Preparation for the Time Reversal Invariance Experiment at COSY (TRIC)

Bernd Lorentz (Yury Valdau) for PAX collaboration

CP/T Violation in Early Universe

Time

Big Bang ————————————————▶ **Today**

Matter and Antimatter

Only Matter!

CP/T violation in SM too weak

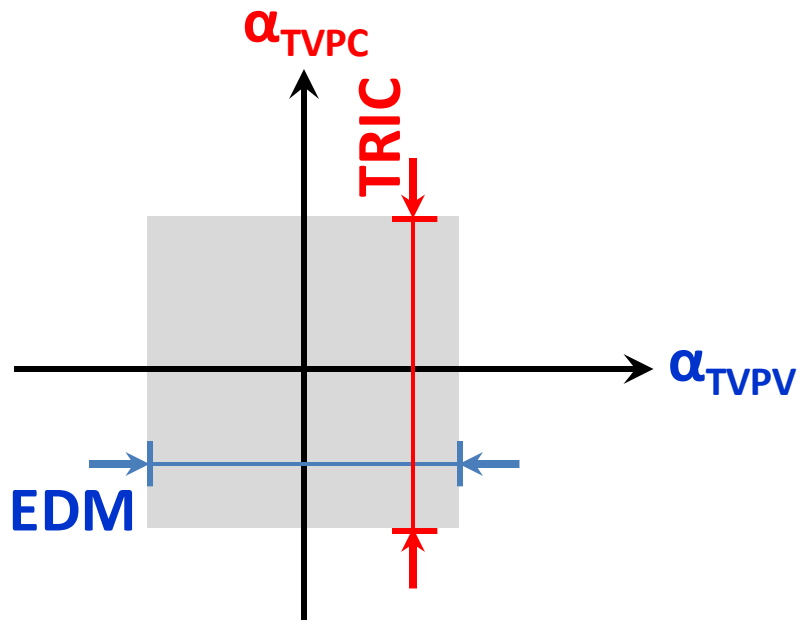## New CP/T violation beyond SM must exist!

Physics Beyond SM

Consider T violation (with and without P conservation)

$$L = L_{SM} + \alpha_{\text{TVPV}} L_{\text{TVPV}} + \alpha_{\text{TVPC}} L_{\text{TVPC}} + \dots$$

EDM

TRIC

EDM and TRIC test different extensions of SM

Search for TVPC effects

Null observable $A_{Y,XZ}$ in double polarized experiments with vector polarized beam and tensor polarized target

Optical theorem:
$$\sigma_{\text{Total}} = \frac{4\pi}{k} \, Im\left[F(0°)\right] = \sigma\left(1 + P_Y^{beam} P_{XZ}^{target} A_{Y,XZ}\right)$$

$A_{Y,XZ}$ accessable via optical theorem in transmission experiment

Present limit: $\vec{n} + {}^{165}\overrightarrow{\text{Ho}}$ $A = \frac{\sigma_{\text{TVPC}}}{\sigma_{\text{Total}}} \leq 2.2 \times 10^{-5}$
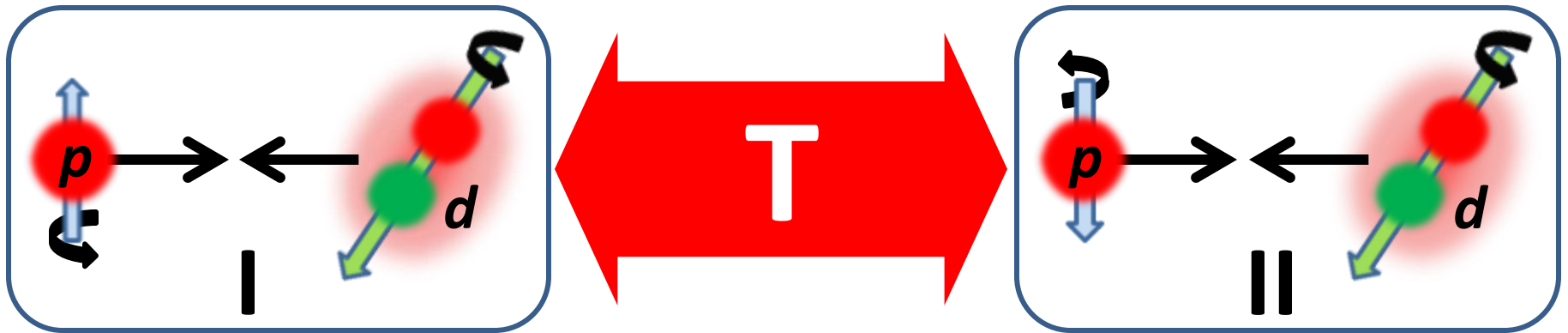
PRC 55 (1997) 2684

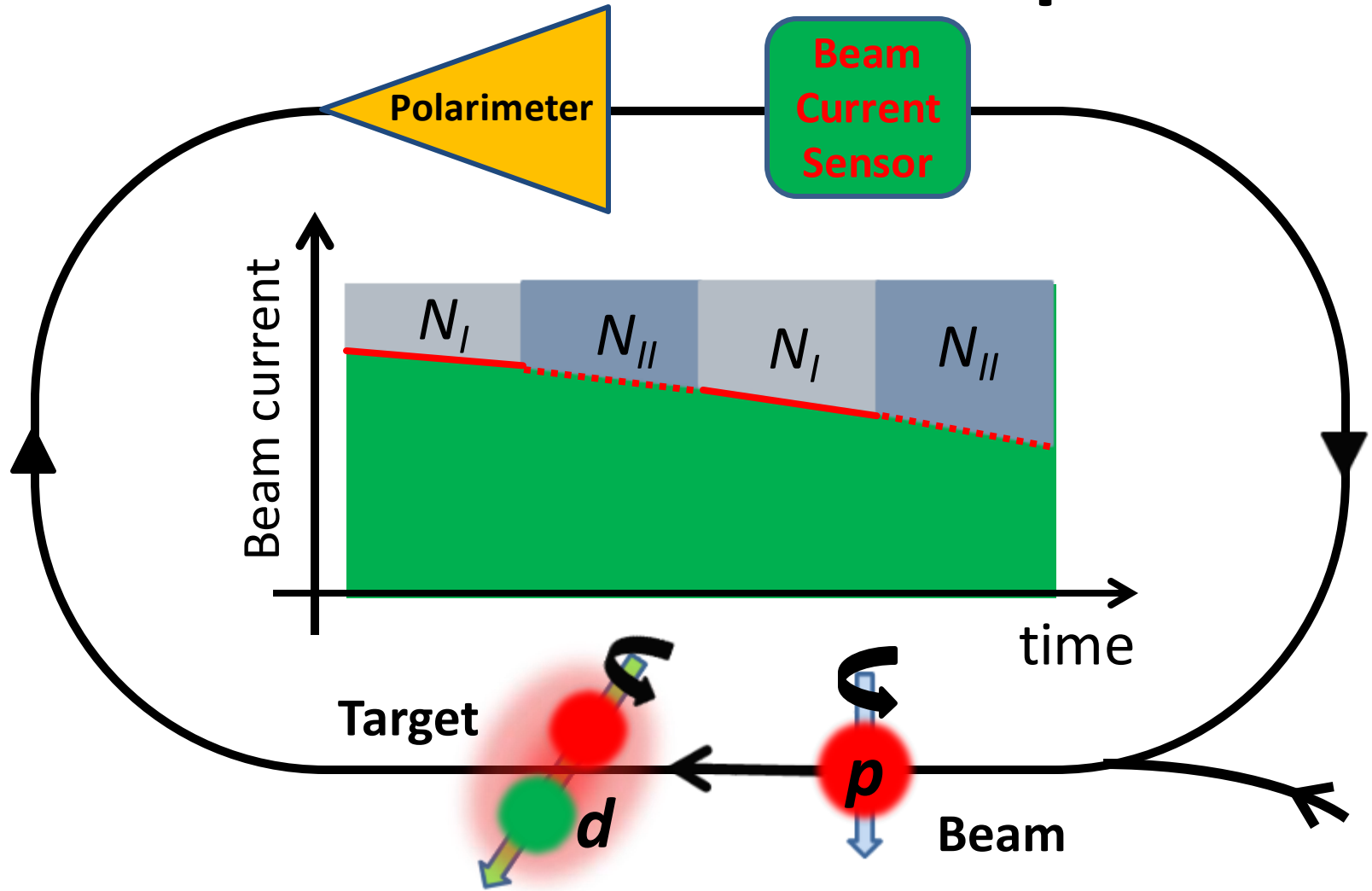**Goal: improve limit by at least one order**

Principle of TRIC

Genuine T-violating observable in $\vec{p}\vec{d}$ scattering:

$$A_{Y,XZ} \sim \frac{1}{P_Y^{beam}P_{XZ}^{target}} \frac{N_I - N_{II}}{N_I + N_{II}} \begin{cases} = 0 & \text{T conserved} \\ \neq 0 & \text{T violated} \end{cases}$$

Trick behind TRIC: T reversal via spin-flip!

Measurement Principle

Polarimeter

Beam Current Sensor

Beam current / time

N_I N_{II} N_I N_{II}
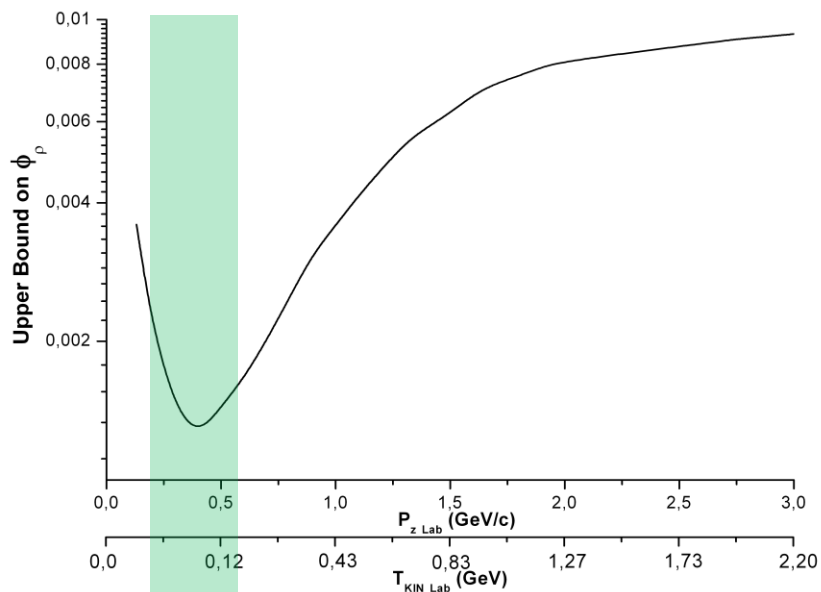
Target

d

p

Beam

Comparison of slopes for I and II

Prerequisites

- Polarised $\vec{p}$ beam

- Polarised $\vec{d}$ target

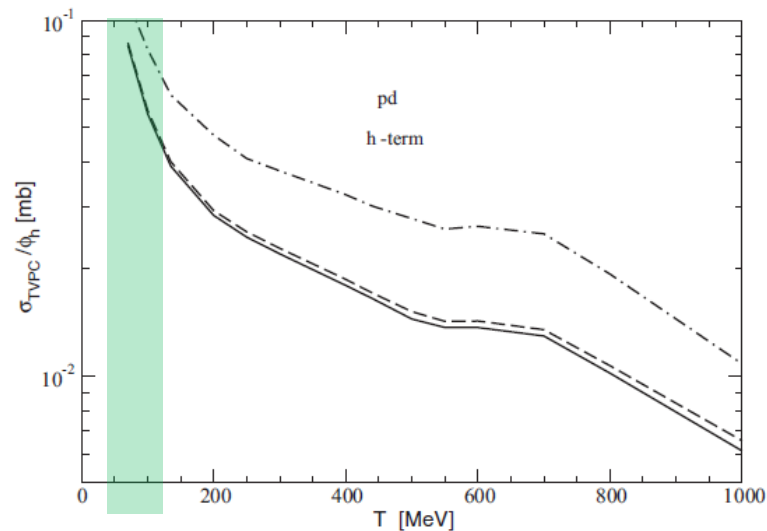- Beam/Target polarimeter

- Beam current sensor

Beam Energy for TRIC

1/(TVPC effect)

TVPC effect

M. Beyer NPA 560 (1993) 895

Yu. Uzikov PRC 92 (2015) 014002

Two independent theoretical calculations suggests to perform TRIC below 200 MeV

Polarimetry data at 135 MeV is available (*PRC 74 (2006) 064003*)
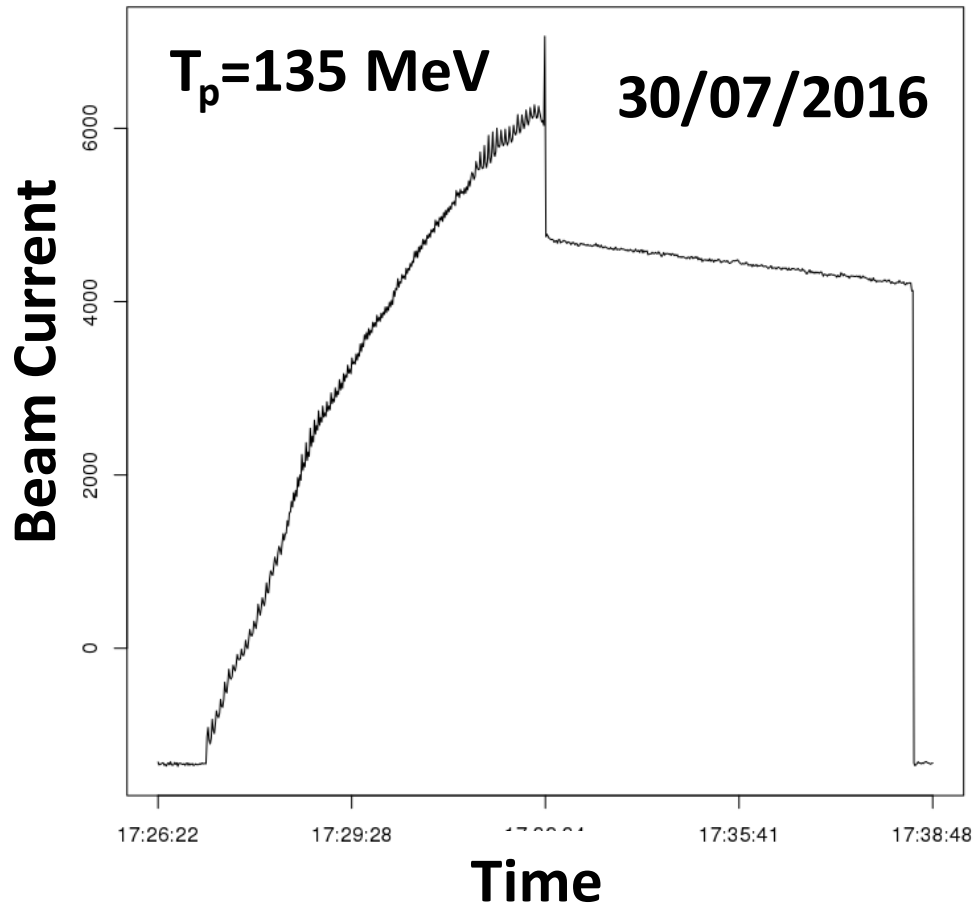
Prerequisites

- Polarised $\vec{p}$ beam

- Polarised $\vec{d}$ target

- Beam/Target polarimeter

- Beam current sensor

COSY Storage Ring

$\vec{p}$ beam: 0.045-2.88 GeV

Polarised beam @ COSY

$T_p=135$ MeV   30/07/2016

- Polarised beam intensity after stacking for:
  - 120 s →1.7×10⁹
  - 600 s →5.0×10⁹
- Polarisation in the ring >50%
- Polarisation life time >10000s
- Beam life time 5000 s (12000 s in Sep 2012)
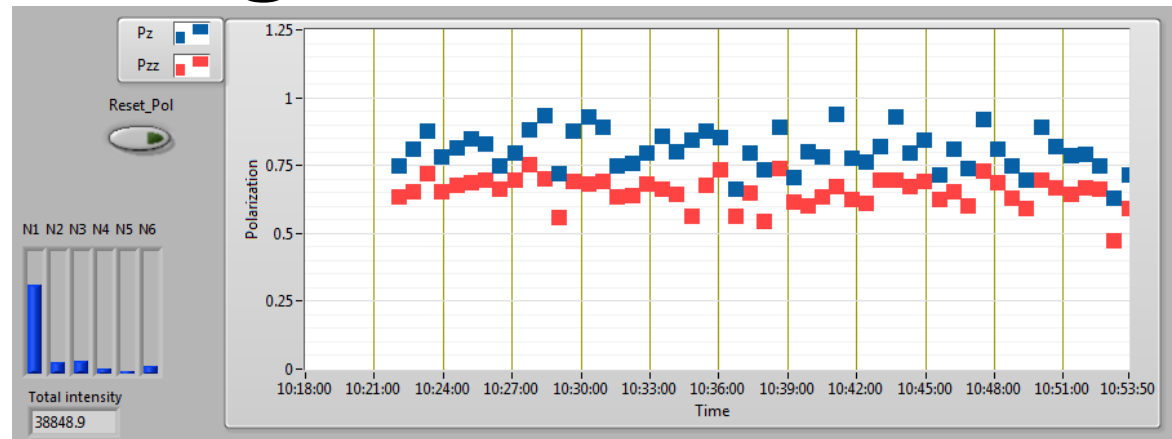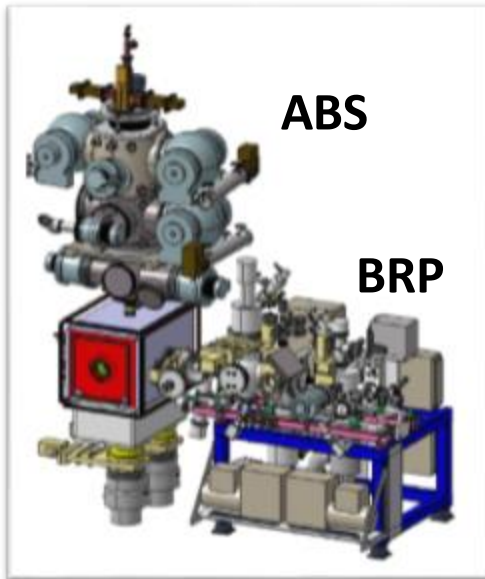
COSY can provide beam for TRIC

Prerequisites

- Polarised $\vec{p}$ beam   COSY

- Polarised $\vec{d}$ target

- Beam/Target polarimeter

- Beam current sensor

Polarised D Target and Polarimeter

ABS

BRP

In July 2016:

- PAX ABS and BRP commisioned with D at COSY
- Deuterium $P_Z \sim 0.8$ and $P_{ZZ} \sim 0.7$ measured with BRP
- Opennable storage is under the preparation by Ferrara group (2017)

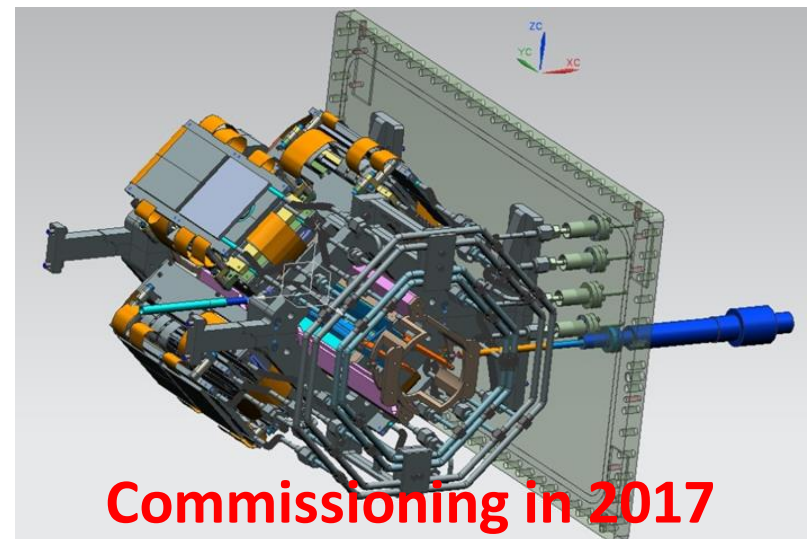**PAX D target is ready for TRIC**

Prerequisites

- Polarised $\vec{p}$ beam   COSY

- Polarised $\vec{d}$ target   PAX target

- Beam/Target polarimeter

- Beam current sensor
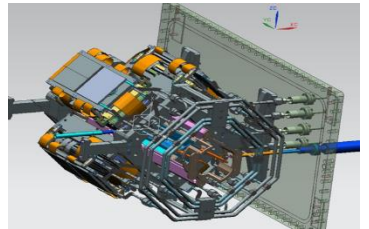
Prerequisites

- Polarised $\vec{p}$ beam   COSY

- Polarised $\vec{d}$ target   PAX target

- Beam/Target polarimeter   **PAX detector**
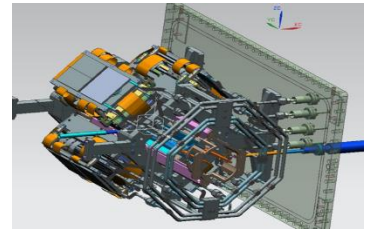
- Beam current sensor

Commissioning in 2017

Prerequisites

- Polarised $\vec{p}$ beam   COSY

- Polarised $\vec{d}$ target   PAX target

- Beam/Target polarimeter   PAX detector
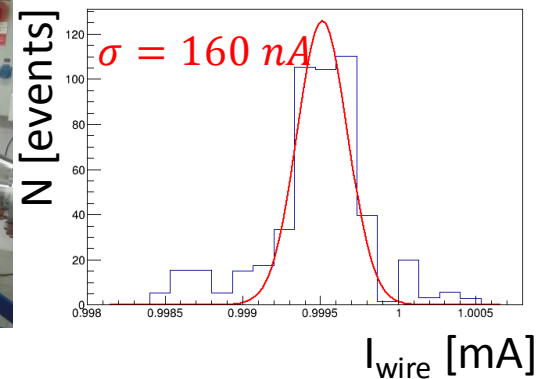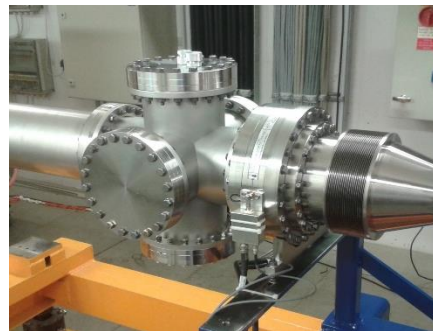
- Beam current sensor

Prerequisites

- Polarised $\vec{p}$ beam   COSY

- Polarised $\vec{d}$ target   PAX target

- Beam/Target polarimeter   PAX detector

- Beam current sensor

Fast Current Transformer (FCT)

Relative resolution achived in Lab $\Delta I/I \sim 10^{-4}$

Yu. Valdau et al., Proceedings to IBIC16

$\sigma = 160\ nA$

N [events]

I_{wire} [mA]
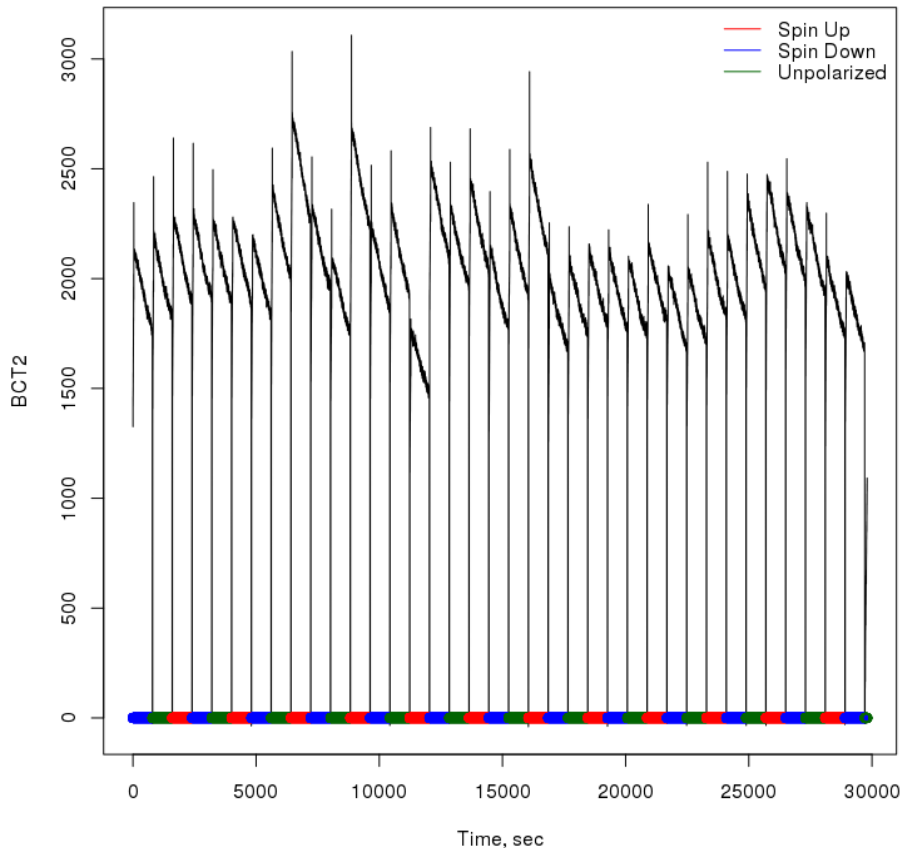
Prerequisites

- Polarised $\vec{p}$ beam   COSY

- Polarised $\vec{d}$ target   PAX target

- Beam/Target polarimeter   PAX detector
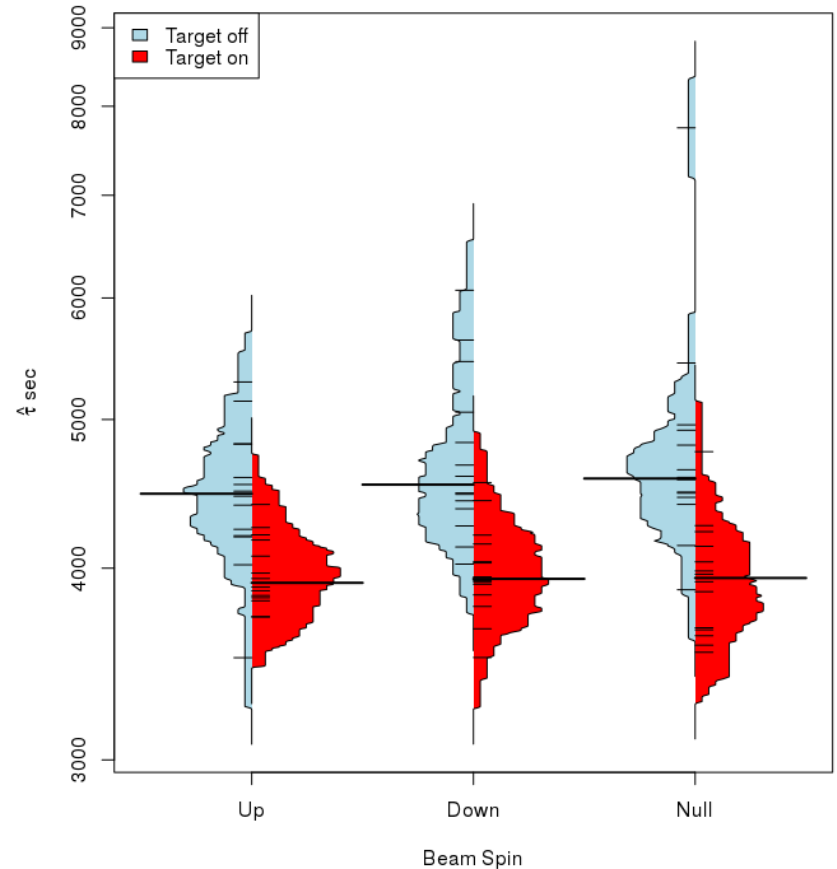
- Beam current sensor   FCT
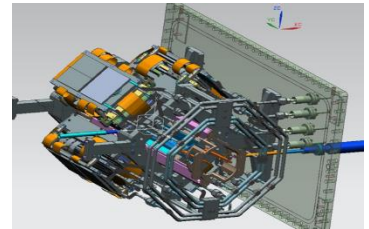
TRIC is possible at COSY

$A_{Y,Y}$ Measurements @ COSY

Data from one night (1/08/2016)

- Preliminary result: $A_{Y,Y} \approx 0.04 \pm 0.03$

- Theoretical prediction $A_{Y,Y} = 0.05$

Yu. Uzikov PRC 92 (2015) 014002

Summary & Outlook

- TRIC is search for physics beyound SM
- TRIC is precision transmission experiment using $A_{Y,XZ}$ null observable in *pd* scattering
- COSY, PAX ABS, PAX BRP, and FCT are ready for the TRIC experiment
- The first measurements of $A_{Y,Y}$ using TRIC method has been done in June 2016
- We plan to apply for a new beam time in 2017