Luminosity Determination at ANKE

- *via nuclear reactions*
- *via energy loss measurements*

- Introduction
- Formalism
- Calibration
- Luminosity determination
- Conclusion

Introduction

Why Luminosity?

$$\frac{d\sigma}{d\Omega} = \frac{1}{L}\frac{N_{\exp}}{A_{det}\,\varepsilon_i}$$

you have to know!

- N_{exp} *reconstructed number of events*
- A_{det} *detector acceptance*
- ε_i *efficiencies*

- The Near-Threshold Production of ϕ Mesons in pp Collisions
M.Hartmann et al., PRL 96, 242301 (2006)

- Precision measurement of the quasi-free $pn \rightarrow d\phi$ reaction close to threshold
Y.Maeda et al., PRL 97, 142301 (2006)

- Precision study of the η^3He system using $dp \rightarrow {}^3He\eta$ reaction
T.Mersmann et al., Accepted by PRL

- Shape of the $\Lambda(1405)$ hyperon measured through its $\Sigma^0\pi^0$ decay.
I.Zychor et al., Submitted to PRL

- There are some more publications

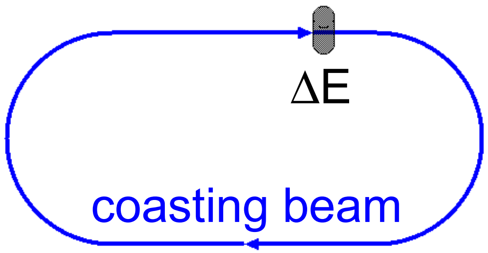
conventional

via nuclear reaction
(elastic >> inelastic)

$$L = \frac{N'_{\exp}}{A'_{det}\,\varepsilon'_i\,(d\sigma/d\Omega)'}$$

alternative

via energy loss measurement



Formalism

$$L = J_{beam} \cdot N_{target}$$

$$J_{beam} = \frac{I_{beam}}{q_{beam}}, \ [s^{-1}] \qquad N_{target} = \frac{dT}{(dE/dx)\,m}, \ [cm^{-2}]$$

$$dT = \frac{\Delta T}{f_0 \Delta t} \qquad \frac{\Delta T}{T_0} = \frac{1+\gamma}{\gamma}\frac{\Delta p}{p_0}$$

$$\frac{\Delta p}{p_0} = \frac{1}{\eta}\frac{\Delta f}{f_0} \qquad \eta = \frac{1}{\gamma^2} - \alpha \qquad \frac{\Delta f}{f_0} = \alpha \frac{\Delta B}{B_0}$$

$$N_{target} = \frac{1+\gamma}{\gamma}\frac{1}{\eta}\frac{1}{(dE/dx)\,m}\frac{T_0}{f_0^2}\frac{\Delta f}{\Delta t}$$

L - luminosity

J_{beam} – flux of beam [s^{-1}]

I_{beam} – COSY beam current [mA]

q_{beam} – electric charge of beam [C]

N_T – effective thickness of target [cm^{-2}]

dT – energy loss per single target traversal

dE/dx - stopping power of protons in hydrogen gas [NIST tables]

m – proton mass (1.673×10^{-24}g)

f_0 - revolution frequency, measured

T_0 - beam kinetic energy

γ – Lorentz factor

p_0 - beam momentum

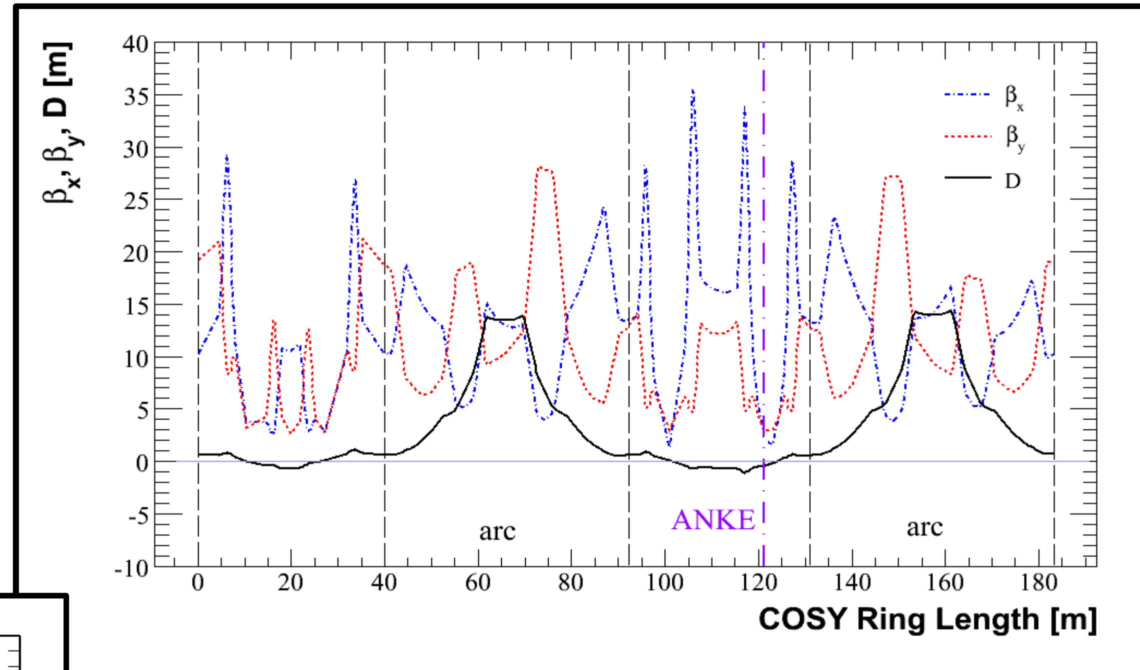
η – off-momentum factor based on measured α

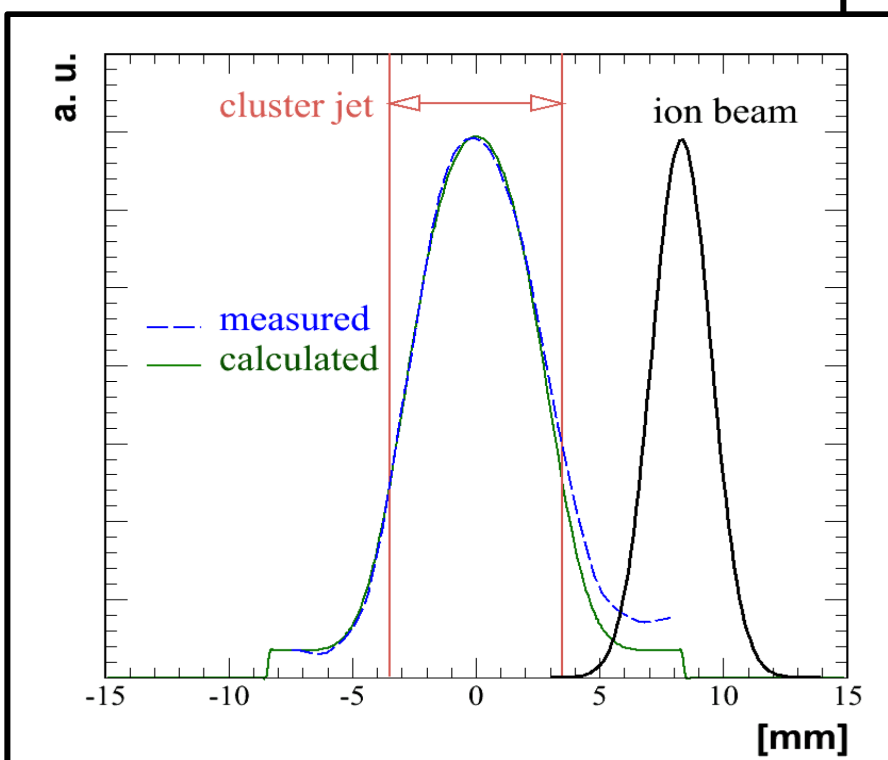
B_0 – COSY dipole magnetic field

Beam target overlap

T=2.65GeV

- estimated emittance growth in 10 minutes = 0.15mm·mrad
- possible beam position shift due to residual dispersion = 0.1mm

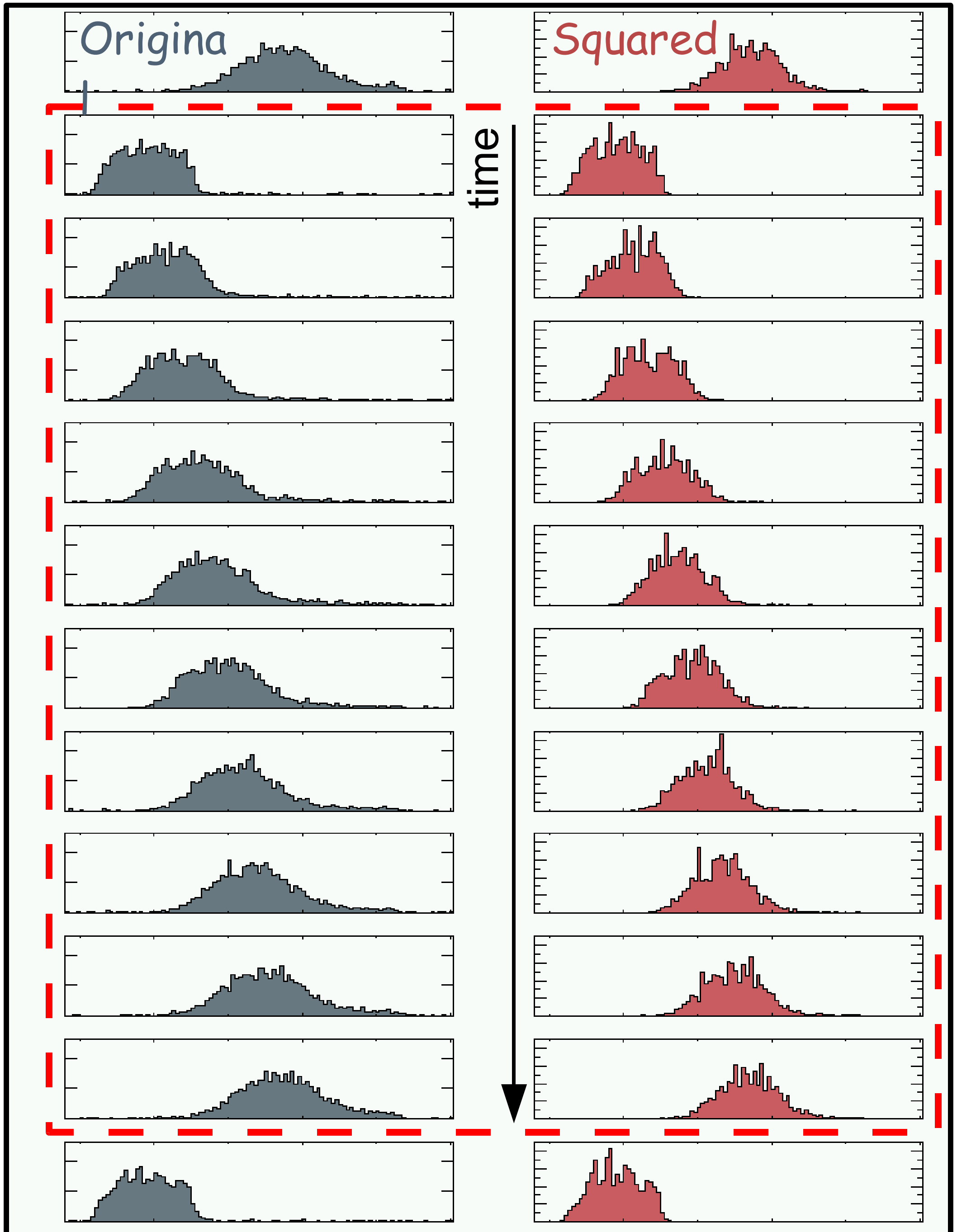




measurement of the beam target overlap

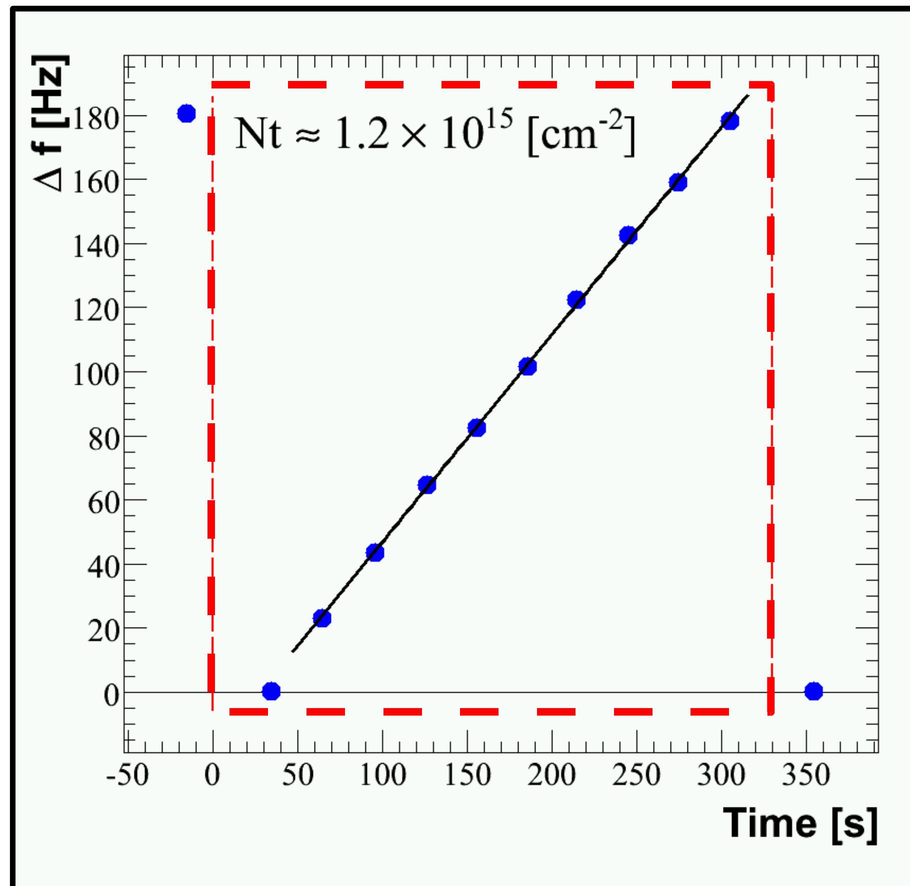
- beam foot width = 4.8mm (4σ)
- cluster jet diameter = 7mm

Raw Schottky Spectra's



Original – measured

Squared ~ momentum

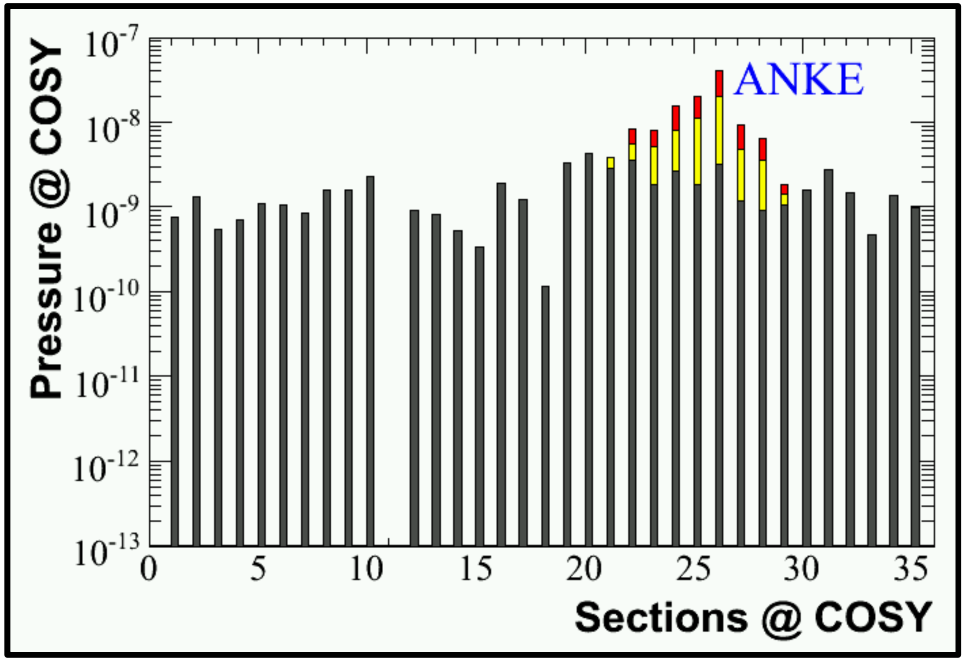


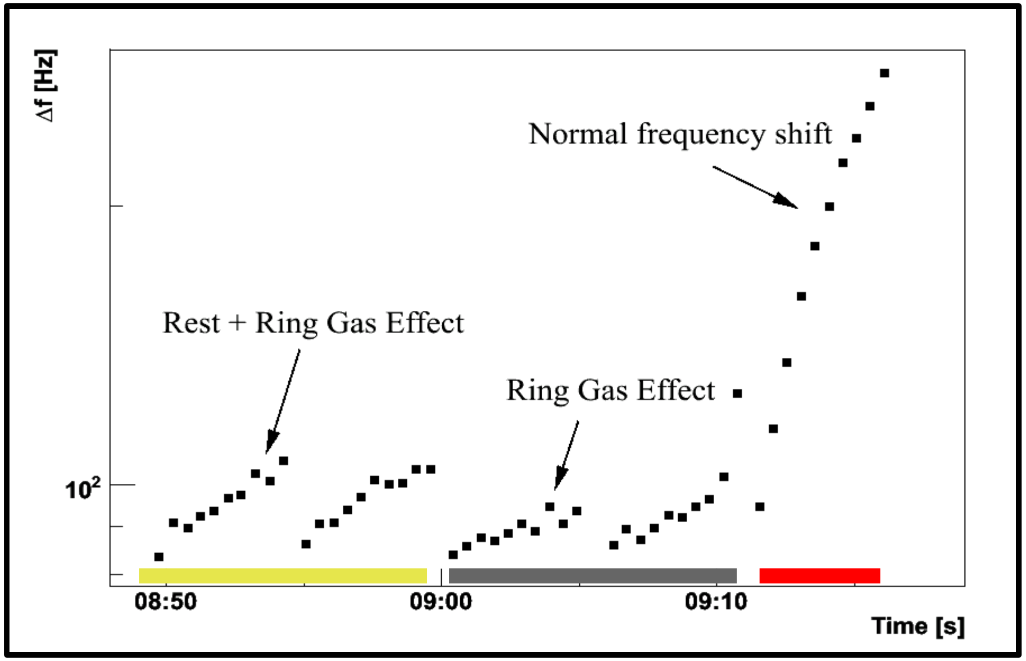
Residual gas effect

- 100% beam+target overlap (red)
- Rest+Ring Gas - target ON but ~0% overlap (yellow)
- Ring Gas - target OFF (black)

$$N_{target} = N_{total} - N_{Ring+Rest}$$

1) Total frequency shift = $1.35 \cdot 10^{15}$ [cm^{-2}]
2) Rest+Ring Gas = $1.32 \cdot 10^{14}$ [cm^{-2}]
3) Ring Gas = $5.31 \cdot 10^{13}$ [cm^{-2}]





α measurement at 2.65GeV

$$\eta = \frac{1}{\gamma^2} - \alpha$$

$$\frac{\Delta f}{f_0} = \alpha \frac{\Delta B}{B_0}$$

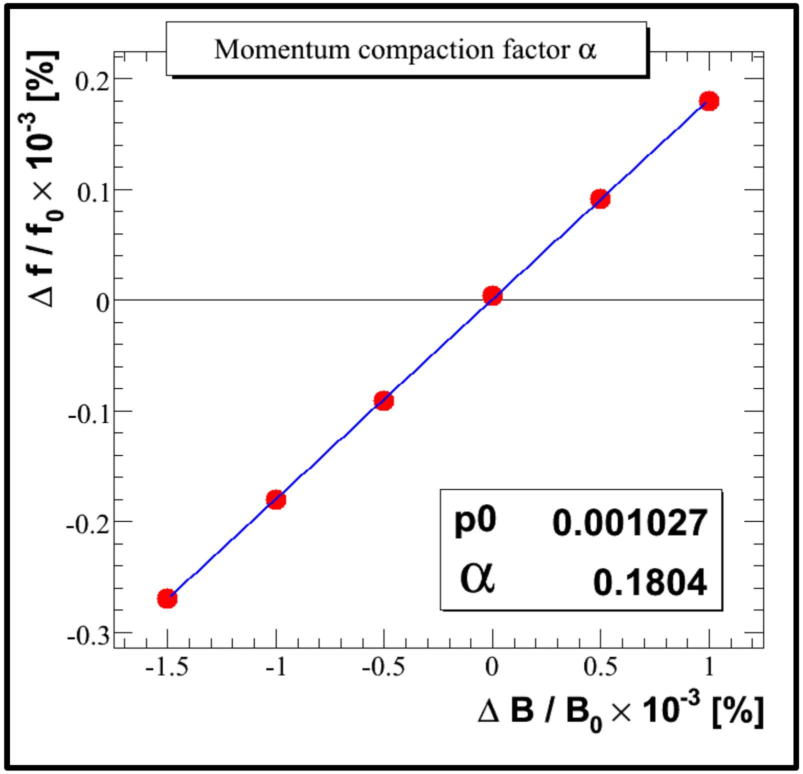
η – off-momentum factor based on measured α

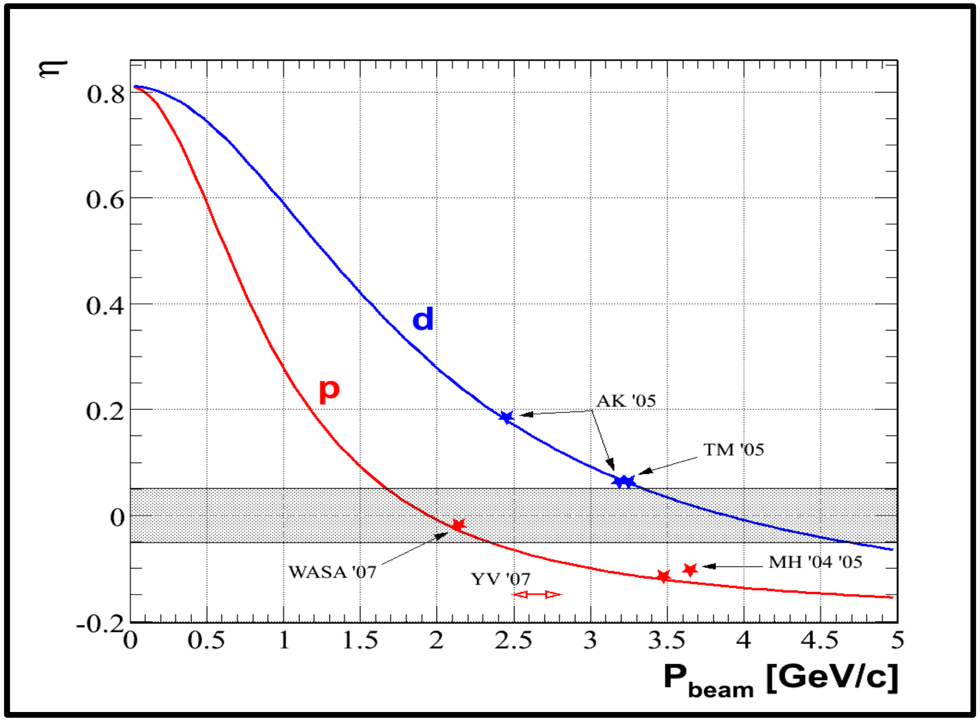
α – momentum compaction factor

f_0 – revolution frequency

γ – Lorentz factor

B_0 – COSY dipole magnetic field



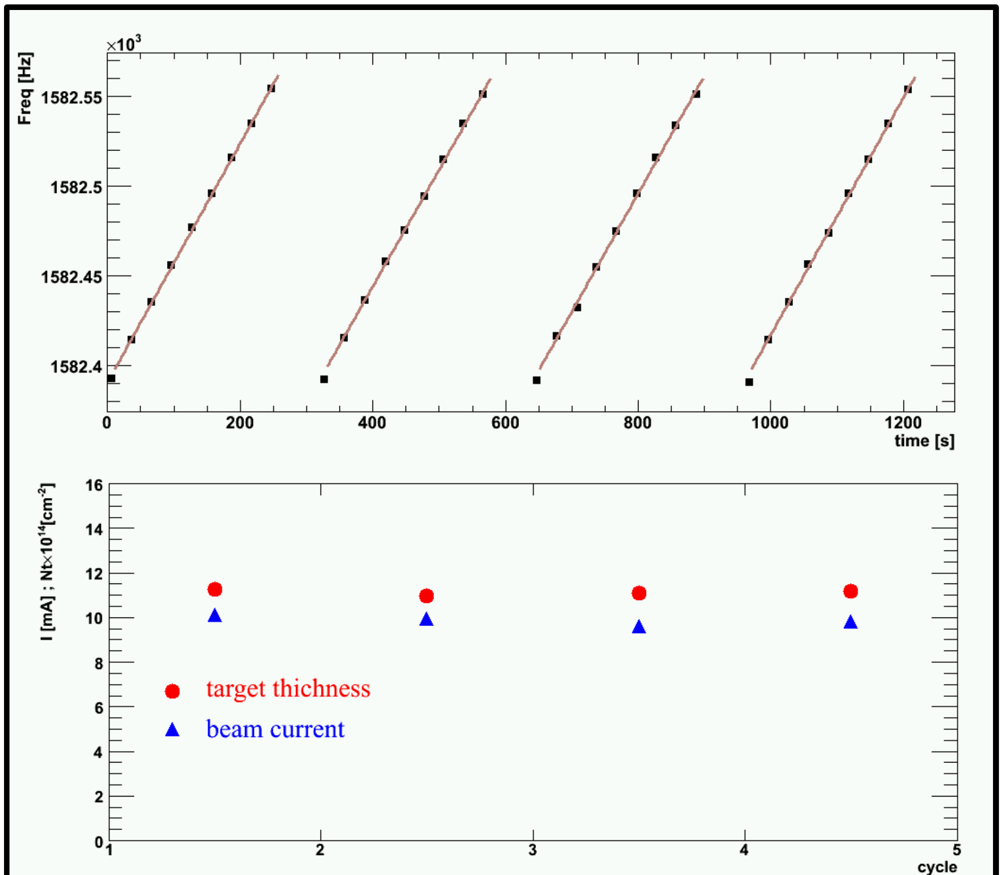


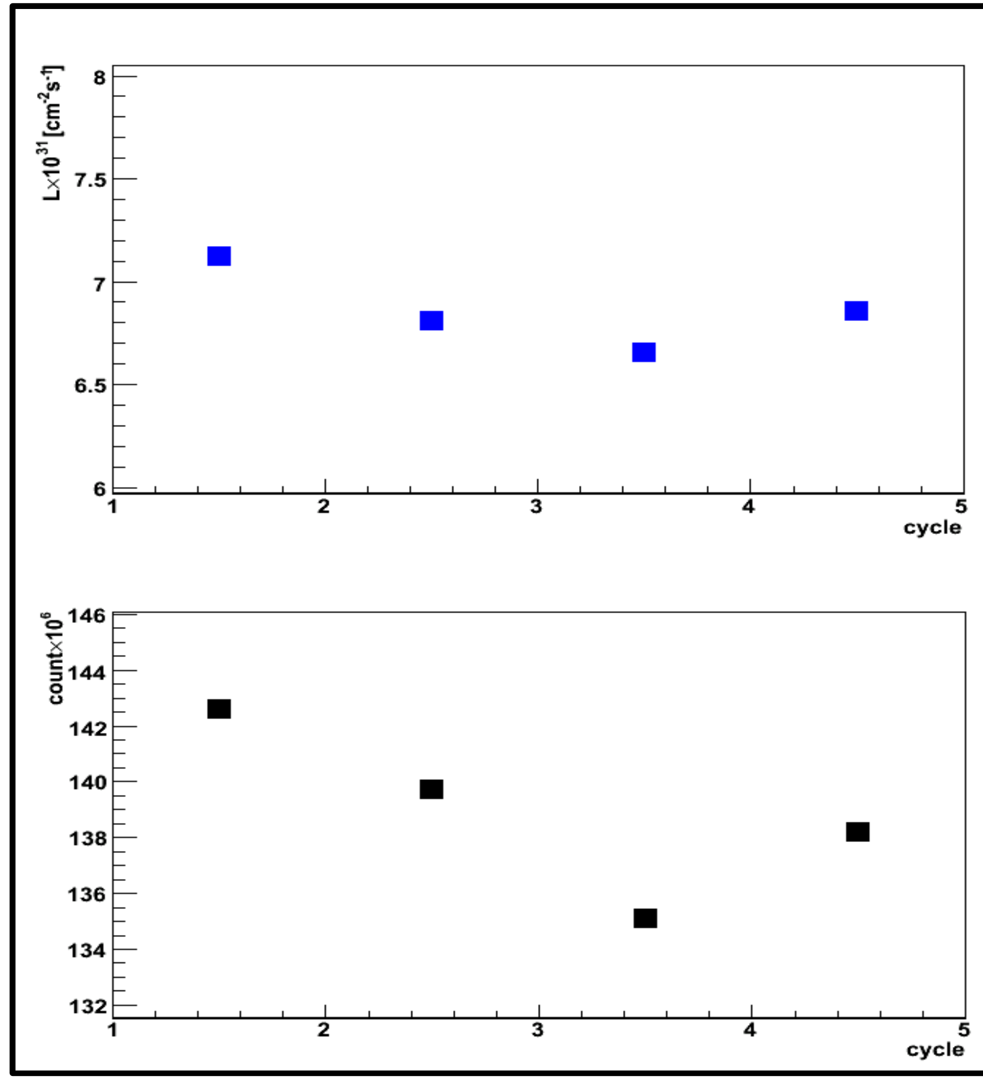
$$\eta = \frac{1}{\gamma^2} - \frac{1}{\gamma_{tr}^2}; \ \gamma_{tr} = 2.3$$

Luminosity determination

$$N_{target} = \frac{1+\gamma}{\gamma}\,\frac{1}{\eta}\,\frac{1}{(dE/dx)\,m}\,\frac{T_0}{f_0^2}\,\frac{\Delta f}{\Delta t}$$

$\Delta f \approx 180$ Hz / cycle

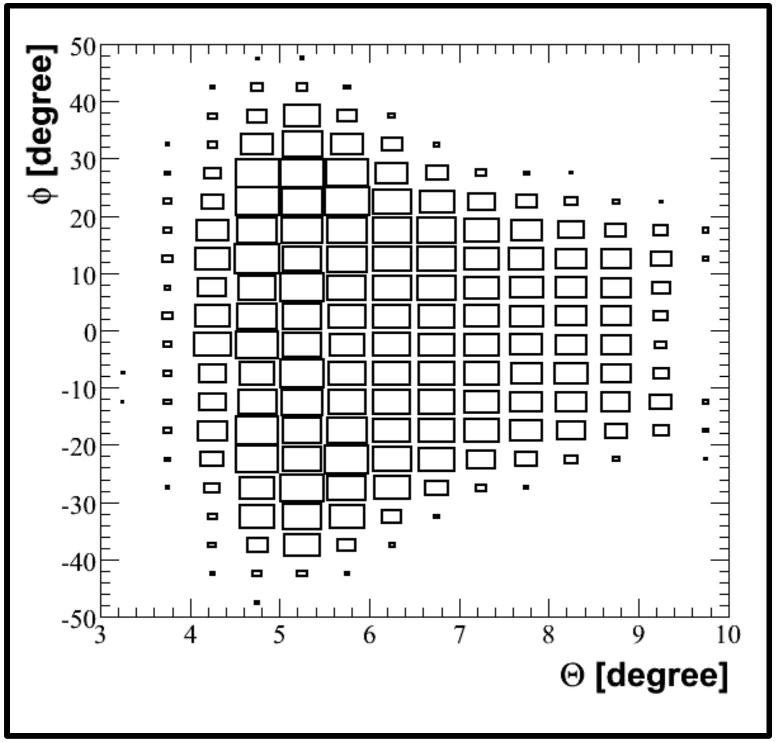


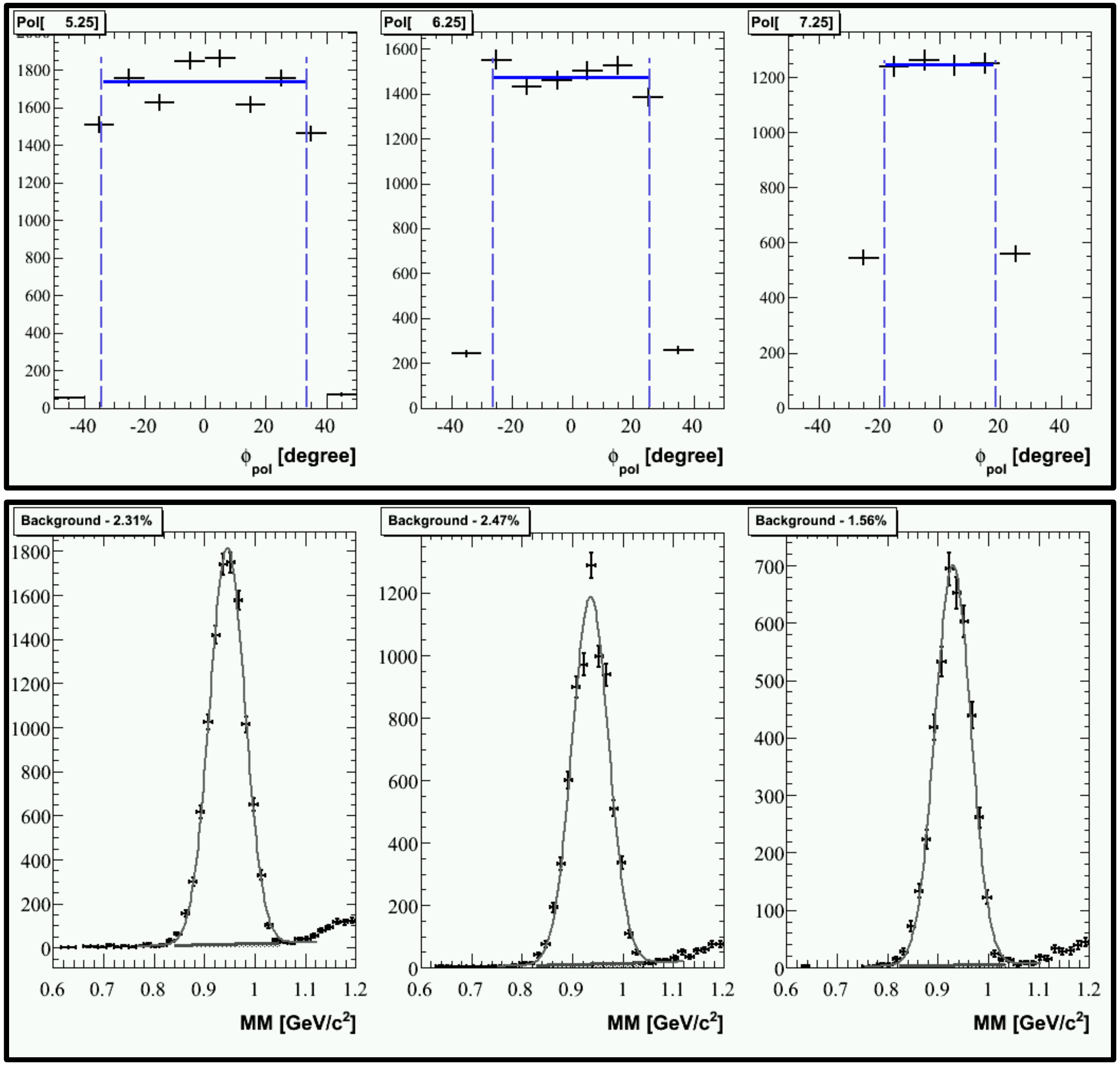


L ~ Countrate (Sum of the Starts)

Luminosity via *pp* elastic scattering

$$L = \frac{N'_{\exp}}{A'_{det}\,\varepsilon'_i\,(d\sigma/d\Omega)'}$$





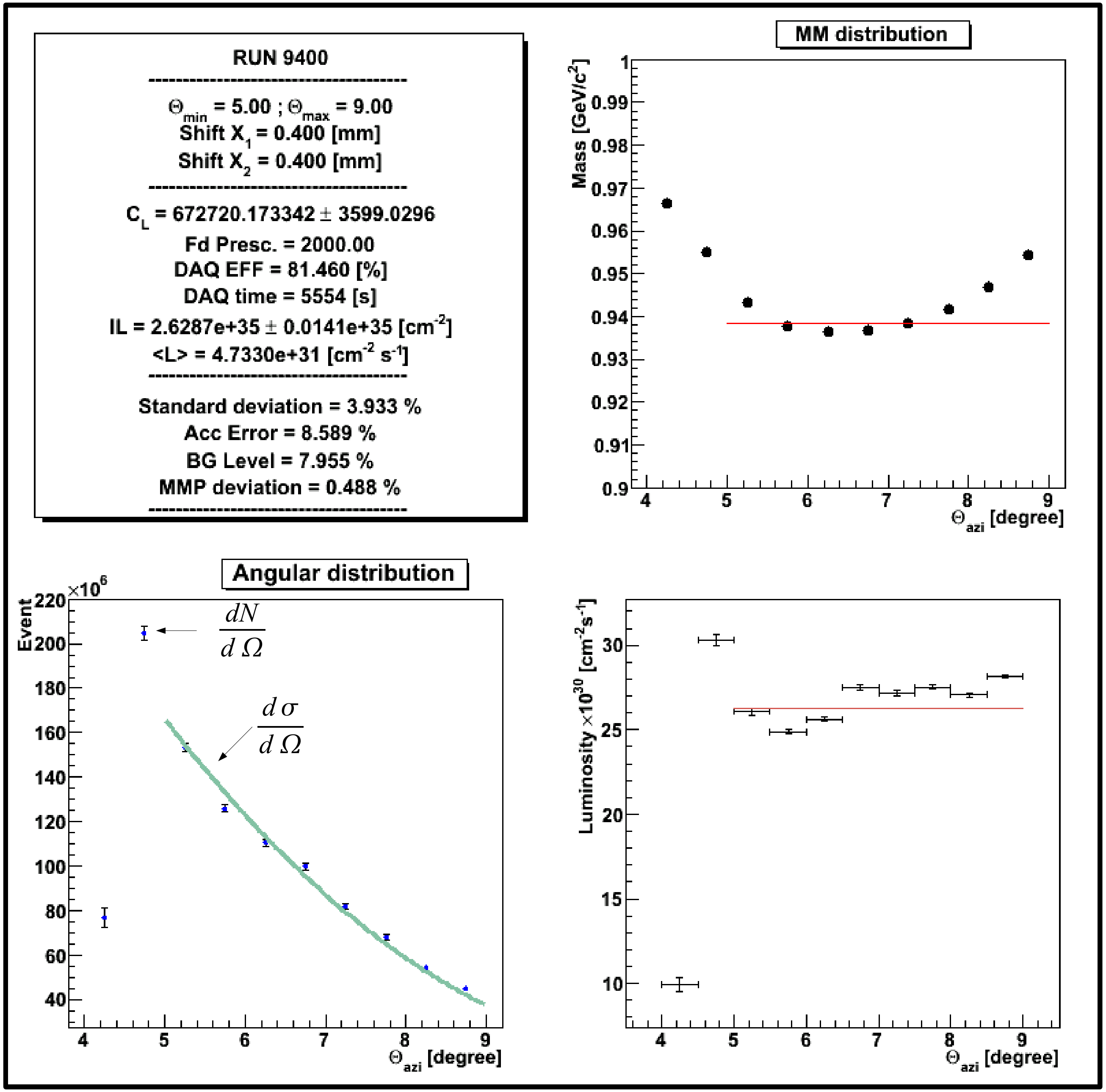
2D acceptance of
pp→*pp* @ ANKE

Luminosity via *pp* elastic scattering

$$N_{pp} = \frac{N_{det} \times p}{\varepsilon_{det} \times \varepsilon_{dt}}$$

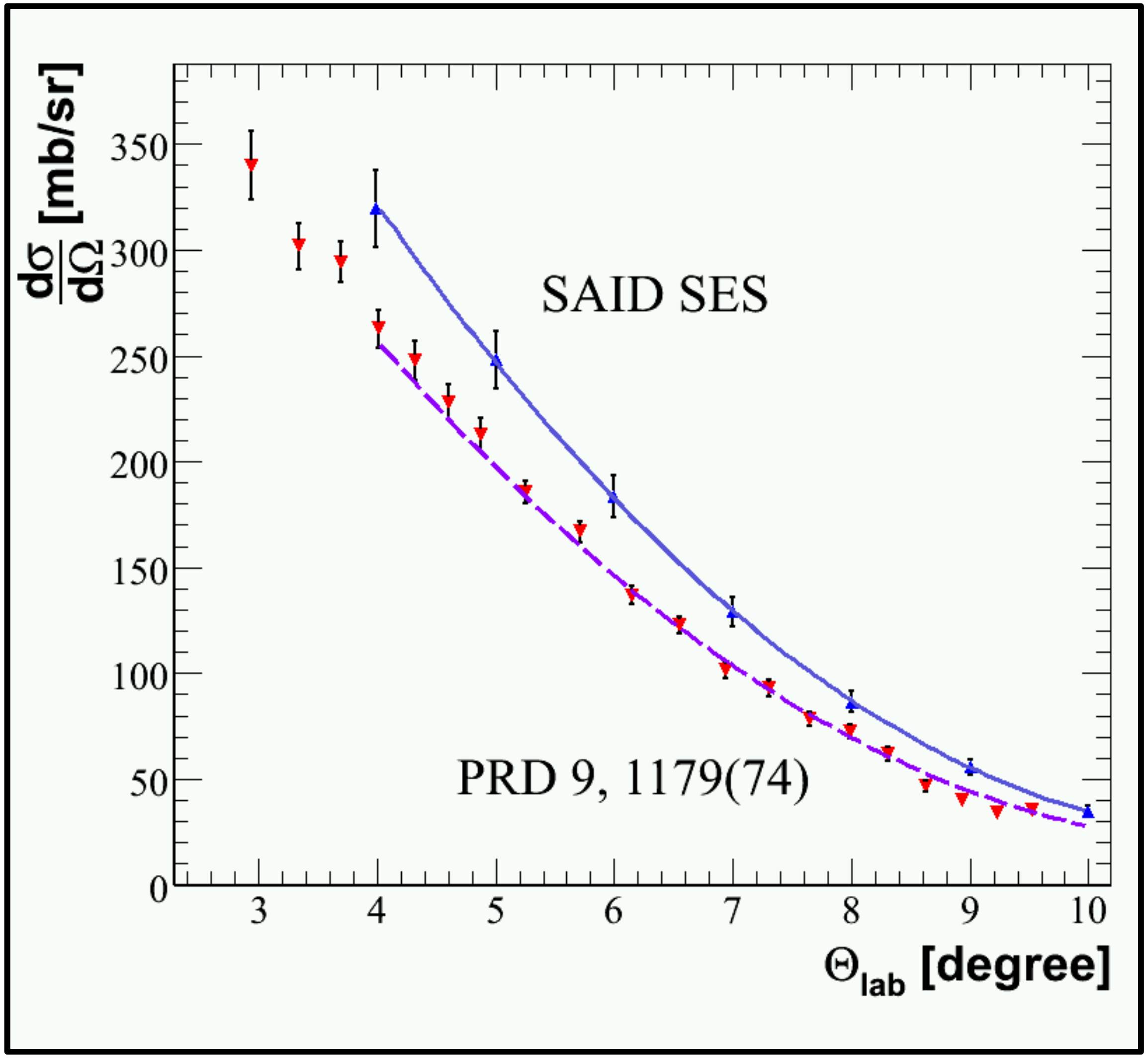
where

- N_{det} is number of reconstructed events via MM
- *p* is prescaling factor
- ε_{det} is detection efficiency
- ε_{dt} is dead time correction

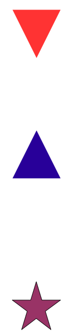


Difference between 2 XS

- ▲ SAID Single Energy Solution for T_p = 2.83GeV
- ▼ Experimental measurements @ 2.83GeV



Comparison of *pp* and Schottky



▼ Schottky

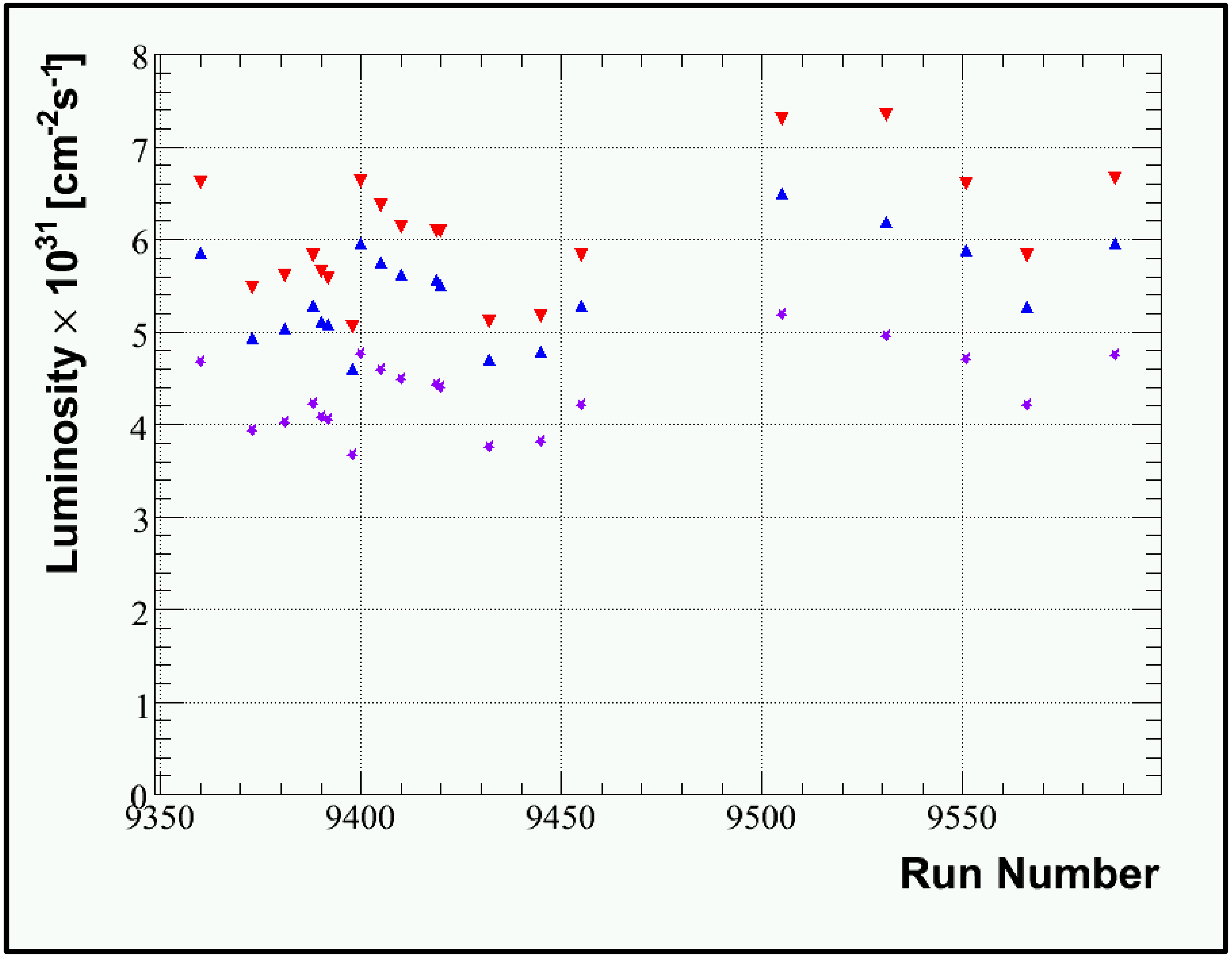
▲ *pp* elastic (experimental data)

★ *pp* elastic (SAID SES)

$$diff = \frac{L_{Schottky} - L_{pp}}{L_{Schottky}}$$

Difference (SAID) ~ 27%

Difference (Exp.) ~ 5%



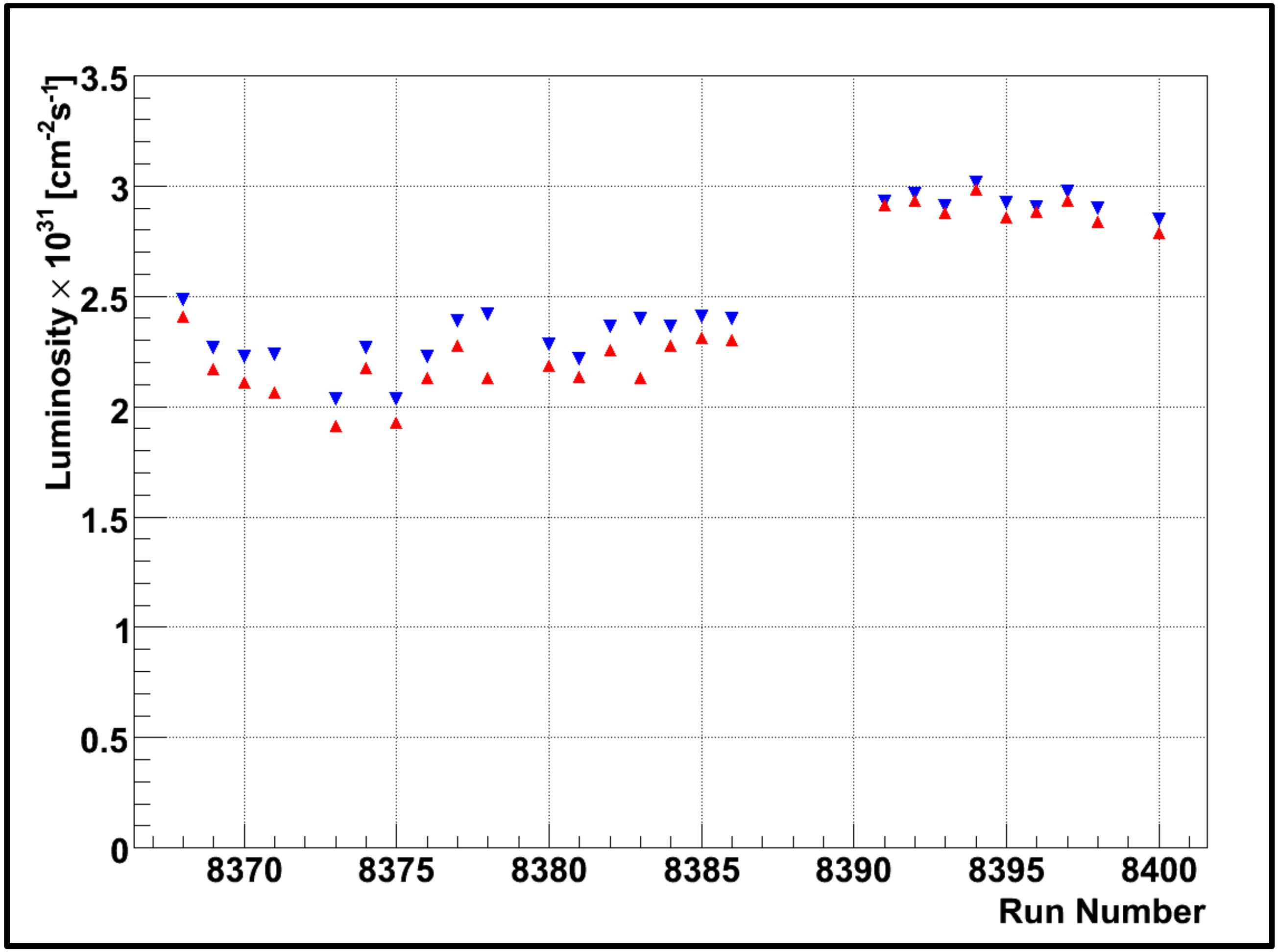
Comparison of *dp* and Schottky

▼ *dp* elastic

▲ Schottky

$$diff = \frac{L_{Schottky} - L_{dp}}{L_{Schottky}}$$

Difference < 5%



Uncertainties for both method

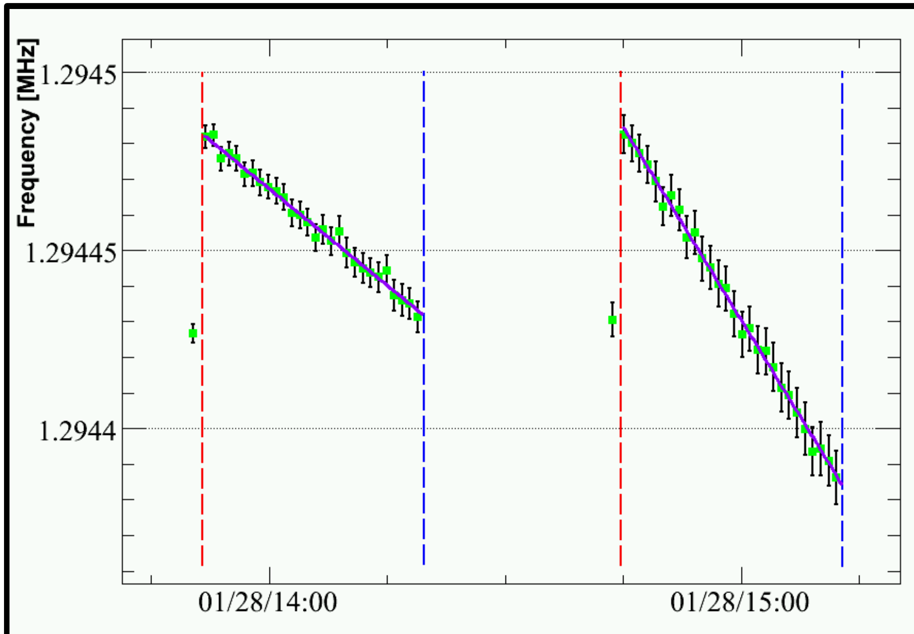
Error propagation via energy loss measurement

BCT:	I≈10mA	σ≲1%
Frequency shift:	Δf/f≈0.6Hz/s	σ≲3%
Eta:	≤η≈-0.103	σ≲5%
Ring gas:	$Nt \sim 10^{14} cm^{-2}$	σ≲3%
Stopping power:	dE/dx	σ≲1%

Error propagation via *pp* elastic reaction

Detector Eff.:	ε~5%
Acceptance:	A~8%
Statistical error:	ε~2%
SAID:	≲2% ?
BG subtraction:	≲3%

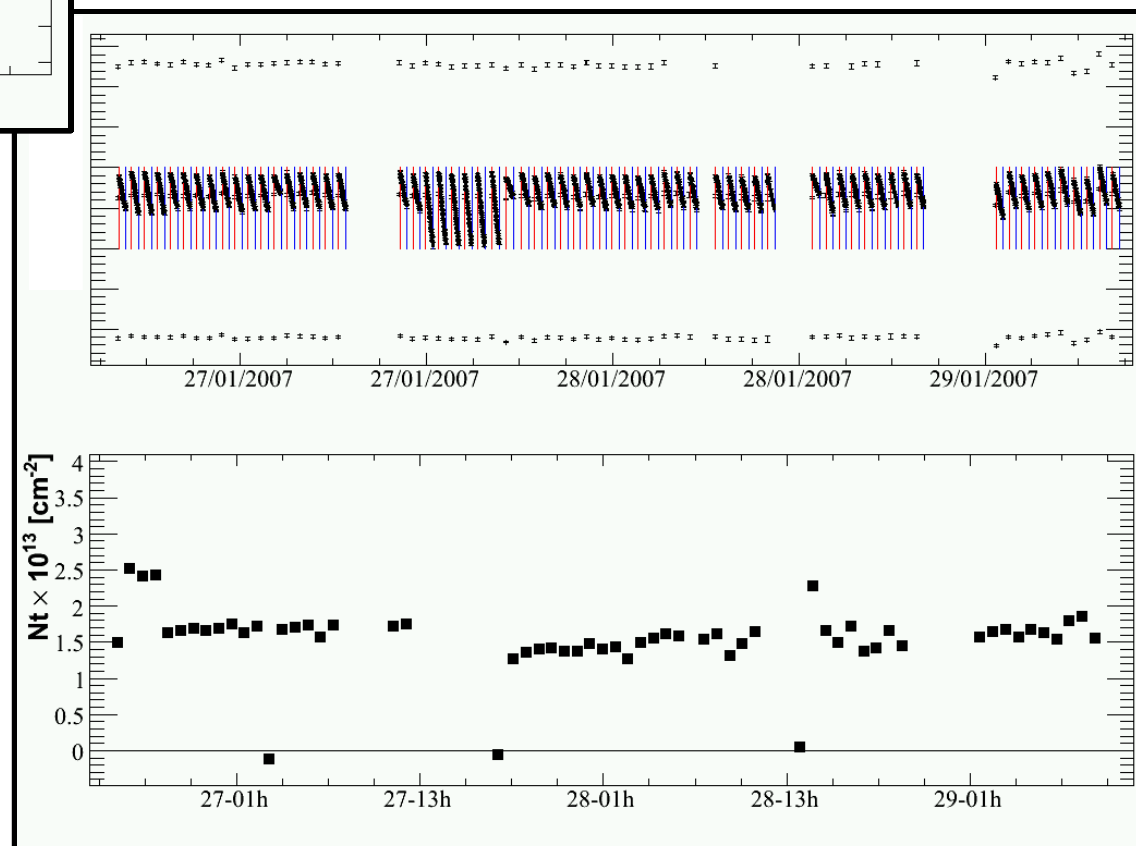
With internal cell target



Total frequency shift ~ $3.6 \cdot 10^{13}$ [cm^{-2}]

Rest+Ring Gas ~ $1.8 \cdot 10^{13}$ [cm^{-2}]

Cell TARGET thickness ~ $1.8 \cdot 10^{13}$ [cm^{-2}]



η = 0.2164; // average

f_0 = 1.294358; // MHz

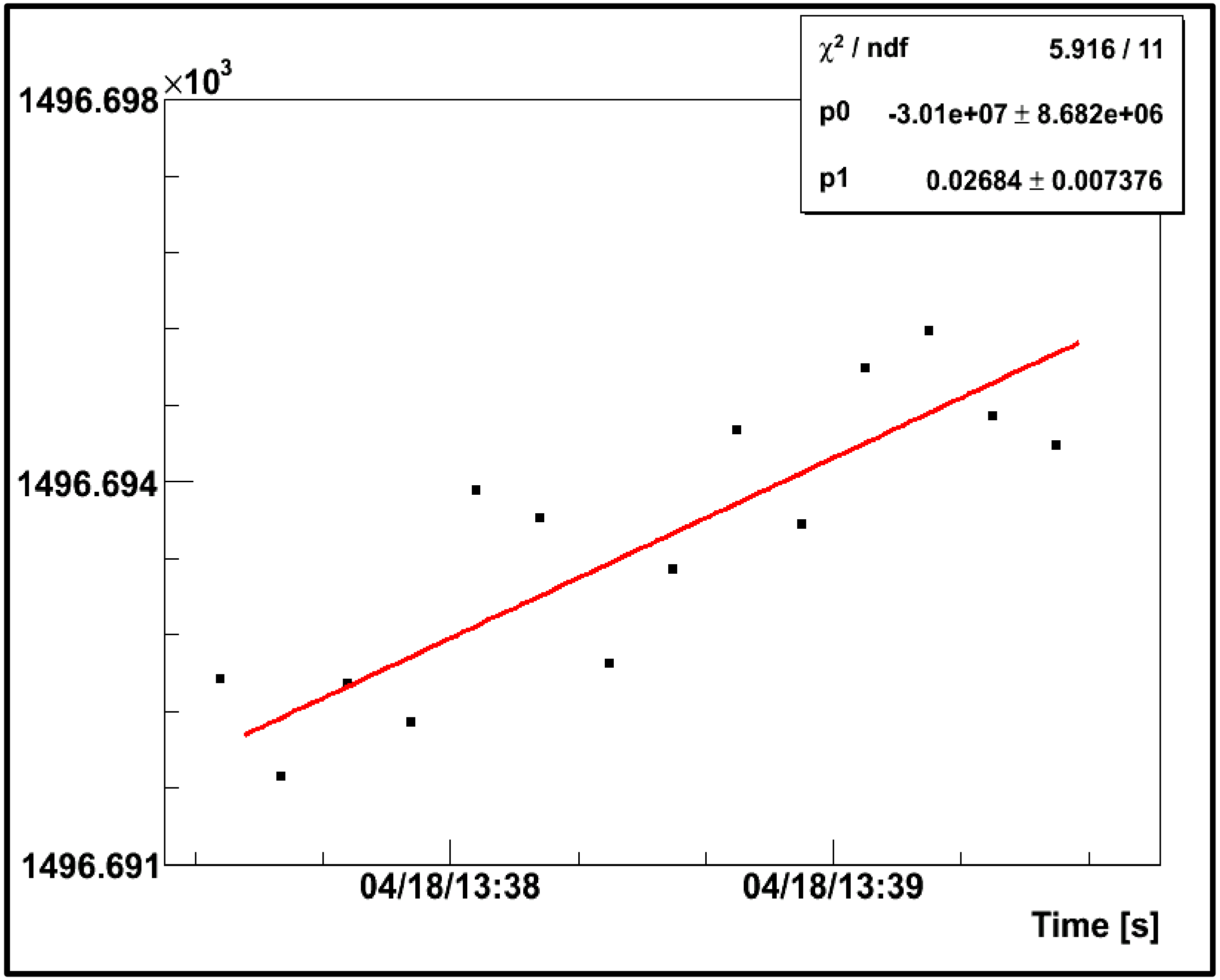
T_0 = 1198; // MeV

With pellet target

η = 0.02; // to small

f_0 = 1.496688; // MHz

T_0 = 1400; // MeV



Conclusion

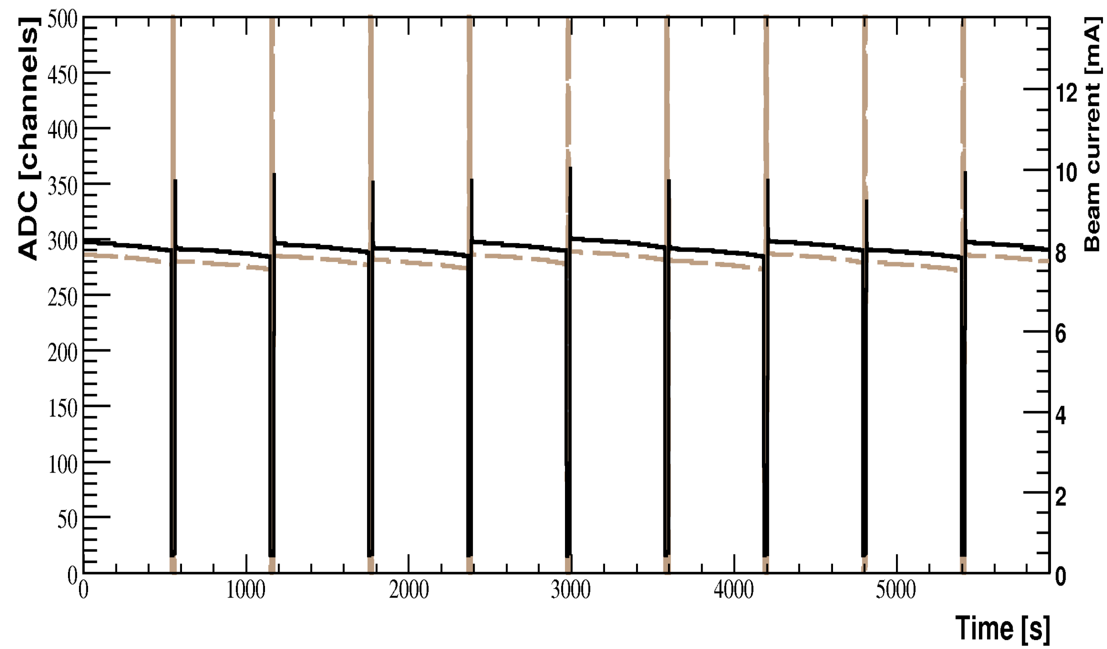
I. We have 2 independent method to determine luminosity
- ◊ via *nuclear* elastic scattering
- ◊ via *energy loss* measurement

II. Both methods just coincide within the error limits

III. We can use 'Schottky' method for different targets
- ◊ with cluster jet target
- ◊ with cell target
- ◊ with pellet target

Beam intensity determination

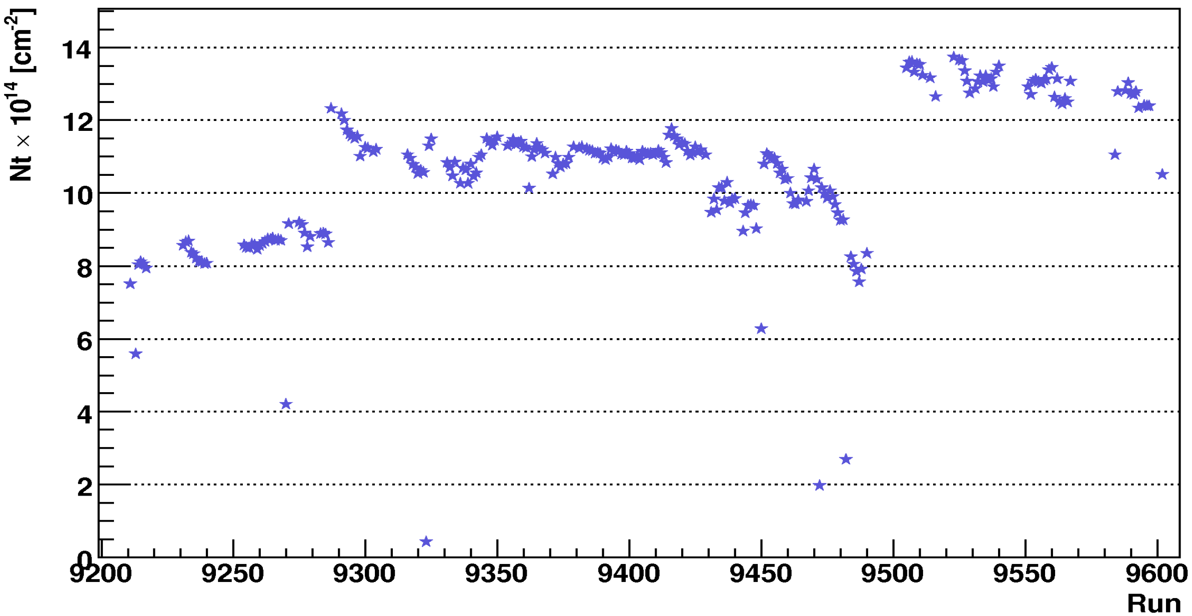
$$J_{beam} = \frac{I_{beam}}{q_p}, \; [s^{-1}]$$

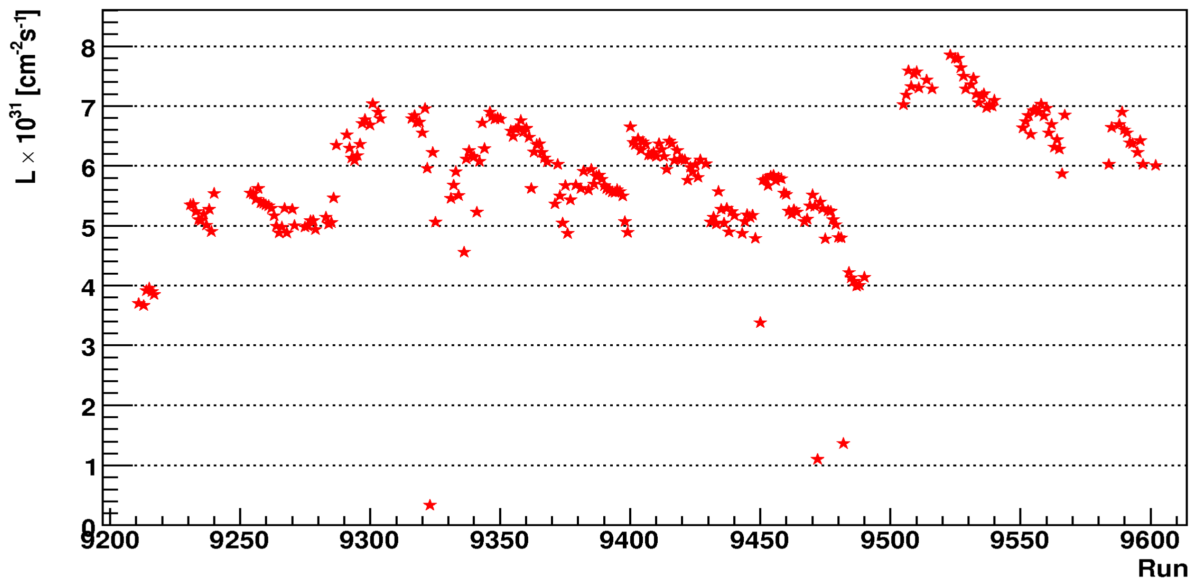


- Calibration (ADC-mA)
- Offset determination

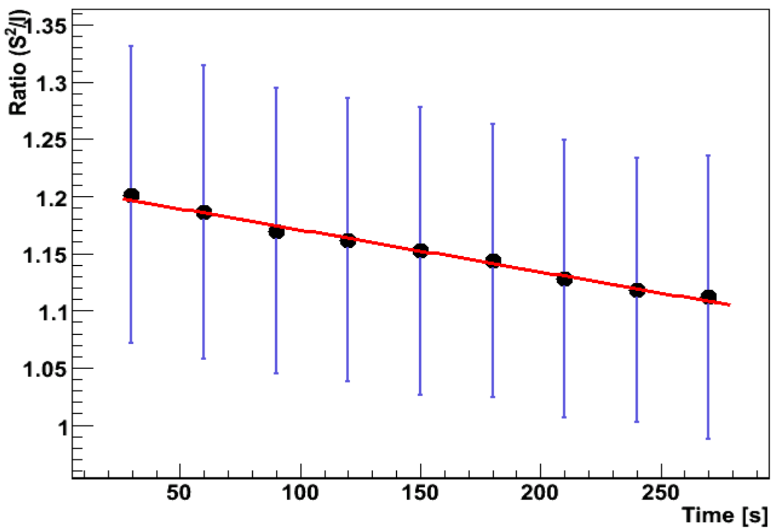
(EDDA, between cycles)

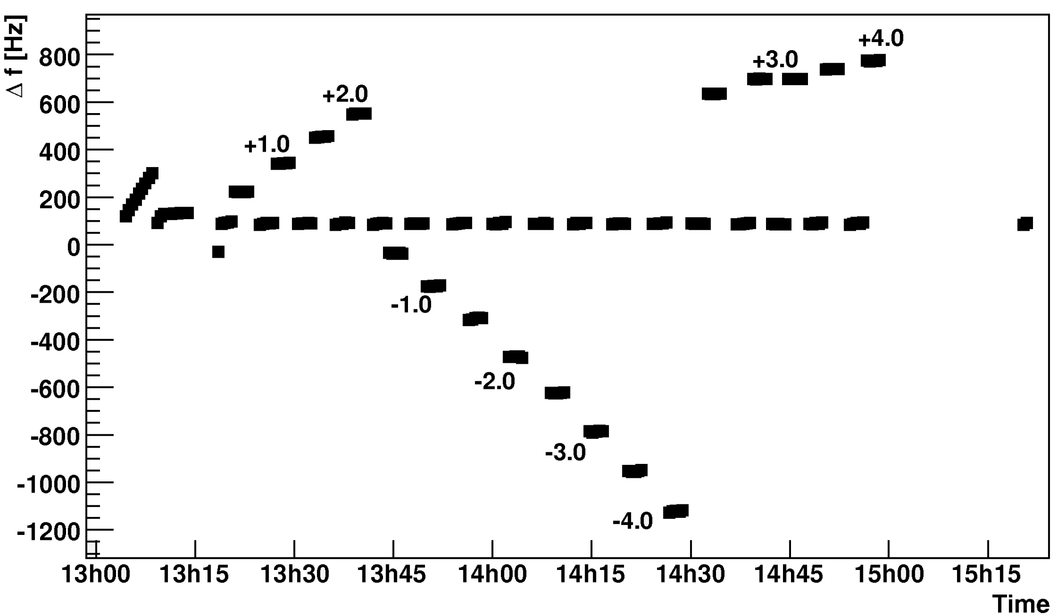
Luminosity determination

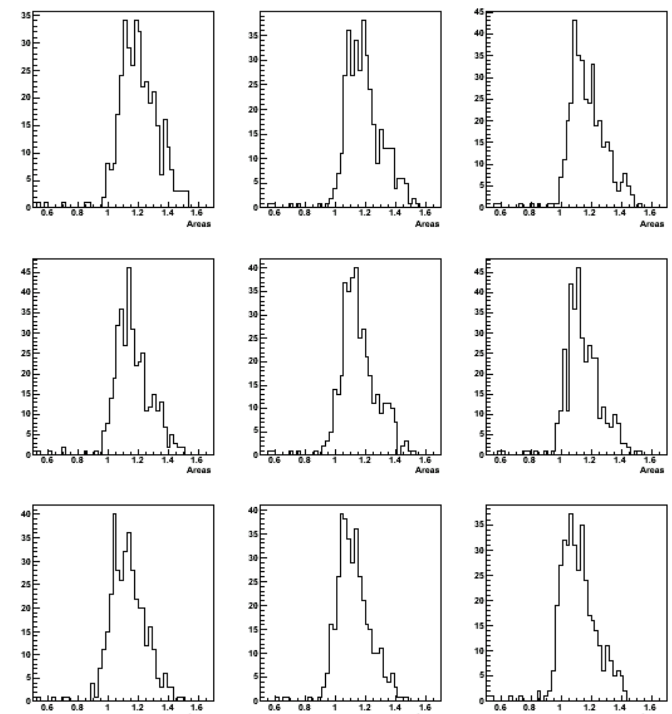


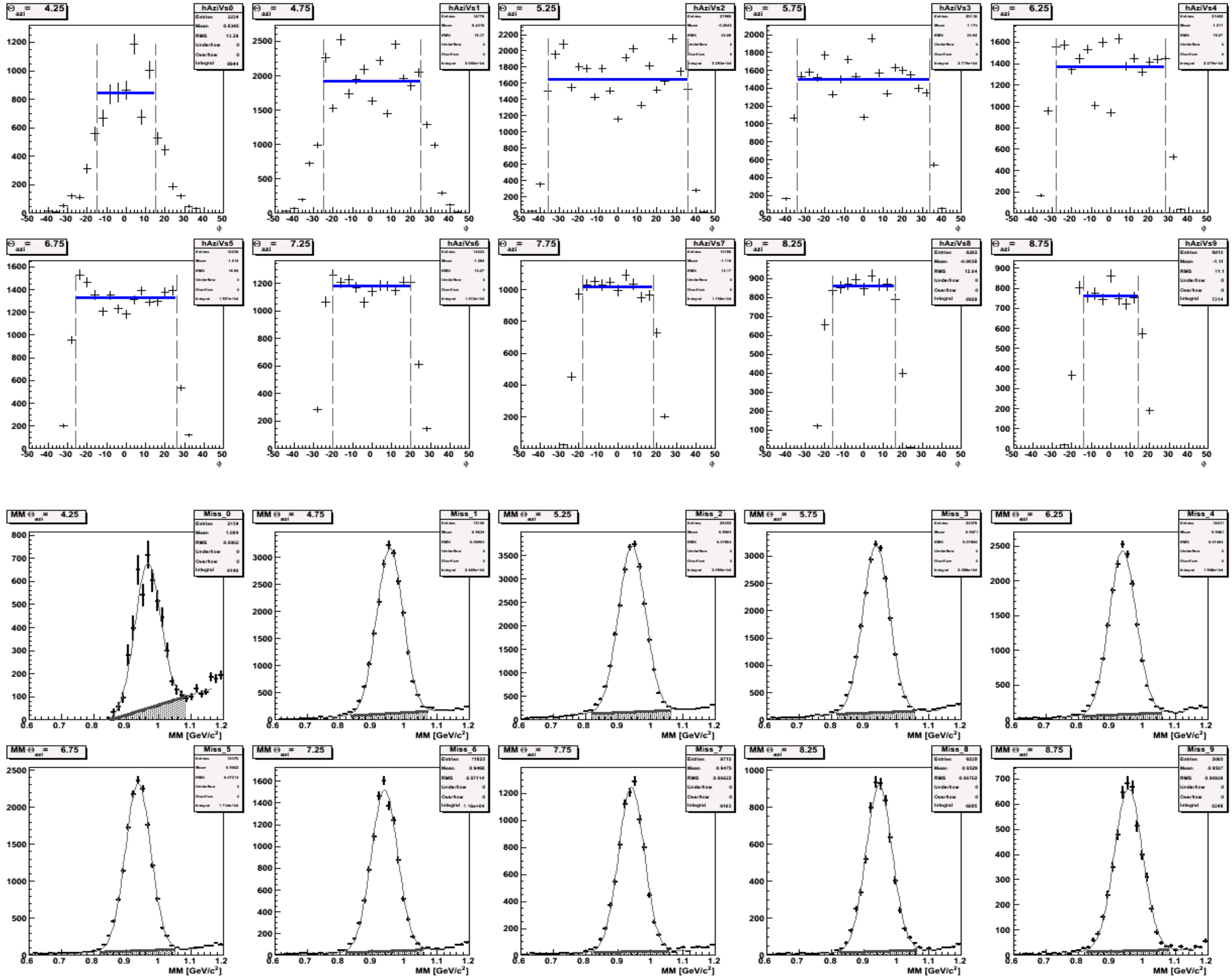


Schottky Method for ANKE









Θ_azi = 4.25
hAziVs0
Θ_azi = 4.75
hAziVs1
Θ_azi = 5.25
hAziVs2
Θ_azi = 5.75
hAziVs3
Θ_azi = 6.25
hAziVs4
Θ_azi = 6.75
hAziVs5
Θ_azi = 7.25
hAziVs6
Θ_azi = 7.75
hAziVs7
Θ_azi = 8.25
hAziVs8
Θ_azi = 8.75
hAziVs9
φ
MM Θ_azi = 4.25
Miss_0
MM Θ_azi = 4.75
Miss_1
MM Θ_azi = 5.25
Miss_2
MM Θ_azi = 5.75
Miss_3
MM Θ_azi = 6.25
Miss_4
MM Θ_azi = 6.75
Miss_5
MM Θ_azi = 7.25
Miss_6
MM Θ_azi = 7.75
Miss_7
MM Θ_azi = 8.25
Miss_8
MM Θ_azi = 8.75
Miss_9
MM [GeV/c²]