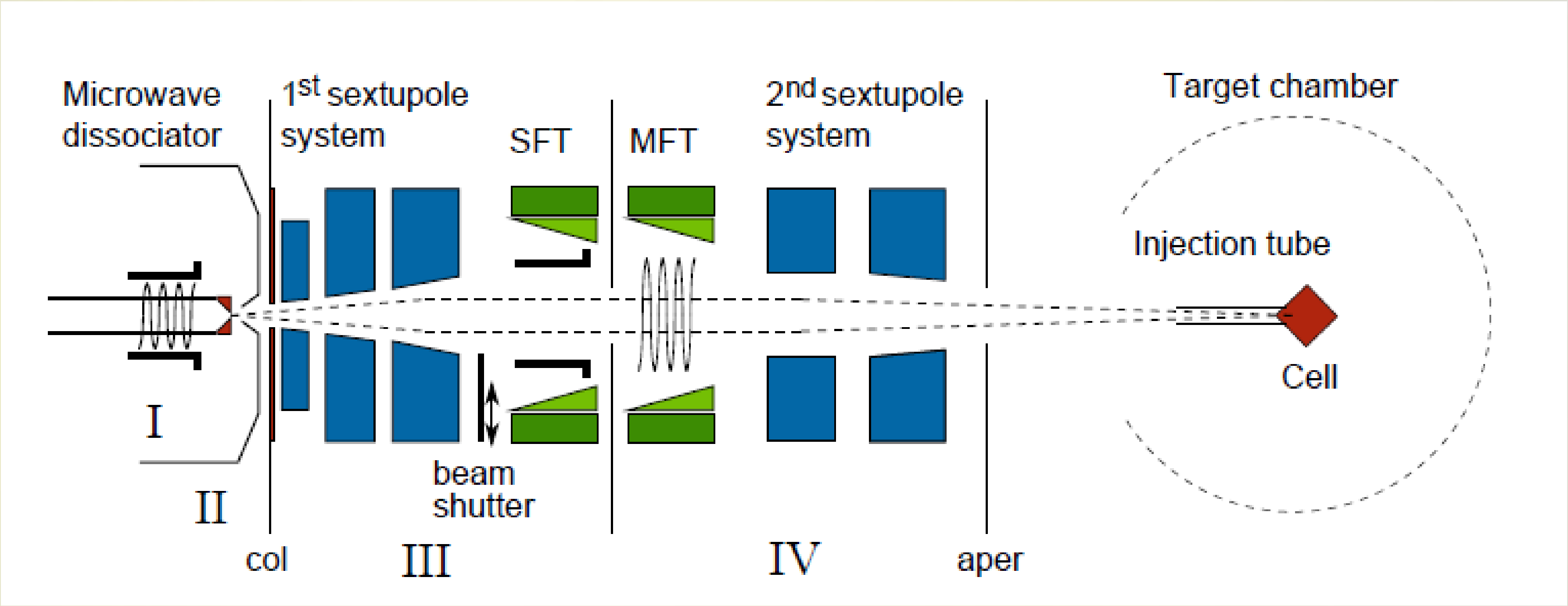
Storage cell to increase target density;

Breit-Rabi Polarimeter: Monitoring of target polarization;

Silicon Tracking Telescope: Particle tracks and energy



Atomic Beam Source



Ionization of hydrogen atoms doesn't change polarization of protons

Hydrogen hyperfine states

Electron Spin: S=1/2

$$m_j = \pm\frac{1}{2}$$

Proton Spin: I=1/2

$$m_I = \pm\frac{1}{2}$$

Total angular momentum: F=S+I

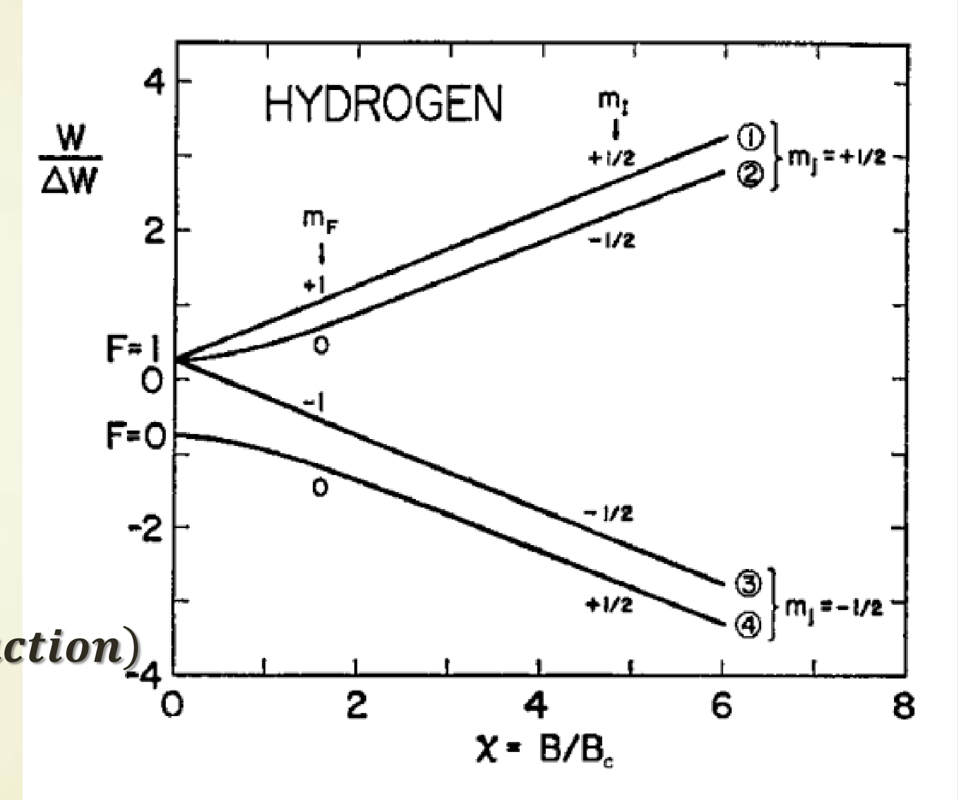
F=0: $m_F = 0$

F=1: $m_F = 0, \pm 1$

No external field:

$$\Delta W \approx 6 \cdot 10^{-6} eV$$

$(electron\ and\ proton\ spins\ interaction)$



With field: Zeeman splitting of F=1 state

Proton polarization

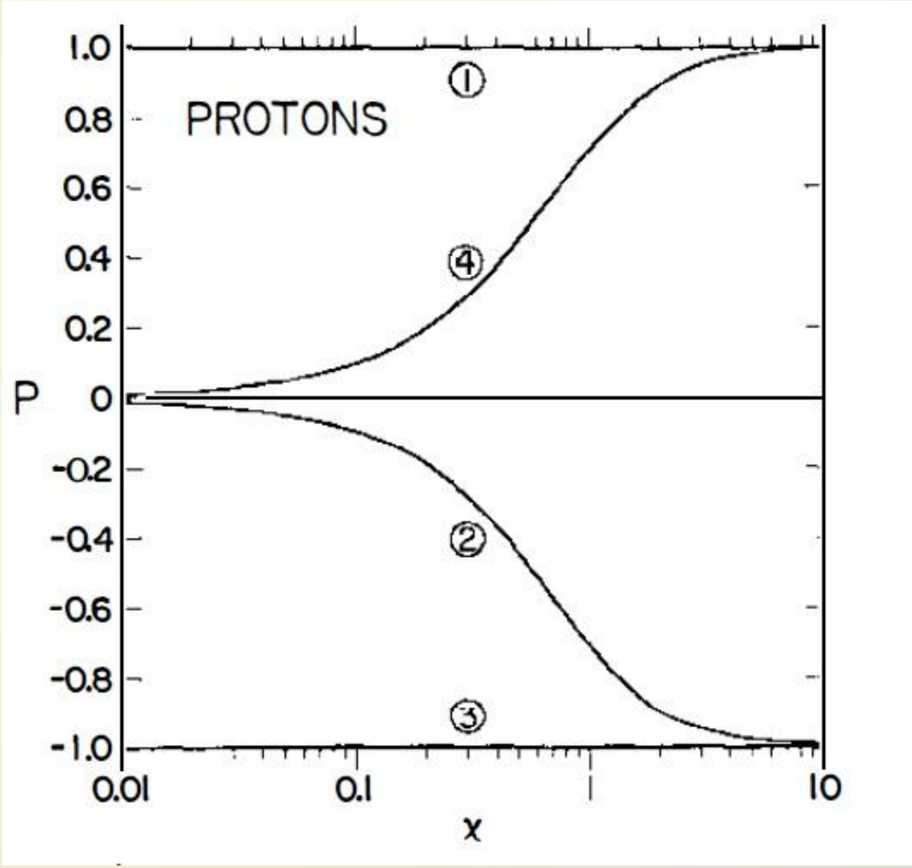
- Polarization: P=$\frac{N_{\uparrow}-N_{\downarrow}}{N_{\uparrow}+N_{\downarrow}}$

- Weak field:
- [1] , [2] -> P=0.5

- [2]->[4] or [1]->[3] possible

- Strong field:

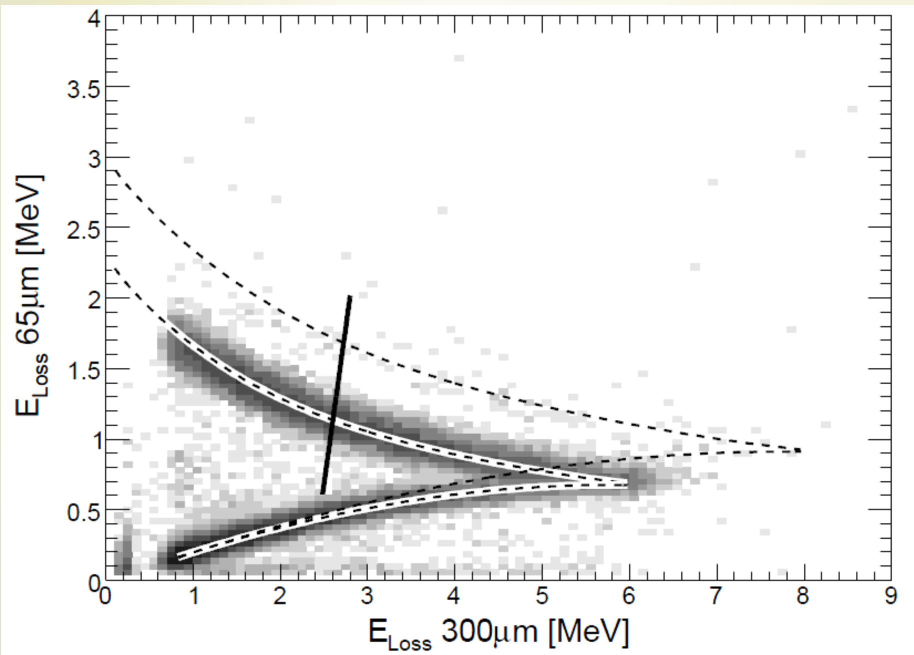
P= 1.0 or P= -1.0

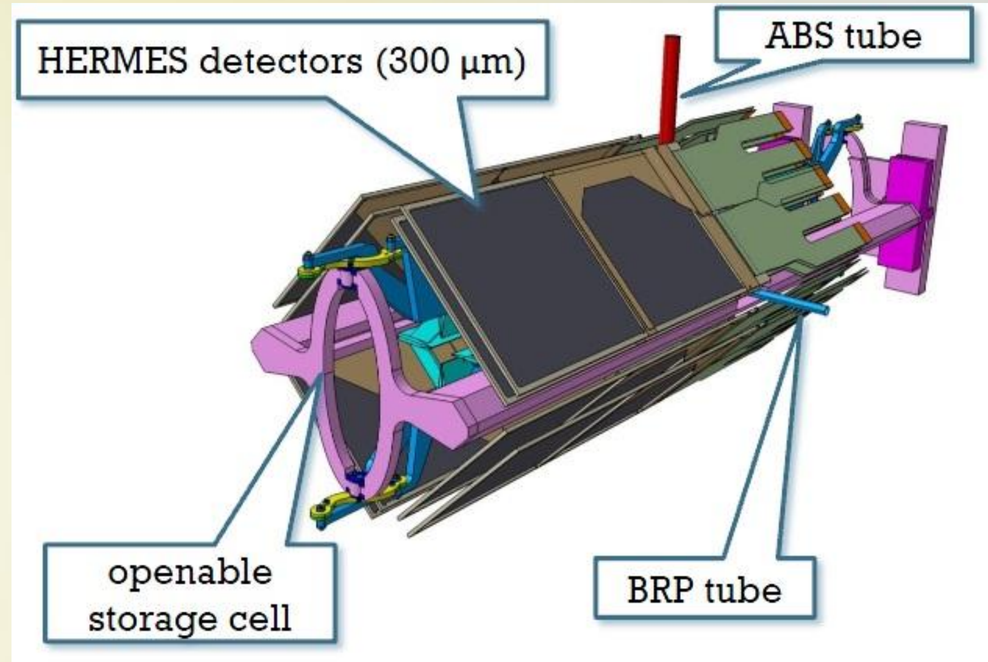


Silicon Tracking Telescope

3 layers of double – sided silicon-strip detectors

Surround storage cell from 4 sides





Particle tracking -> Vertex

Stopping particle -> Total energy

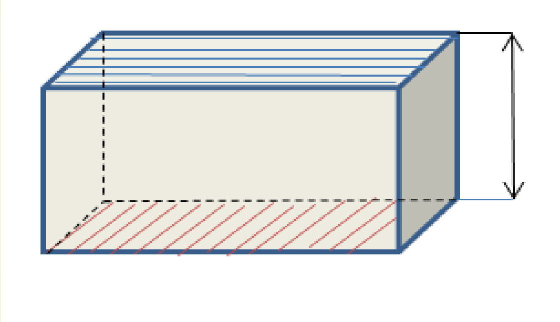
Distinguishing protons and deuterons

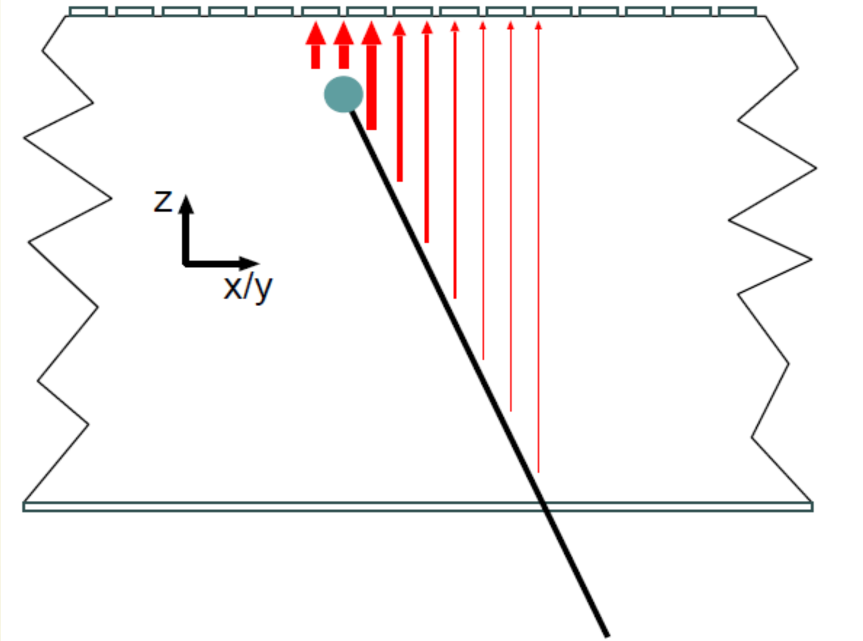
Silicon detector (Energy)

- *n-doped stripes (30 µm)*
- *p-doped stripes (30 µm)*
- *Particle moves through detector-> Electron-hole couple: 3.6 eV*
- *p-n junctions: energy transferred to the semiconductor.*
- *The sum of energy losses*

$$E_{sum} = \sum_{segments} E_{segment}$$

- *To determine the total energy, particle should be stopped in the detector*





OBSERVABLES

$\vec{k}_{in}$ – incident wave vector

OZ ↑↑ $\vec{k}_{in}$

OY ↑↑ $\vec{k}_{in} \times \vec{k}_{out}$

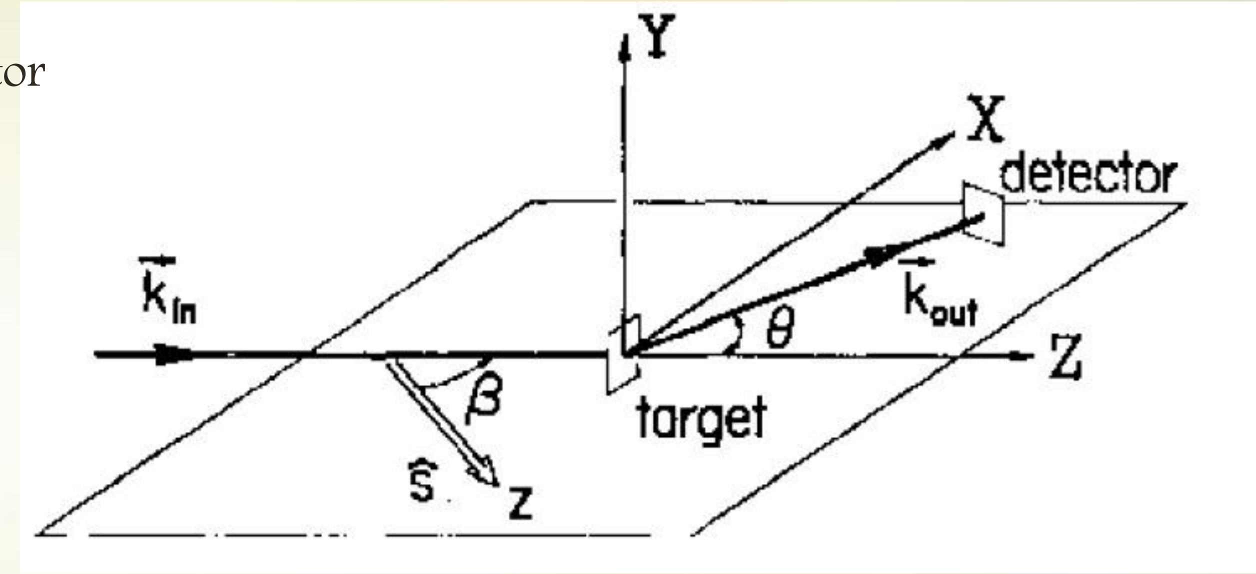
OX ↑↑ OY×OZ

$\hat{s}$–polarization axis

$$\beta = \angle(\hat{\mathbf{s}},\mathbf{Z})$$

$$\theta = \angle(\mathbf{Z},\vec{k}_{out})$$

$$\varphi = \angle(\mathbf{X},[\hat{\mathbf{s}} \times \vec{k}_{in}])$$



$$\boldsymbol{\sigma(\theta,\varphi) = \sigma_0(\theta)\left[1 + PA_y cos\varphi\right]}$$

ONLY the polarization component normal to reaction plane affects the cross section

A_y– Analyzing Power of the reaction: the polarization, obtained in the reaction, initiated with an unpolarized beam.

Kinematics for different reactions should be known well

WHAT I DID

Back to ROOT

(not that I had big experience before, but still)

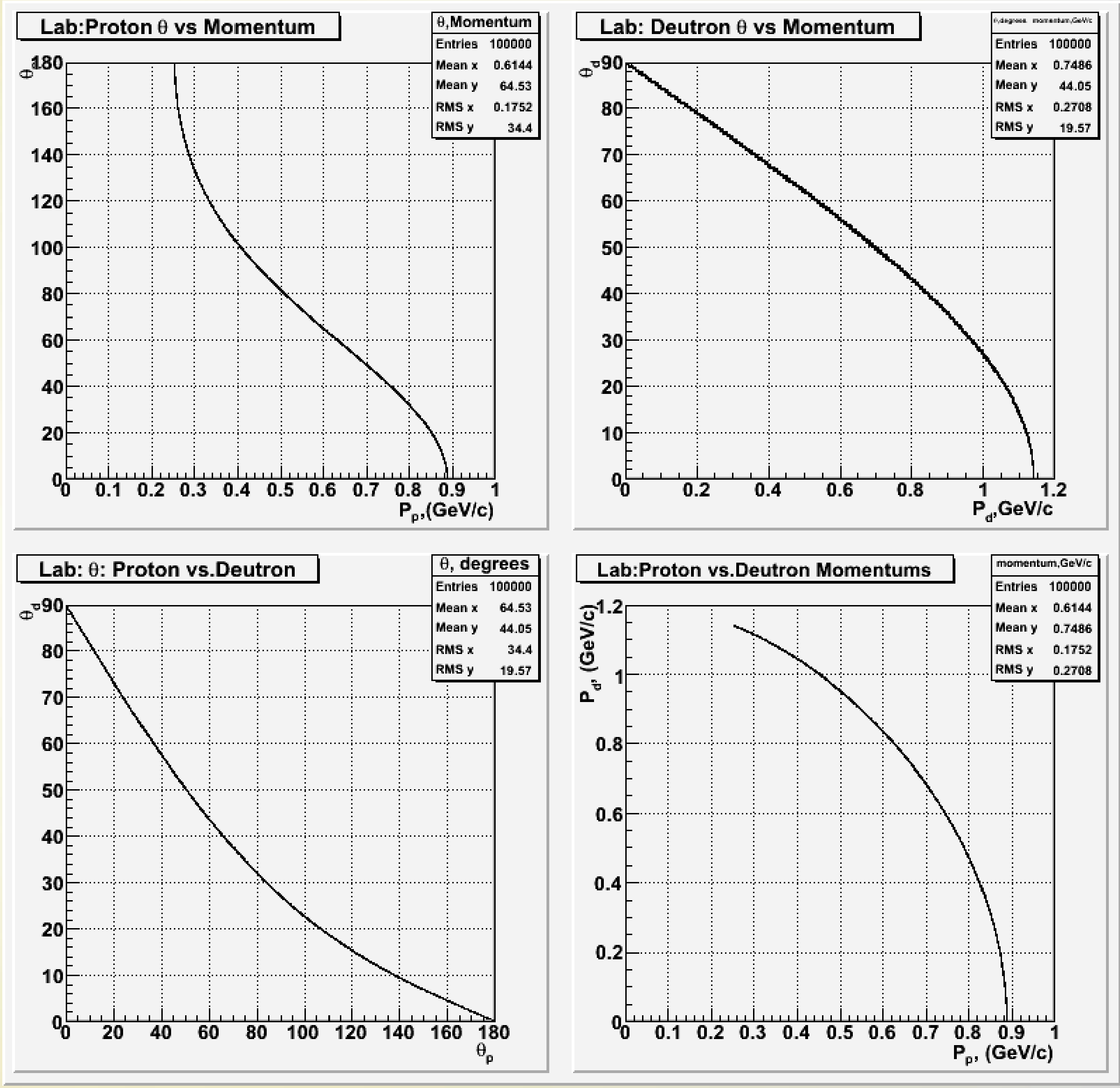
KINEMATICS

- $p_a + p_b \rightarrow p_1 + p_2$
- s=$(p_a + p_b)^2$ is known
- Interesting dependences : p_1 vs. θ_1, p_2 vs. θ_2, θ_1 vs. θ_2
- $p_1 = \frac{\sqrt{\lambda}(t, m_b^2, m_1^2)}{2m_b}$ where t=$(p_b - p_2)^2$, u=$(p_a - p_2)^2$
- $p_2 = \frac{\sqrt{\lambda}(u, m_b^2, m_2^2)}{2m_b}$ $\lambda(x, y, z) = (x - y - z)^2 - 4yz$
- $tg\theta_1 = \frac{sin\theta_1^*}{\gamma(cos\theta_1^* + g_1^*)}$ $g^* = \frac{v}{v^*} = \frac{Velocity\ of\ LCS\ in\ CM}{Velocity\ of\ particle\ in\ CM}$
- $tg\theta_2 = \frac{sin\theta_1^*}{\gamma(-cos\theta_1^* + g_2^*)}$ $g^* < 1$ $0 < \theta < 180°$
- $g^* \geq 1$ $\theta < \theta^{max} \leq 90°$

Kinematics: elastic Proton-Deutron scatering

- TGenPhaseSpace Class
- T–353 MeV
- θ – p dependence for Protons and for Deutrons
- Proton vs. Deutron:

θ's and p's



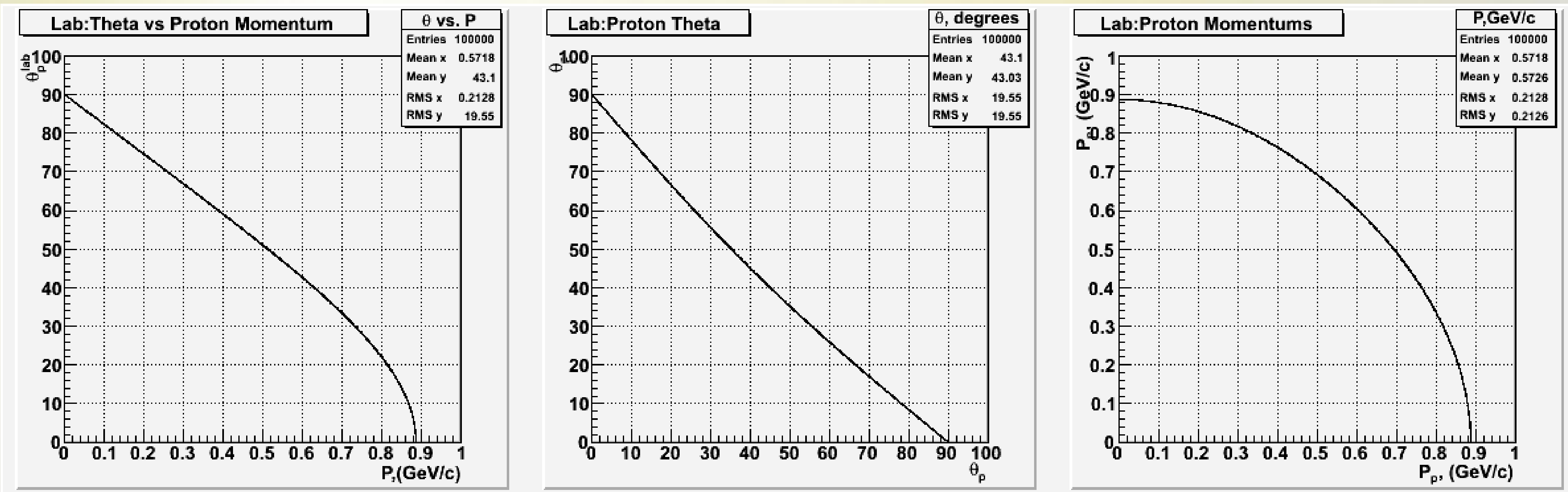
Analysis tools: kinematics pp elastic scattering

T=353 MeV

Used for beam polarization measurement
– Large Analysing Power

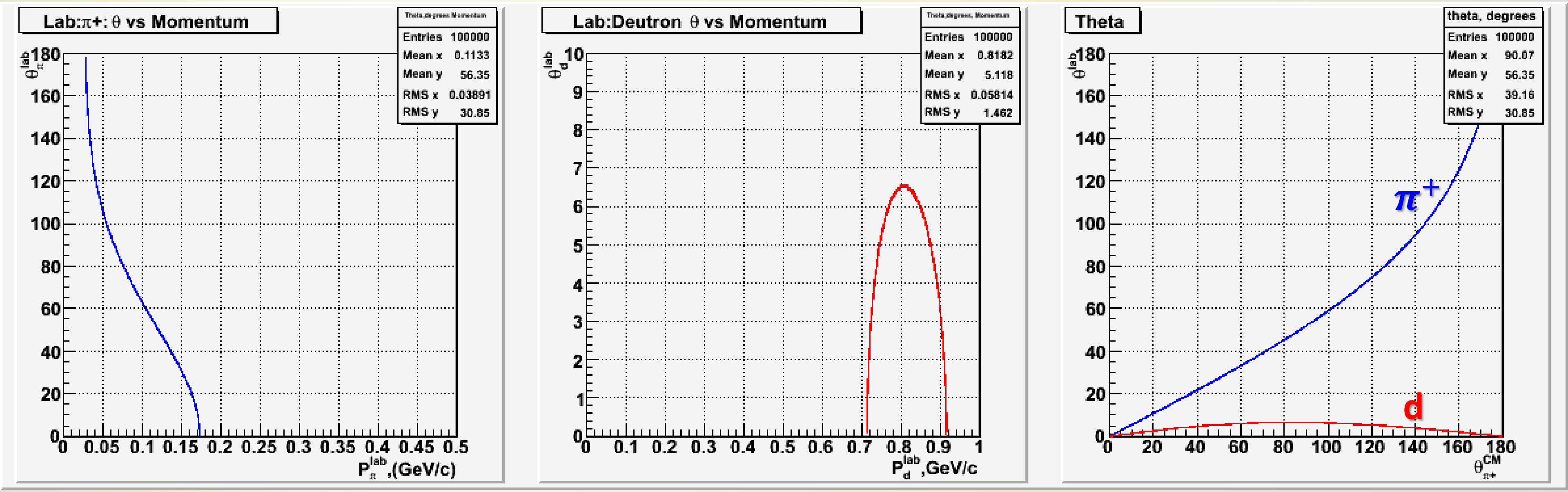
- Laboratory Coordinate System: θ - θ ,

θ – p, p–p dependences



Kinematics($pp \to \pi^+ d$)

T=353 MeV



Analysis Tools: Simulations

- GEANT 4

(describe the passage of elementary particles through the matter)

  - The tracking of particles through an experimental setup for simulation of detector response
  - The graphical representation of the setup and of the particle trajectories

NEED TO LEARN!

LAST BUT NOT LEAST

Hadron Physics Summer School in Bad Honnef

- Interesting lectures
- Working group : Rare η decays

(Dr. Andreas Wirzba & Dr. Magnus Wolke)

- My task: Motivation

- Pleasant atmosphere of Bad Honnef

- Interesting discussions with other students and a lot of fun

CONCLUSION

Before Visit:

- Huge amount of names and notions:

COSY, ANKE, PAX, FAIR, and of course, spin-filtering

- confused & tired

After Visit:

- Even larger ocean of notions:

Atomic Beam Source, Breit-Rabi Polarimeter, Silicon Tracking Telescope

- BUT knowledge receives some shape: happy & interested

Found IKP and Juelich very cosy

Have a desire to come back

P.S. Just an interesting fact:

- PAX experiment timeline nicely matches with my educational timeline:

- 2010-2012: PAX @ COSY Me@Master's Program
- 2012-2015: PAX@CERN ME@PhD
- 2015-2020: PAX@FAIR Me@ PostDoc

ACKNOWLEDGEMENTS

- Dr. Hans Stroeher for very kind and supportive attitude, for giving me this opportunity to spend these amazing weeks here and learn so much.
- Dr. Andro Kacharava for guiding me before, during and probably after visit, for providing me with interesting information both from dialogues and literature.(and of course, for giving me a ride to IKP and back home ☺)
- Dr. Nodar Lomidze for not believing me when I claimed I knew smth ☺, and asking very interesting useful questions, it was very helpful during the learning process
- Dr. Mirian Tabidze for introductory talks before my arrival
- Dr. Gela Devidze for permanent support and informing about opportunity to give a talk on the workshop (He also wrote the recommendation for DESY, without which I wouldn't even have anything to present on the conference, and hence be here now)
- Davids ☺ for being always ready to help and just being a nice company
- And also DB and Schumacher company for making possible to travel that cheap

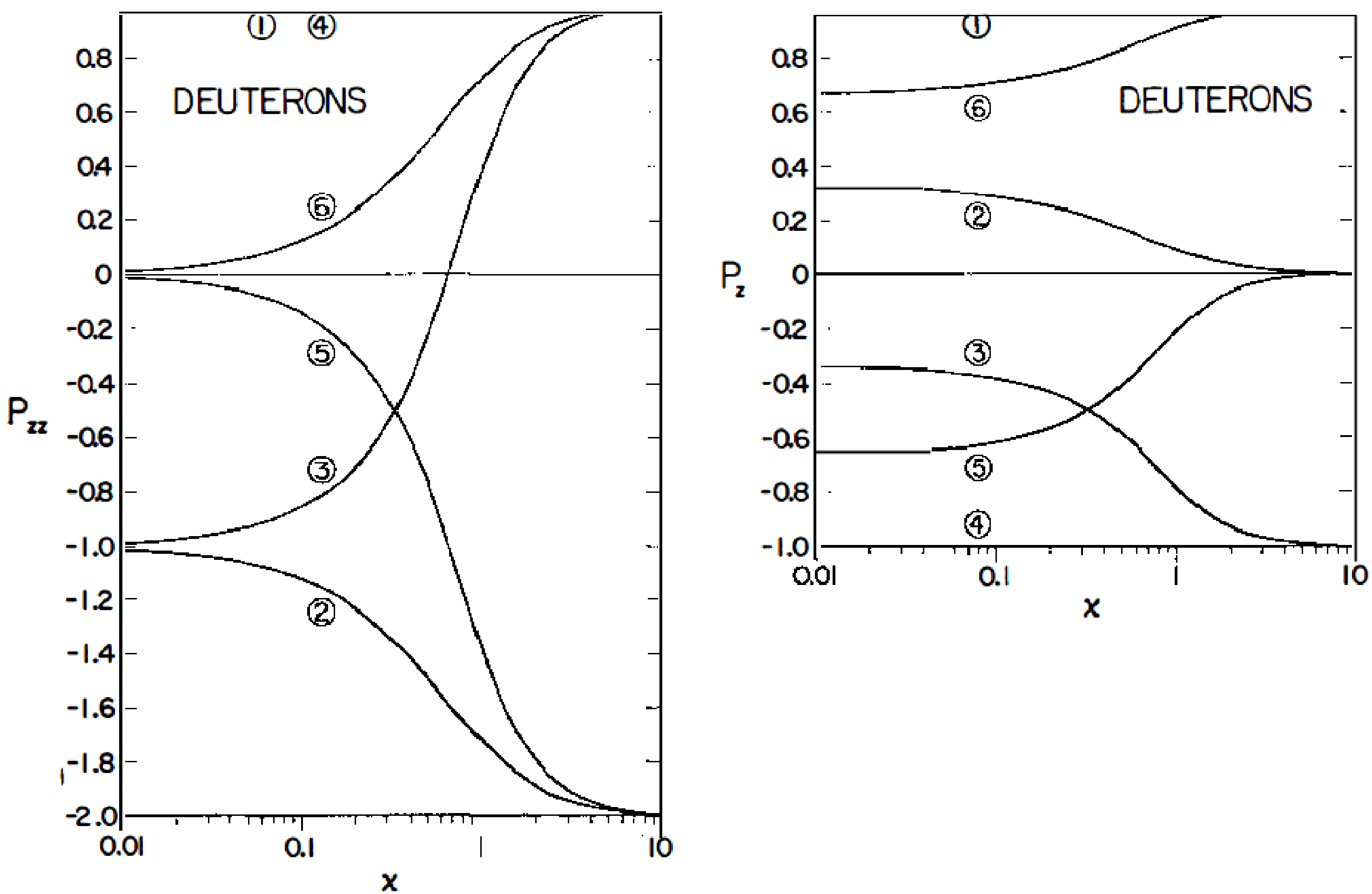
REFERENCES

- D. Oellers. "Polarizing a Stored Proton Beam by Spin-Flip?"
- C. Barschel. "Calibration of the Breit-Rabi Polarimeter for the PAX Spin-Filtering Experiment at COSY/Juelich and AD/CERN"
- A. Mussgiller. "Identification and Tracking of Low Energy Spectator Protons"
- *D. Chiladze*. "Deuteron Polarimetry Studies at COSY-Jülich with the ANKE Spectrometer"
- W. Haeberli. "Sources of Polarised Ions"
- http://www.fz-juelich.de/ikp/cgswhp/cgswhp10/program/program.shtml

BACK-UP

(or things I've learned but they will be too much for the talk)

Deuterium Polarization



Silicon Detector (Tracking)

1-D hit point

- *primary threshold of that segment*
- *corresponding secondary threshold.*

- *Criteria for secondary threshold: reasonable size of the hit, reducing the errors, caused by loss summation*

- *The position of the hit: weighted energy loss center of all segments in the hit.*

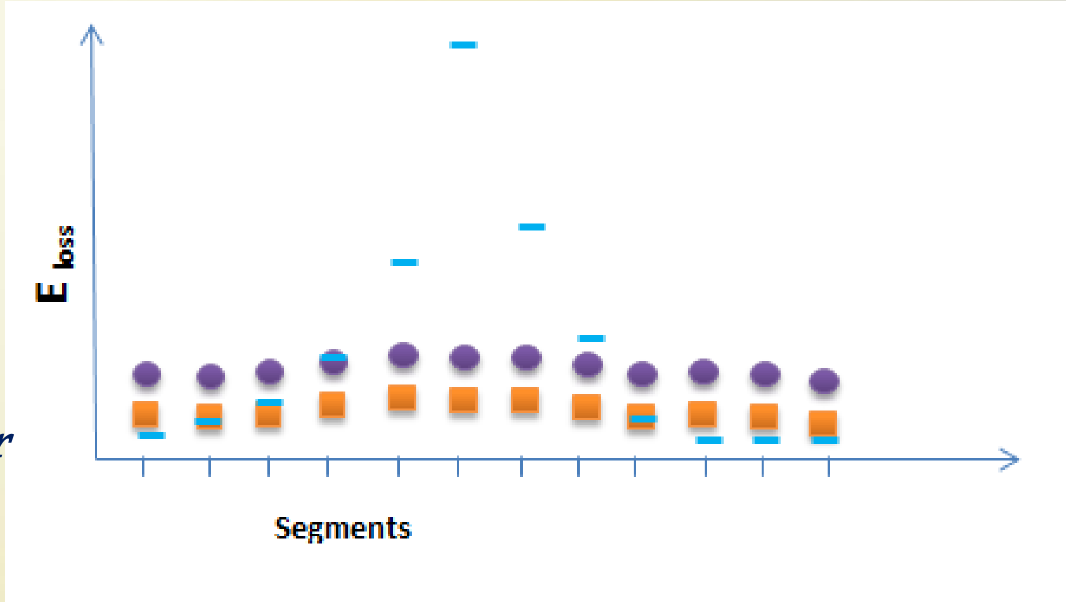
2-D hit point

Combining 1–D hits from both sides

n-doped stripes (y coordinate)

p-doped stripes (x coordinate)

- *Criteria: both energy losses may differ only by small certain percentage.*



DETECTORS

Introduction from Valerie Serduk

- ***Drift chambers, ready to install on ANKE,***
- ***Straw detectors for the PANDA***
- ***and also scintillators, counters, and many wires to analyze the data, given by the detectors.***