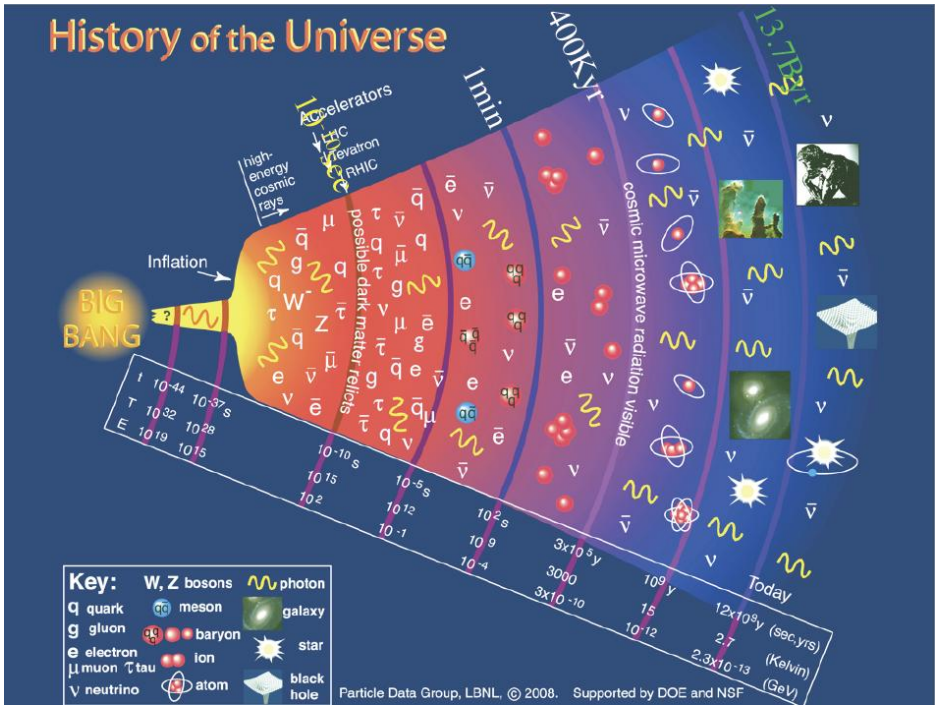
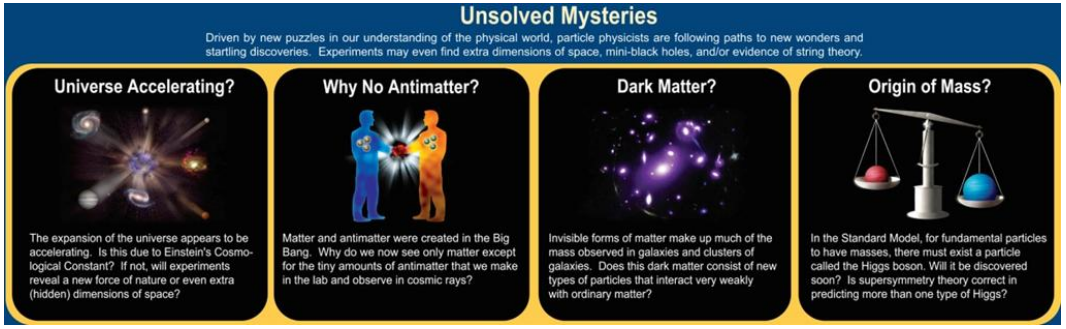
Outline

- Why is this experiment interesting ?
- What do we measure ?
- How do we measure ?
- Some experimental details
- Summary

The TRIC Experiment at COSY: Status and Preparation

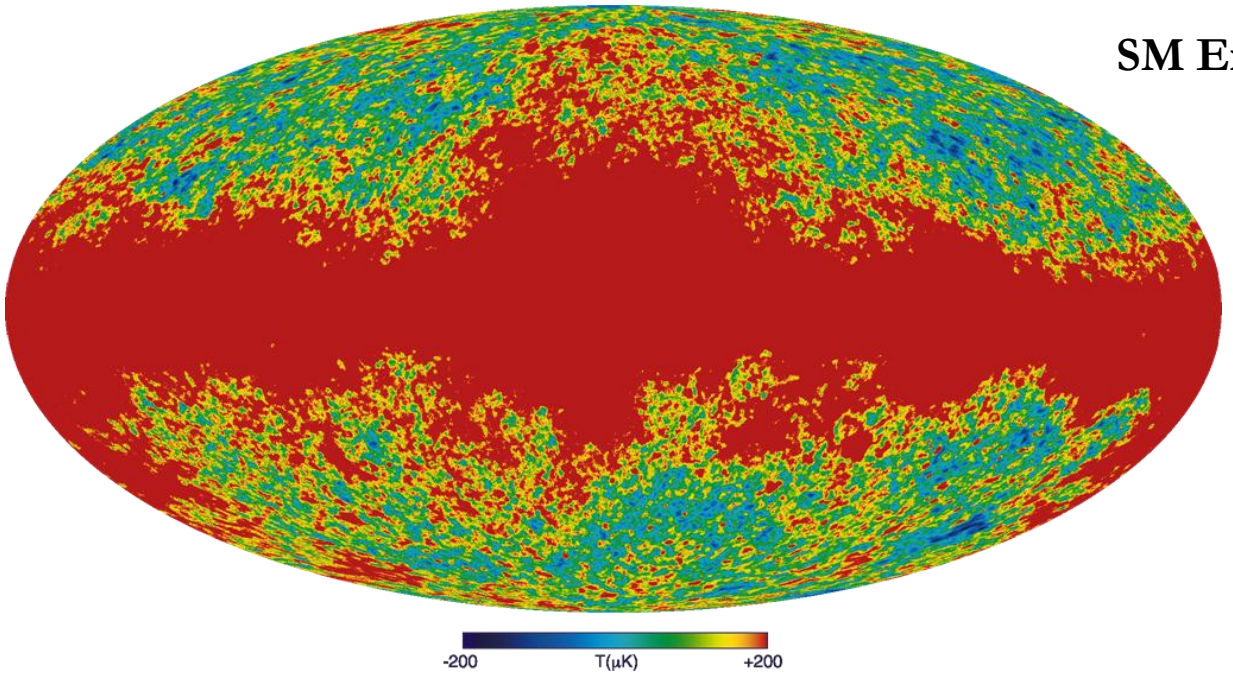
Why is this experiment interesting ?





Why is this experiment interesting ?

Baryon Asymmetry of the Universe



Observed: $(n_B-\bar{n}_B)/n_\gamma = 6\cdot10^{-10}$

SM Expected: $(n_B-\bar{n}_B)/n_\gamma \sim 10^{-18}$

WMAP+COBE, 2003

8 orders of magnitude are missing!

What do we measure?

5.9 MeV Neutron Transmission Experiment through ^{165}Ho

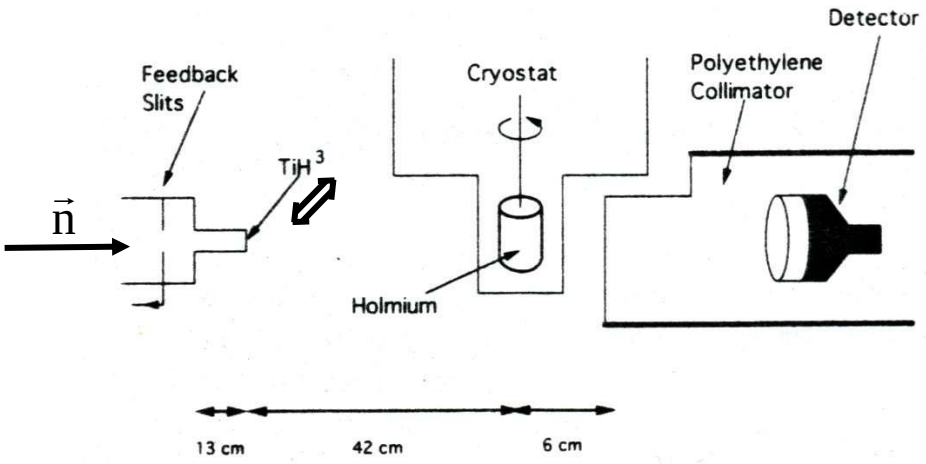
Observable (A5) : $\vec{p}\cdot(\vec{\sigma}_1\times\vec{\sigma}_2)(\vec{p}\cdot\vec{\sigma}_2)$

Result : $\bar{g}_{\rho T} : 2.3 \pm 2.1 \cdot 10^{-2}$

P.R. Huffmann et al., Phys.Rev. ***C55*** *(1997) 2684*

Prediction: $\bar{g}_{\rho T} < 1.5 \cdot 10^{-3}$

W.C.Haxton. Antje Höring and M.J. Musolf, Phys.Rev. ***D50*** *(1994) 3422*



J.E.Koster et al., Phys. Rev. C ***49*** *(1994) 710*

- Since the tensor polarization in ^{165}Ho is generated by one valence nucleon, the effect is diluted by the other 164 nucleons
- Therefore:
  Restrict experiment to most simple Spin1-Spin½ system, i.e. $\vec{p}-\vec{d}$ scattering at COSY (as an internal experiment)

What is Tensor Polarization ?

- **It makes no sense to talk about polarization without having defined a quantisation axis.**
- An **unpolarized system** has all states populated equally .

	Spin ½: (p ,n ,e, . . .)	**Spin 1:** (d)
• **Vector polarization:**	$P_V = \frac{1}{A_V} \cdot \frac{N^+ - N^-}{N^+ + N^-}$	$P_V = \frac{1}{A_V} \cdot \frac{N^+ - N^-}{N^+ + N^0 + N^-}$
• **Tensor polarization:**		$P_T = \frac{1}{A_T} \cdot \frac{(N^+ - N^0) + (N^- - N^0)}{N^+ + N^0 + N^-} = \frac{1}{A_T} \cdot \frac{N^+ + N^- - 2N^0}{N^+ + N^0 + N^-}$
Example: $N^0 = 0$		$P_V = 0, \quad P_T = \frac{1}{A_T} \cdot 1$

What do we measure?

- Have a **model** to get an idea about the **size** of the effect.
- Choose a **simple system** (that can be easily analysed).
- Identify an **observable** with a **clear signature**.
- Design the **experimental set-up**.
- Consider the **principal error contributions**.

What do we measure?

- (Most) accurately test TRI (T-odd, P-even) in nuclear matter
- Dynamics independent;
  especially: Not sensitive to final state interaction
- Only dependent on the structure of the reaction matrix as determined by general conservation laws „True test of TRI“
- Simple reaction (Two particles in → two particles out)

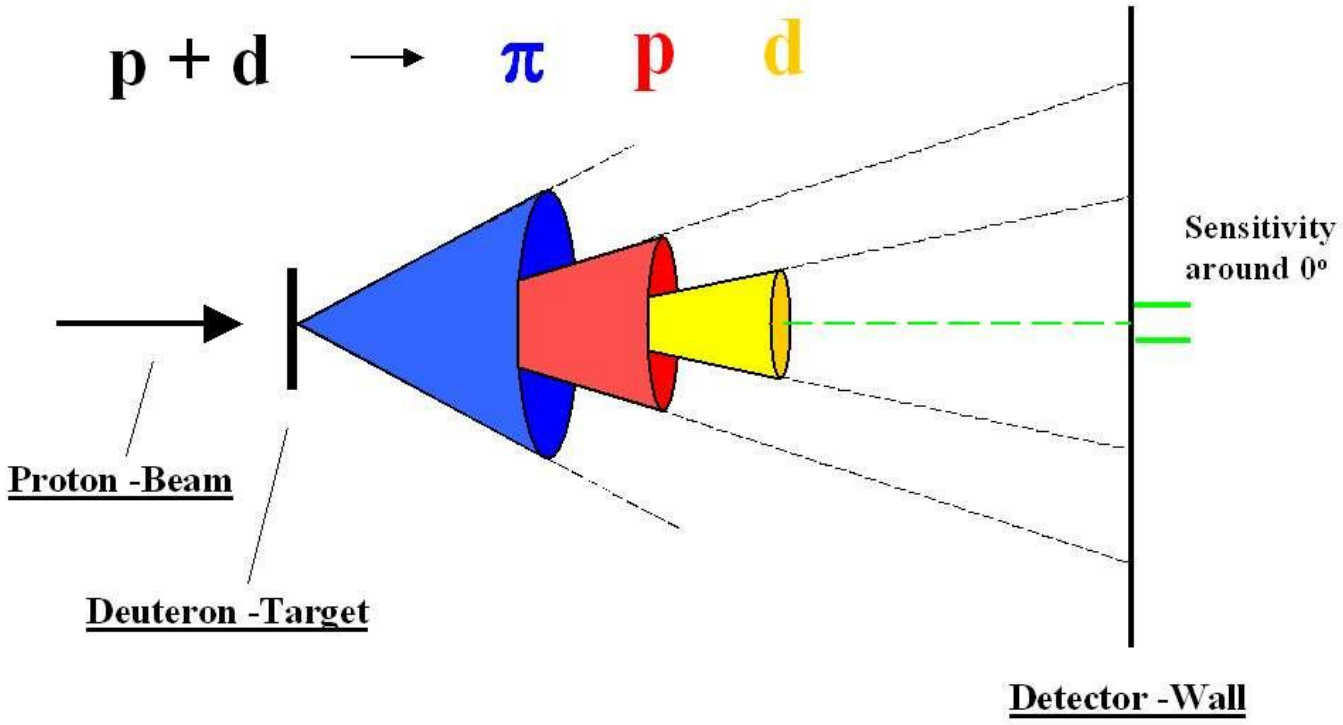
True TRI Null-Test

Measure total $A_{y,xz}$ in $\vec{p}$ - $\vec{d}$ scattering

How do we measure?

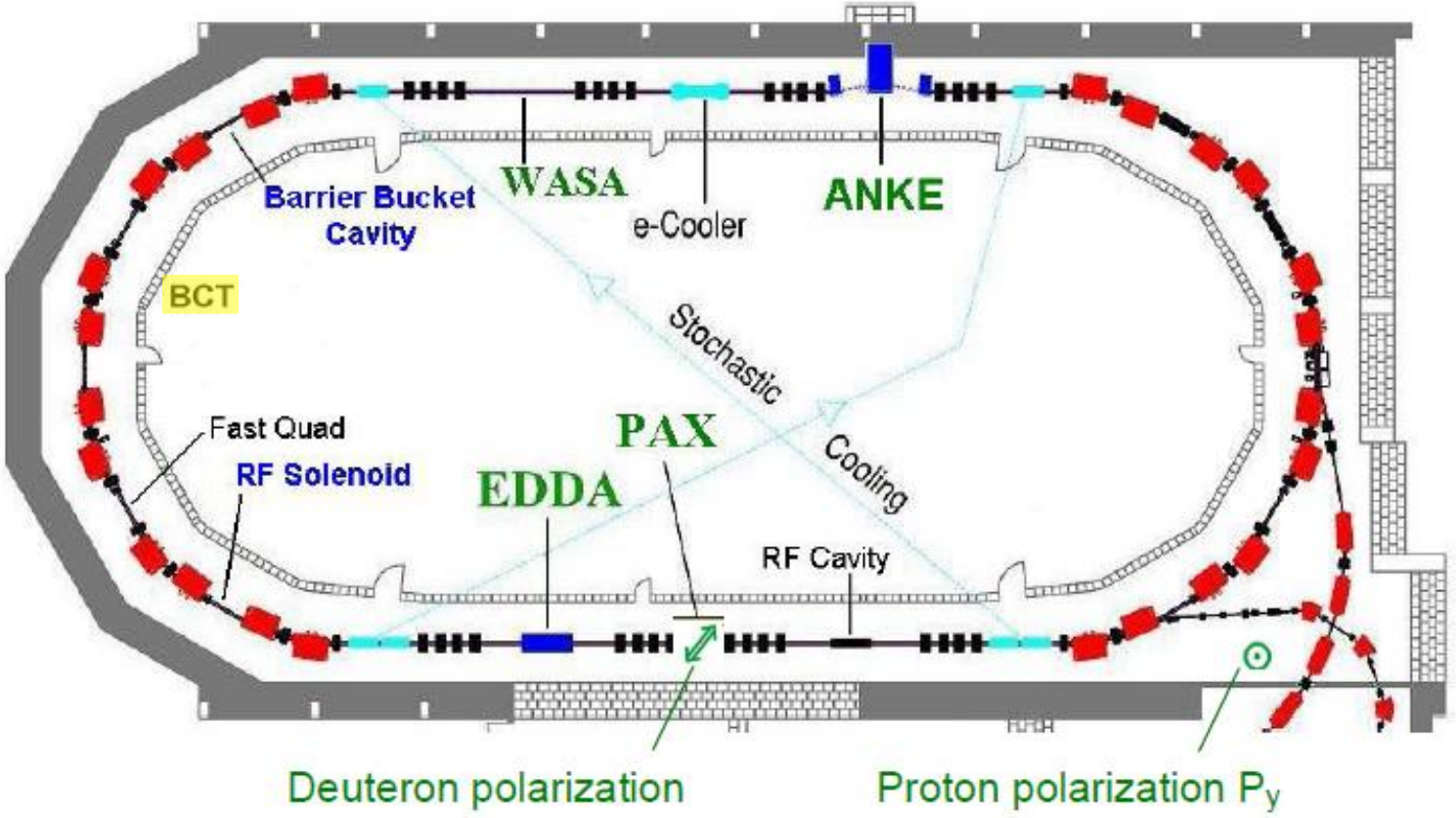
External Fixed Target

Scattering-Cones and Detector-Sensitivity



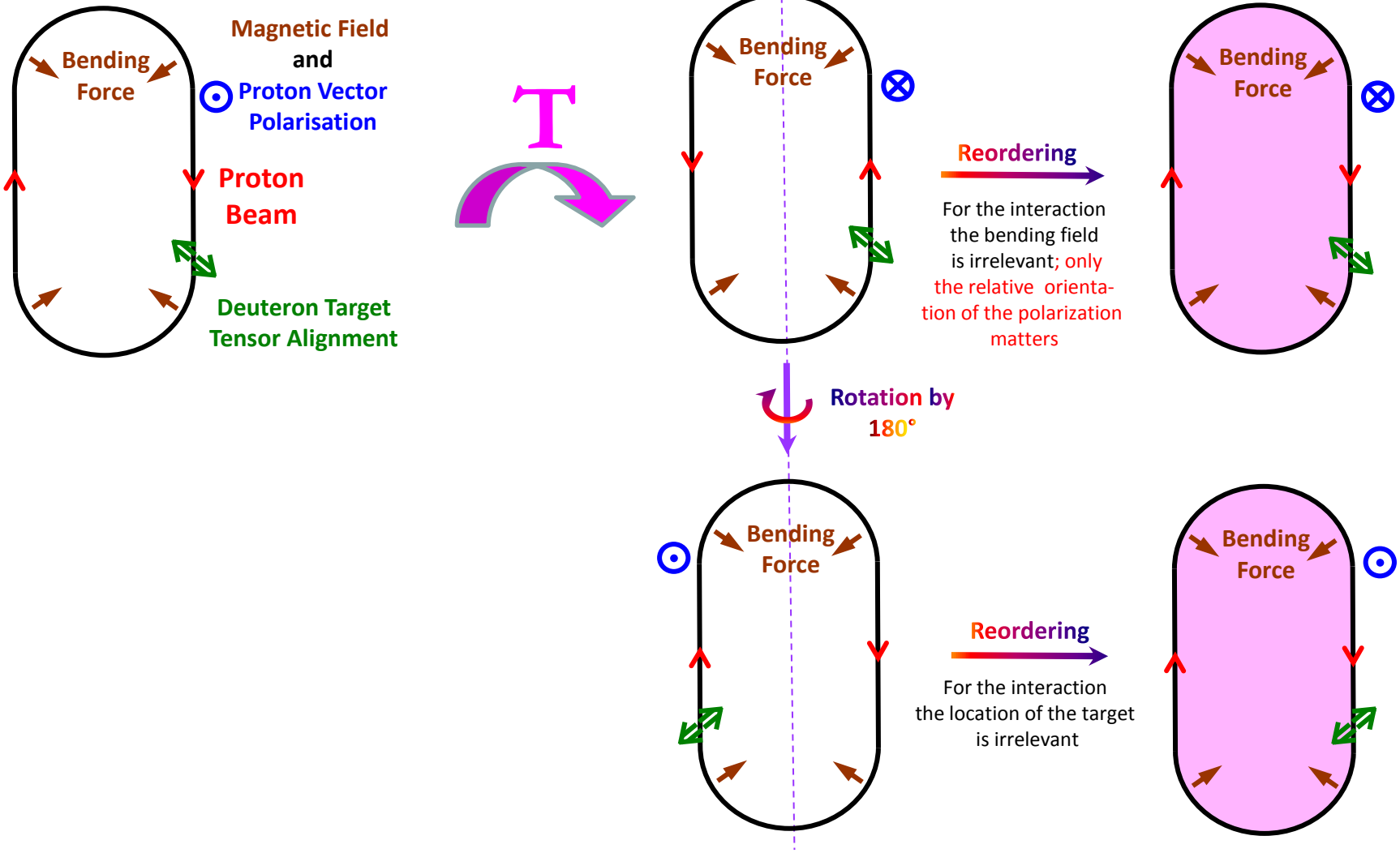
The TRIC Experiment at COSY: Status and Preparation

How do we measure?



The TRIC Experiment at COSY: Status and Preparation

How do we measure?



The TRIC Experiment at COSY: Status and Preparation

How do we measure?

The total pol. correlation $A_{y,\,xz}$ is measured via the forward scatt. amplitude $\mathcal{F}(0)$

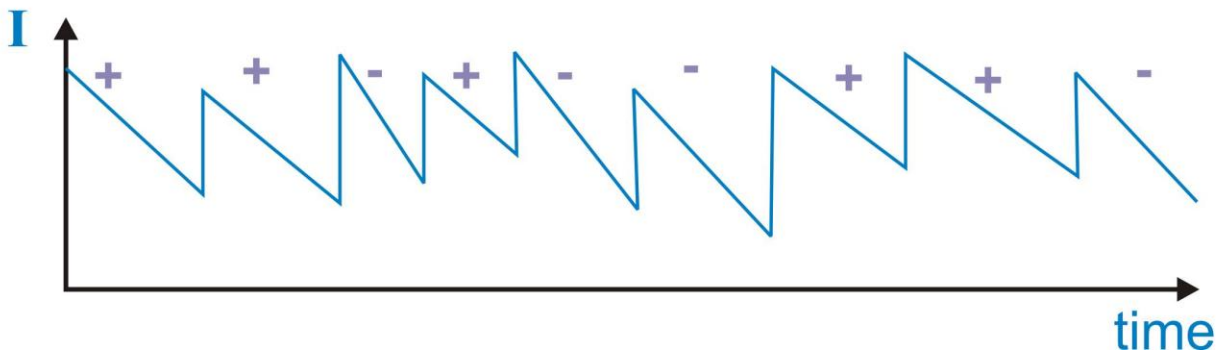
$$\sigma_{tot} = \frac{4\pi}{k}\, Im\, F(0) \quad \rightsquigarrow \quad \frac{4\pi}{k}\, Im\, tr\,(\,\rho\, \mathcal{F}(0)\,)$$

$F(0)$ - Forward scatt. amplitude for unpolarized particles

ρ - Density matrix

$\mathcal{F}(0)$ - Forward scatt. amplitude (matrix) for polarized particles

$A_{y,\,xz}$ is proportional to the relative difference of the current slopes of the circulating proton beam with respect to the chosen polarization configuration (+/-) of the proton beam and deuteron target.



The TRIC Experiment at COSY: Status and Preparation

How do we measure?

Involved Spins: $\frac{1}{2} + 1 \rightarrow \frac{1}{2} + 1$

$I_{0,0}$	$A_{0,X}$	$A_{0,Y}$	$A_{0,Z}$
$A_{X,0}$	$A_{X,X}$	$A_{X,Y}$	$A_{X,Z}$
$A_{Y,0}$	$A_{Y,X}$	$A_{Y,Y}$	$A_{Y,Z}$
$A_{Z,0}$	$A_{Z,X}$	$A_{Z,Y}$	$A_{Z,Z}$

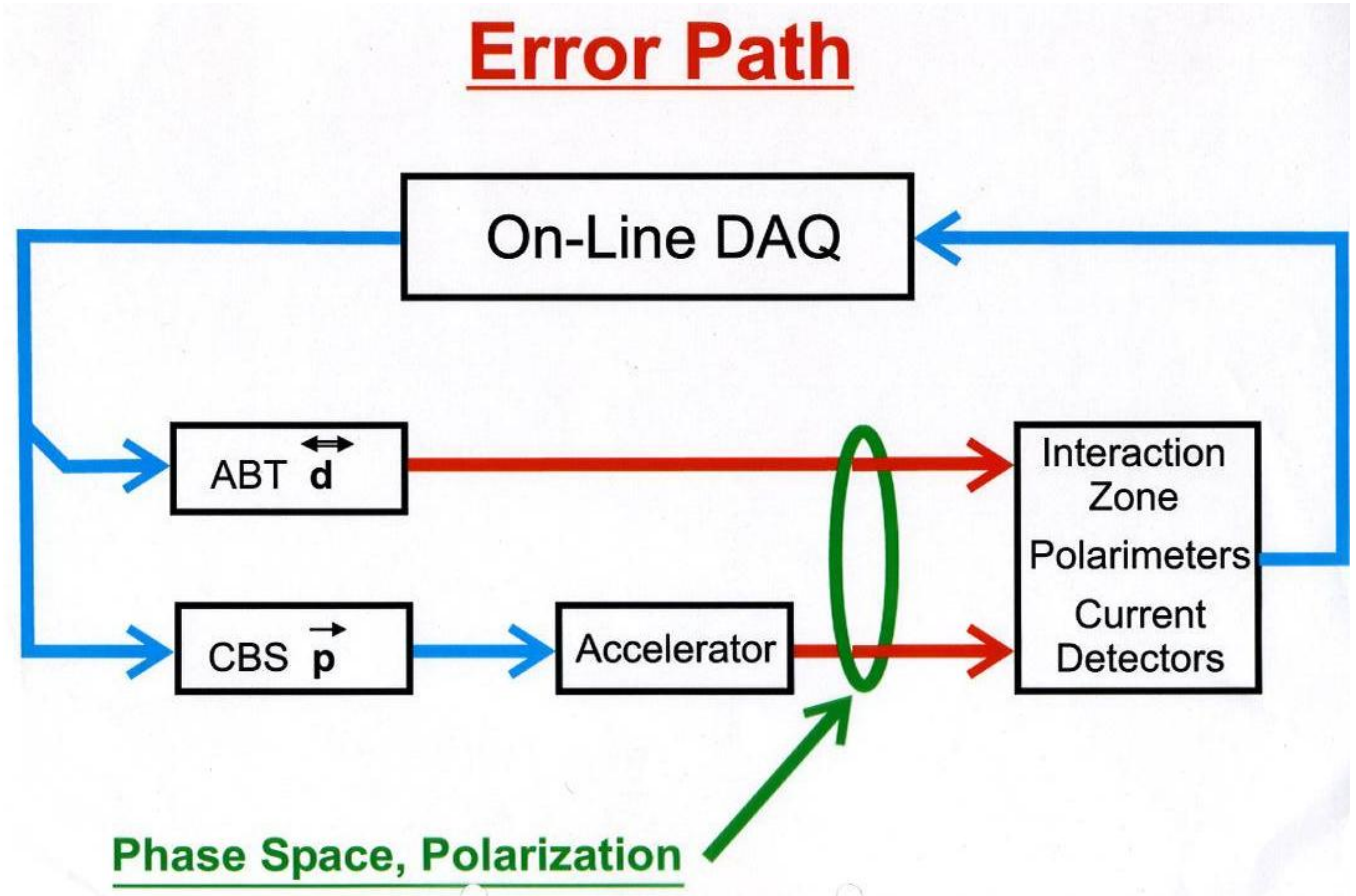
$A_{0,XX}$	$A_{0,YY}$	$A_{0,ZZ}$	$A_{0,XY}$	$A_{0,YZ}$	$A_{0,XZ}$
$A_{X,XX}$	$A_{X,YY}$	$A_{X,ZZ}$	$A_{X,XY}$	$A_{X,YZ}$	$A_{X,XZ}$
$A_{Y,XX}$	$A_{Y,YY}$	$A_{Y,ZZ}$	$A_{Y,XY}$	$A_{Y,YZ}$	$A_{Y,XZ}$
$A_{Z,XX}$	$A_{Z,YY}$	$A_{Z,ZZ}$	$A_{Z,XY}$	$A_{Z,YZ}$	$A_{Z,XZ}$

Line cancels because of : **Protonspinflip**

p_x, p_z negligible for protons

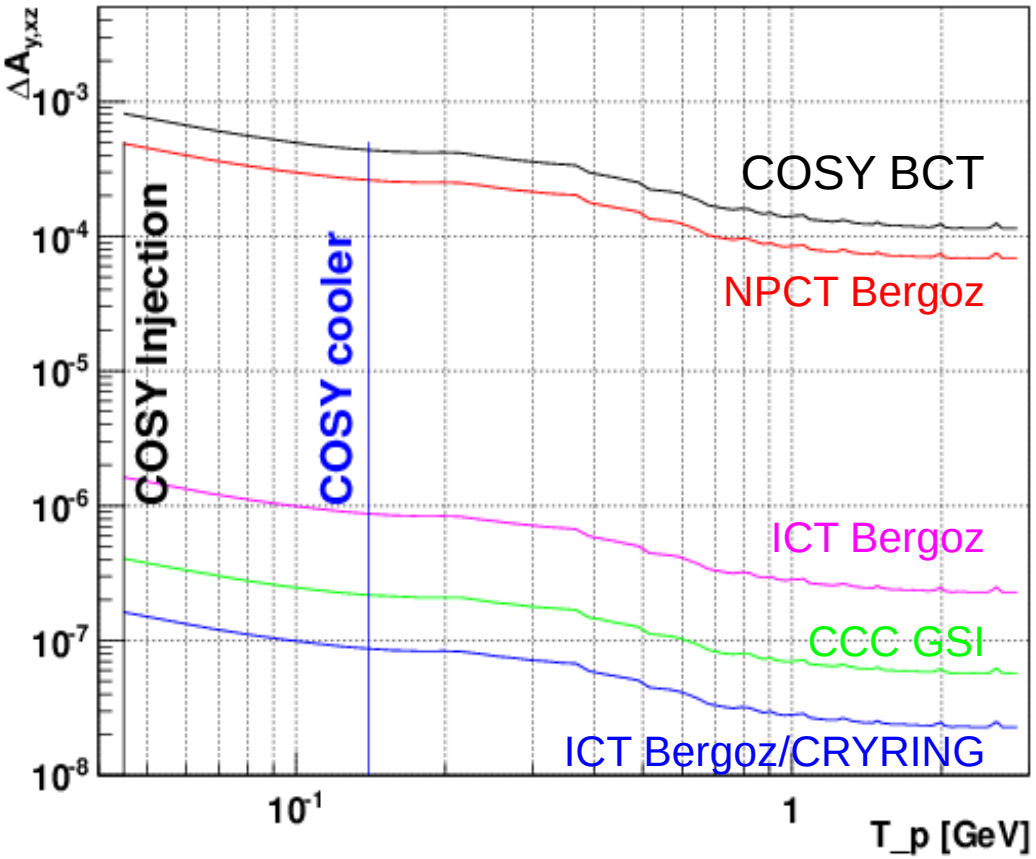
Quantity cancels because of : ~~R~~, ~~P~~

How do we measure?



The TRIC Experiment at COSY: Status and Preparation

Some experimental details



Assuming:

N_p = $3 \cdot 10^9$ protons in the ring

ϱd – target density ($8 \cdot 10^{13}$ atoms/cm^2)

$p_y p_{xz}$ – target and beam polarization (1)

h – spin flip time (3 min)

Δt – measurement integration time (0.1 s)

H – total measurement time (30 days)

Some experimental details

$$\delta A_{y,xz}^{meas} = \frac{8 \cdot 10^{-6}}{I_0 \, \sigma_0 \, \rho d \, \nu \, P_y \, P_{xz}} \frac{\sqrt{\Delta t}}{h\sqrt{H}} \delta I$$

with:

- I_0 - the initial circulating proton current in COSY at the start of a slope measurement [A]
- σ_0 - the total unpolarized cross-section [cm^2]
- ρd - the areal target density [atoms/cm^2]
- ν - the revolving frequency of the COSY beam [Hz]
- P_y and P_{xz} - the polarizations of beam and target, respectively
- Δt - the time interval between two consecutive current measurements on a slope [s]
- h - the spin flip period of the target [h]
- H - the total measuring time [h]
- δI - the error of the current measurement in the interval Δt [A]

Some experimental details

When are these accuracies equal ? $\delta A_{y,xz}^{meas} = \delta A_{y,xz}^{shot}$

$$h_{equal} = \frac{1.1 \cdot 10^{19}}{\nu^{3/2} \cdot \sqrt{\sigma_0 \, \rho d \, N_0}} \cdot \frac{1}{P_y P_{xz}} \cdot \delta I$$

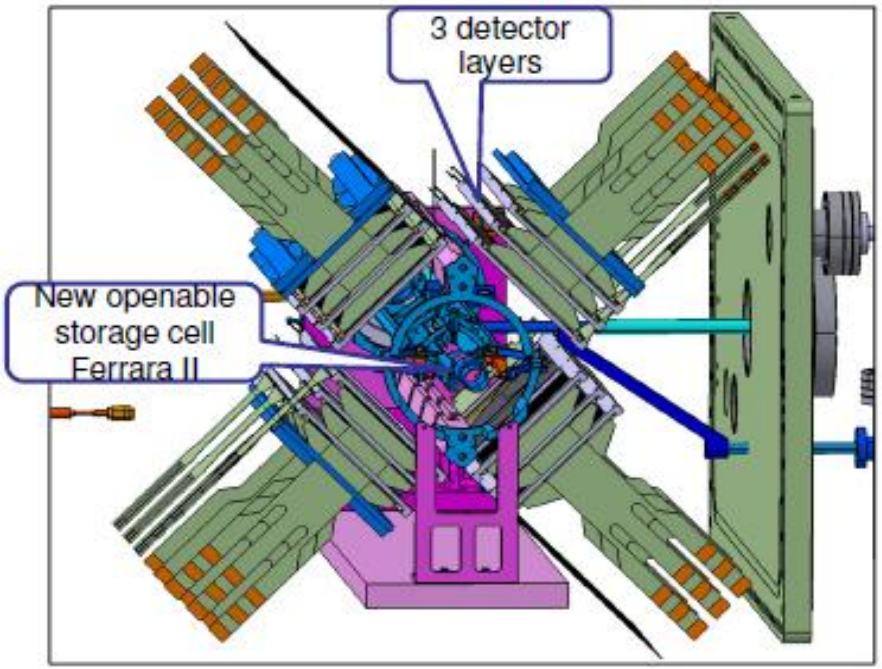
Given:

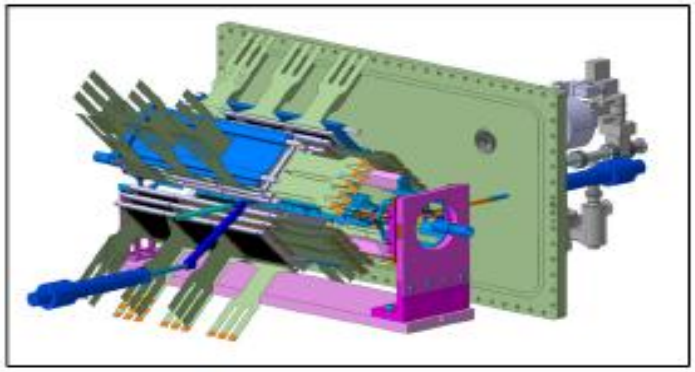
σ_0	- 80 mb
ρd	- $8 \cdot 10^{13}$ atoms/cm^2 (PAX target with openable cell)
ν	- $8 \cdot 10^5$ Hz (@ 135 MeV)
N_0	- $3 \cdot 10^9$ protons
P_y, P_{xz}	- 0.8
Δt	- 1 s
δ_I	~ 1nA

h_{equal} ~ 2.9 min

The TRIC Experiment at COSY: Status and Preparation

Some experimental details



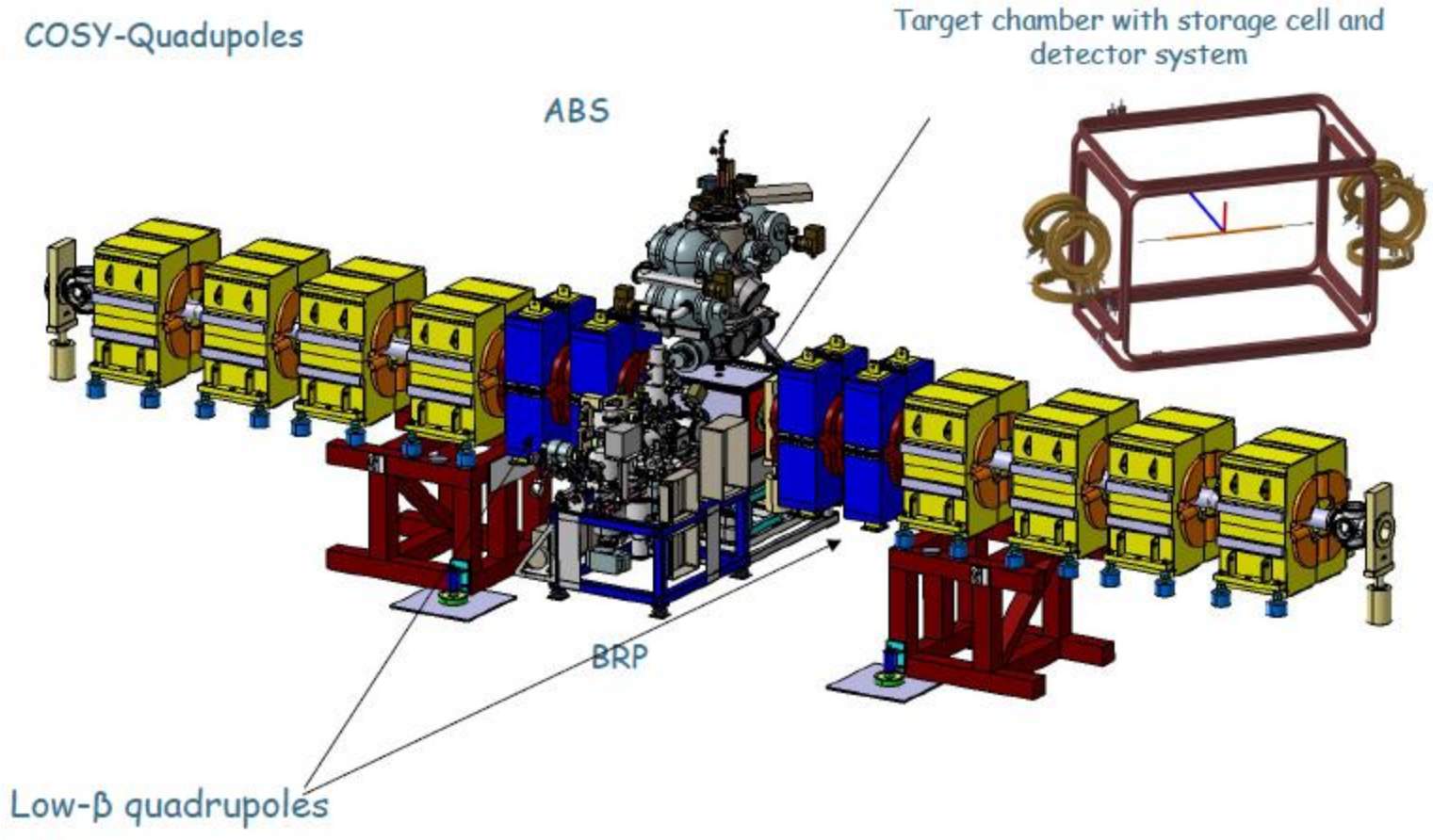


In 2014 at the PAX target place will be available:

- The Atomic Beam Source and Breit-Rabi Polarimeter will be capable to operate with deuterium
- The opennable storage-cell for high polarized target density
- The holding field system to preserve and flip the target polarization during the measurement cycle
- The φ - symmetric multipurpose PAX detector for beam and target polarimetry

The TRIC Experiment at COSY: Status and Preparation

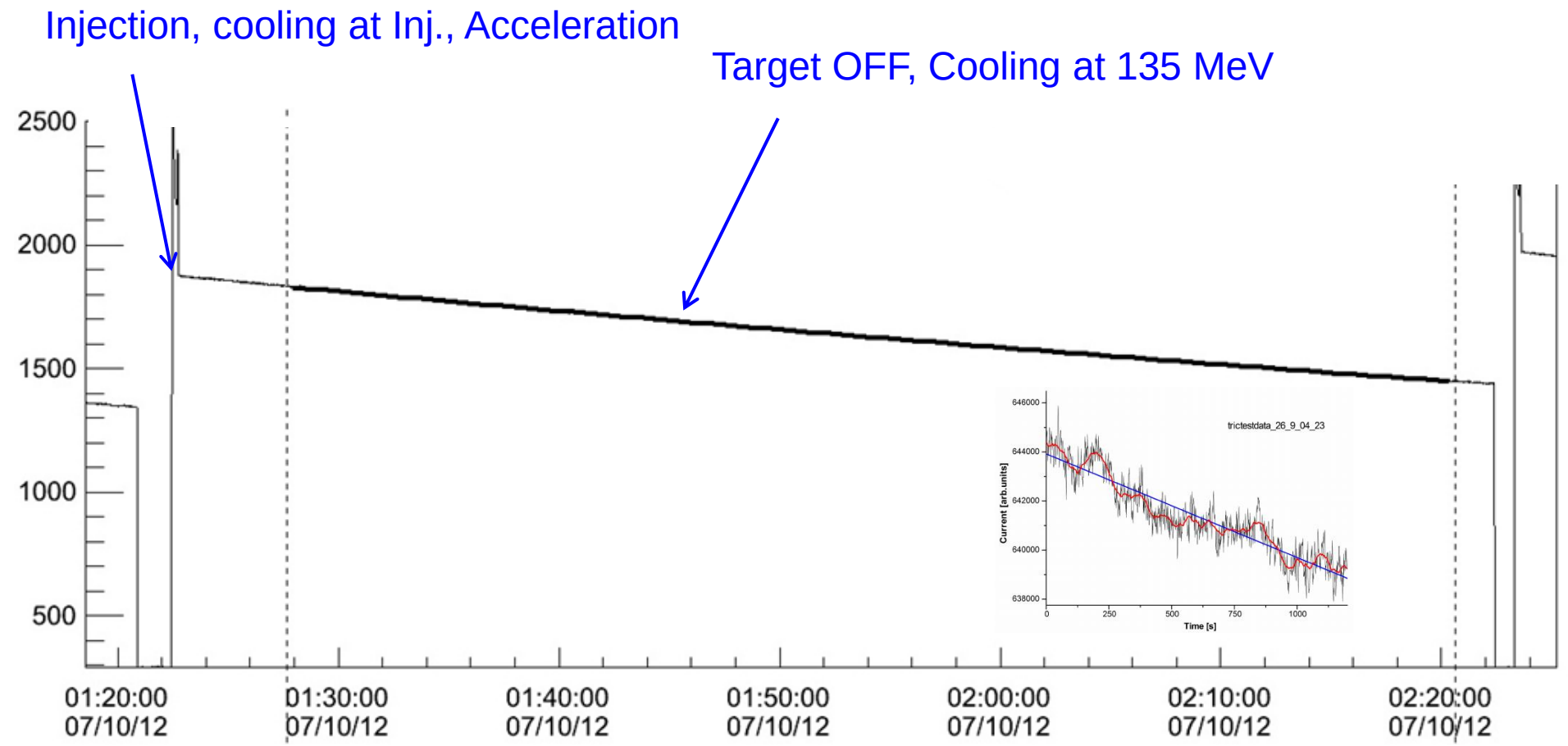
Some experimental details



P. Lenisa and F. Rathmann CERN-SPSC-2012-013/SPSC-SR-099

The TRIC Experiment at COSY: Status and Preparation

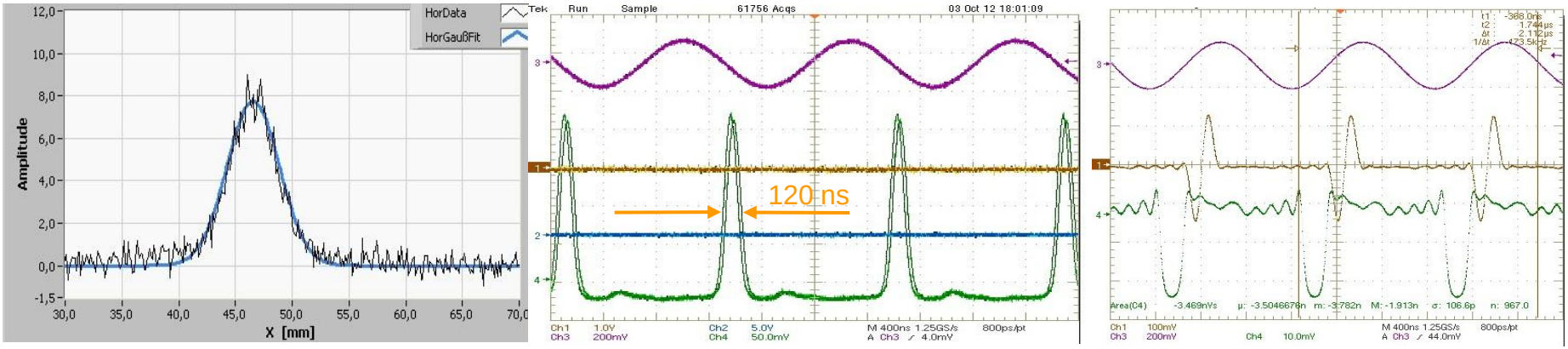
Some experimental details



With target ON beam life time is ~10000 s

The TRIC Experiment at COSY: Status and Preparation

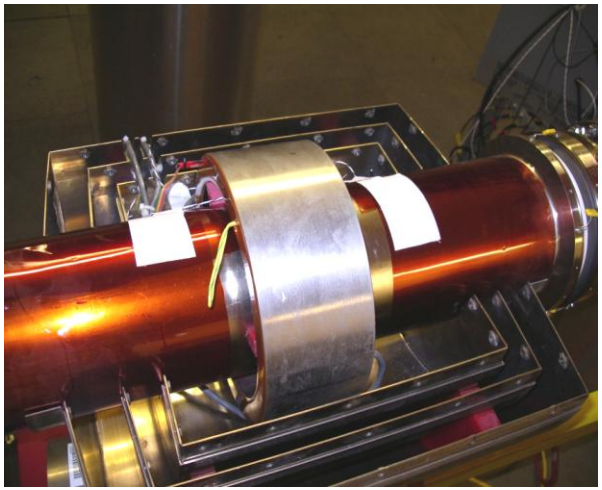
Some experimental details



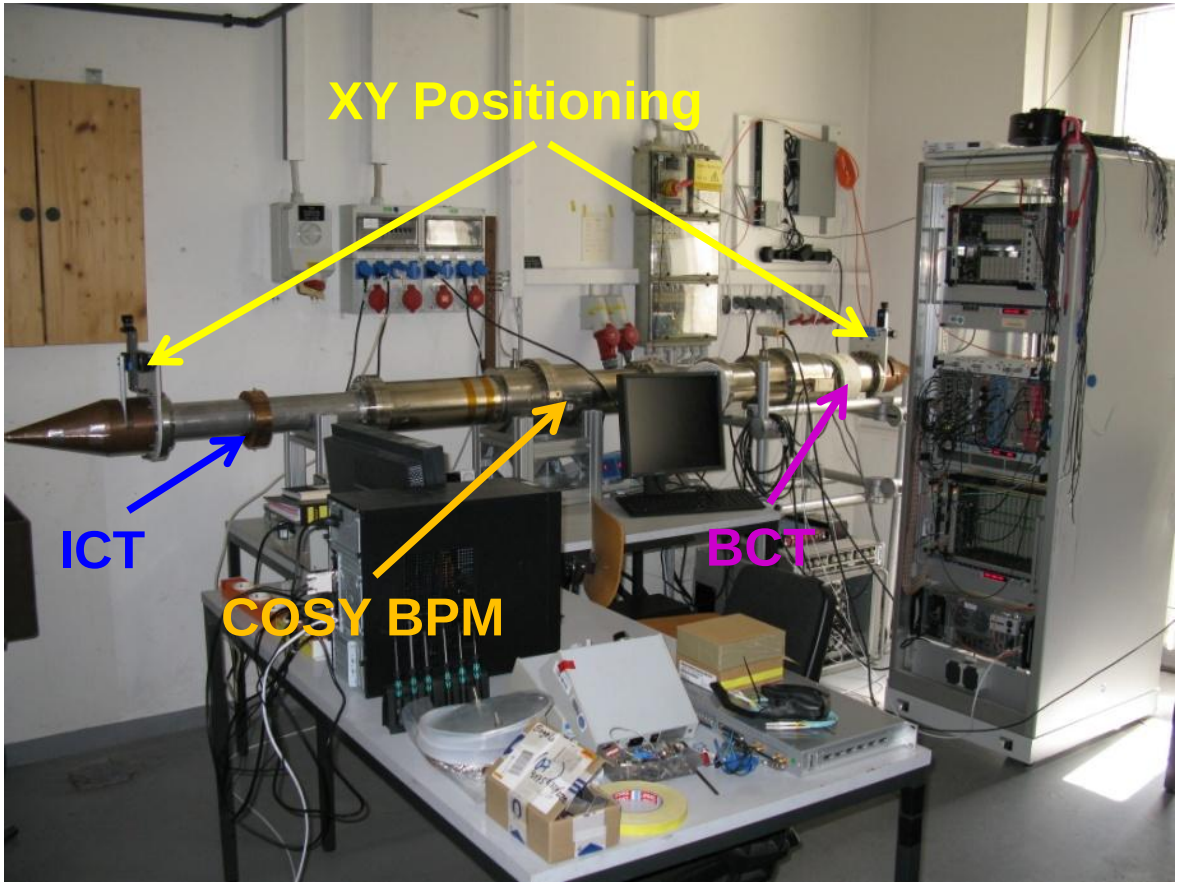
- COSY can provide stable e-cooled proton beam accelerated to 135 MeV through the low beta section and storage cell of Ø = 9.6 mm
- Two different methods of bunching were tested: A beam bunched with Barrier Bucket has a longer beam life-time than a beam bunched with the COSY RF
- The beam intensity ($4 \cdot 10^9$) and target thickness ($6 \cdot 10^{13}$ atoms/cm^{2}s) are sufficient to perform the experiment

The TRIC Experiment at COSY: Status and Preparation

Some experimental details



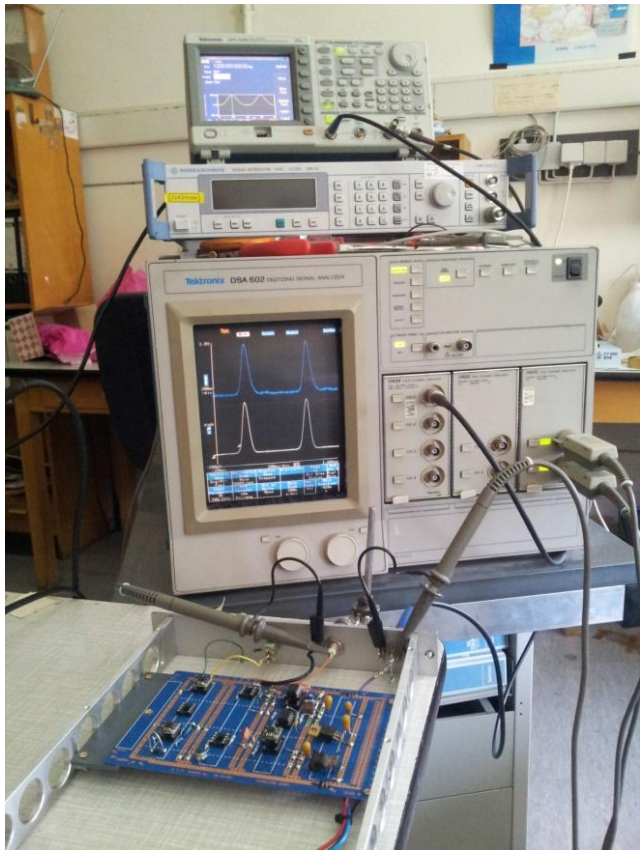
Beam Current Transformer



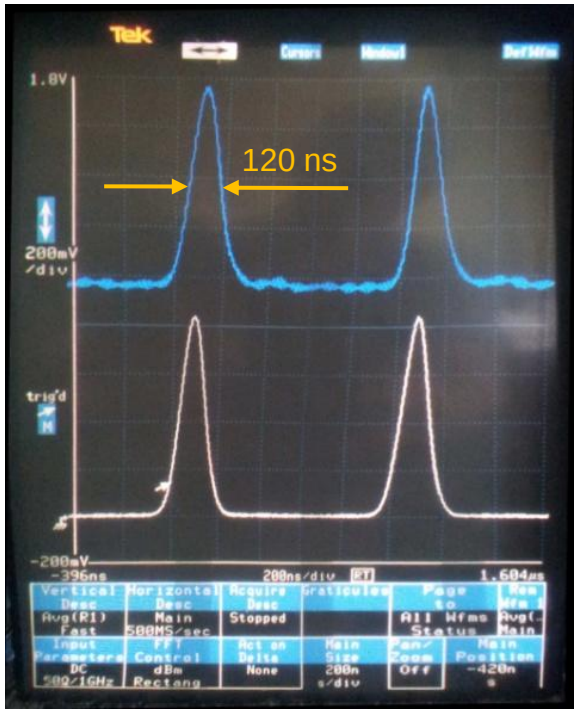
Test Bench with Data Acquisition

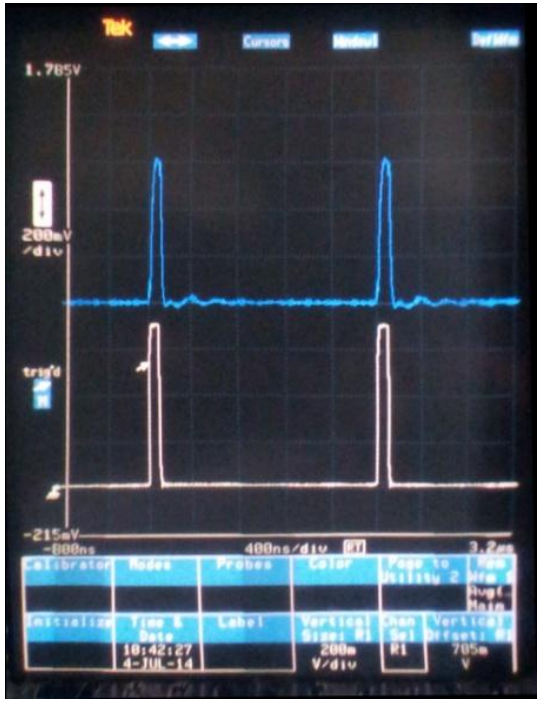
The TRIC Experiment at COSY: Status and Preparation

Some experimental details



V-I Converter Test Bench





White Track – Voltage

Blue Track – Current

The TRIC Experiment at COSY: Status and Preparation

Summary I

The TRIC experiment at COSY constitutes a T-odd, P-even True TRI Null-Test

Accelerator

- E-cooler and low ß-section operate from stacked injection to 135 MeV
- Beam current through the target and proton polarization are sufficient for TRIC
- Beam life-time has to be improved for bunched beam
- Proton polarization life-time has to be tested

Target

- Openable cell, Breit-Rabi polarimeter and deuteron polarization are available
- Deuteron beam density is sufficient for TRIC
- Holding field has to be tested
- Beam and target detector polarimetry have to be built for the target

Summary II

Beam Intensity and Position Measurement

- Noise, misalignment and pulse shape sensitivity meas. will be finished by 2015
- Improved BPMs can be tested (cf. talk by Helmut Soltner)
- Data acquisition with pulse shape analysis will be finished by 2015
- Improved ICT-readout will have been tested by end of 2014

A machine development run in the second half of 2015 is highly desired

"Go right to the frontiers of science
and you will learn soon what is missing"

Georg Christoph Lichtenberg (1742-1799)

Thank You