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Absolute measurement of the differential cross section for pp elastic scattering at ANKE-COSY

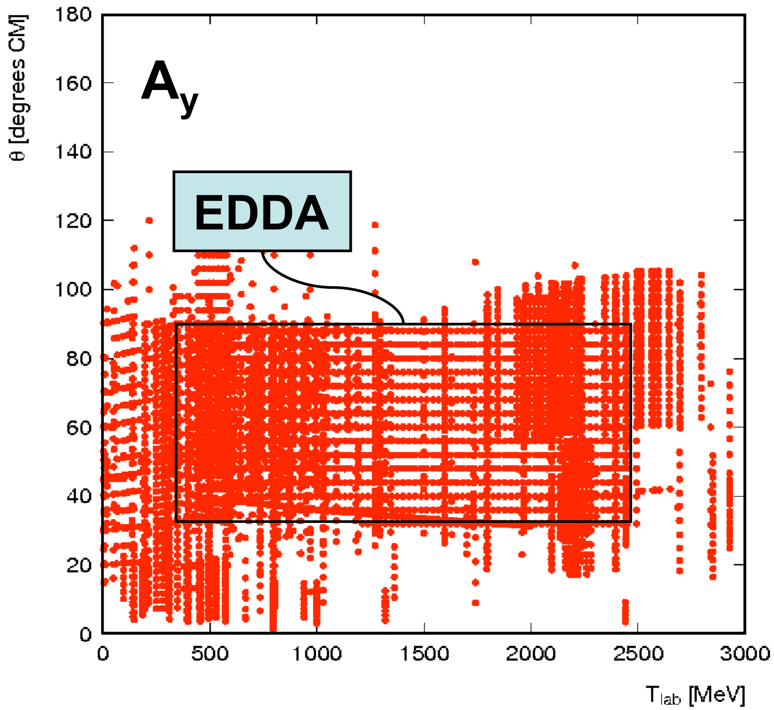
October 10, 2011 | David Chiladze (HEPI, Tbilisi State University)

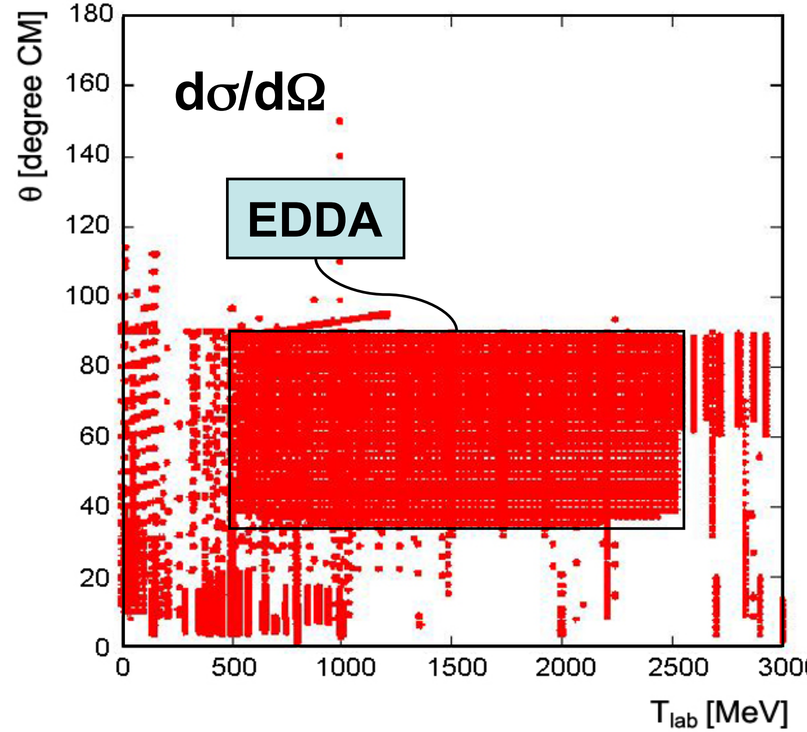
Outline

- Motivation
- Experimental Setup
- Measurement Technique
- Target Density Determination
- Luminosity
- Preliminary Results
- Summary

Motivation

- NN description requires precise data for Phase Shift Analysis.
- pp system well known up to 2.0 GeV.





In order to deduce information on np system it is necessary to have equally robust pp data in the same angular range.

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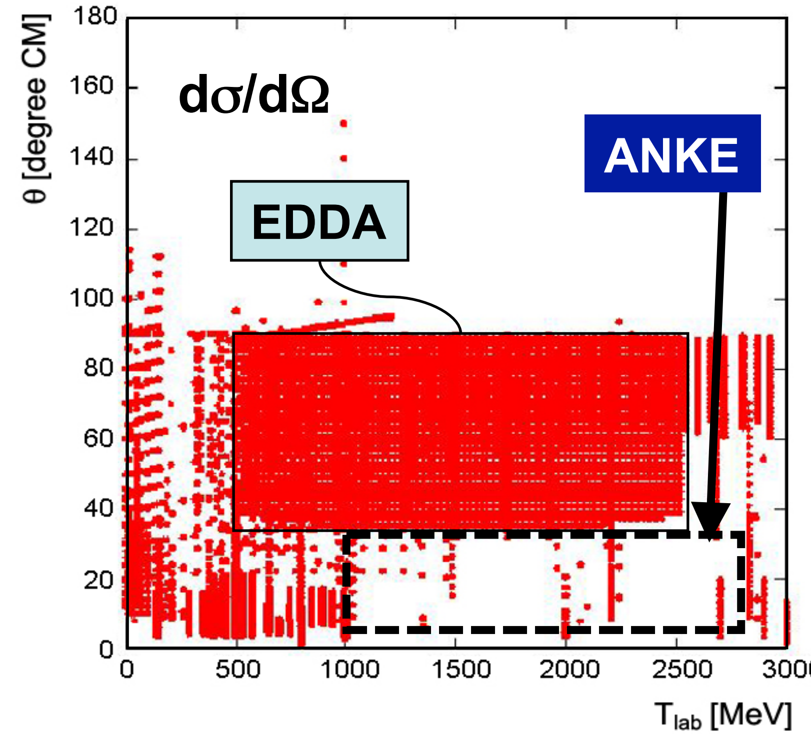
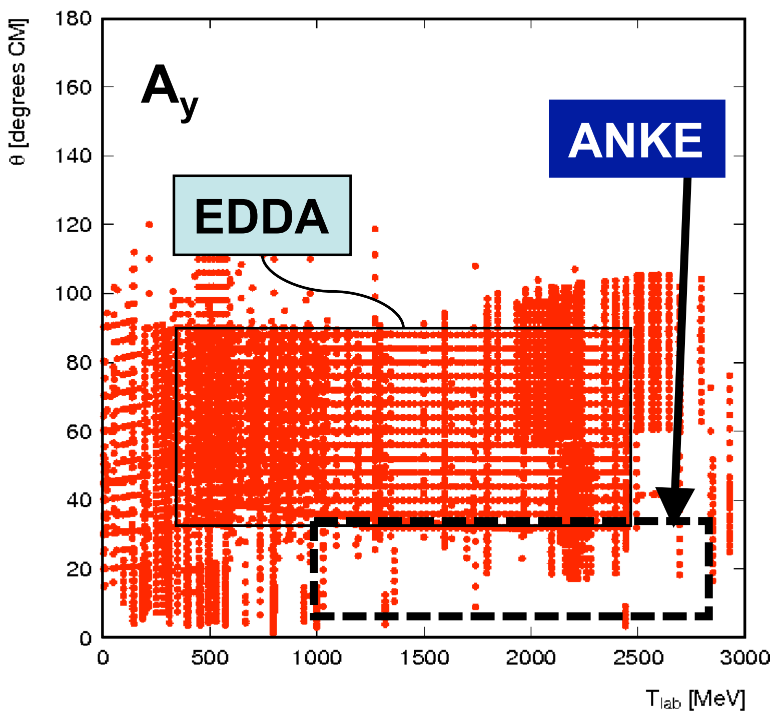
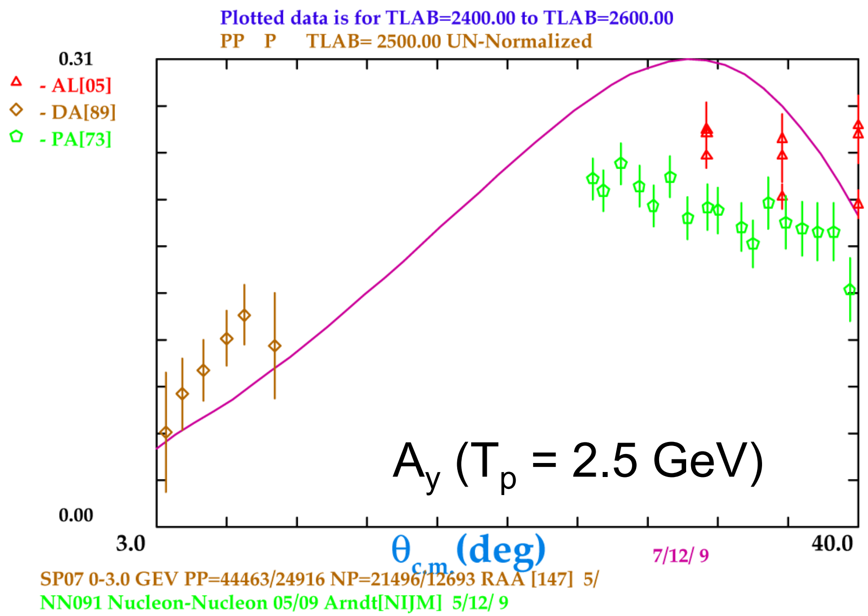


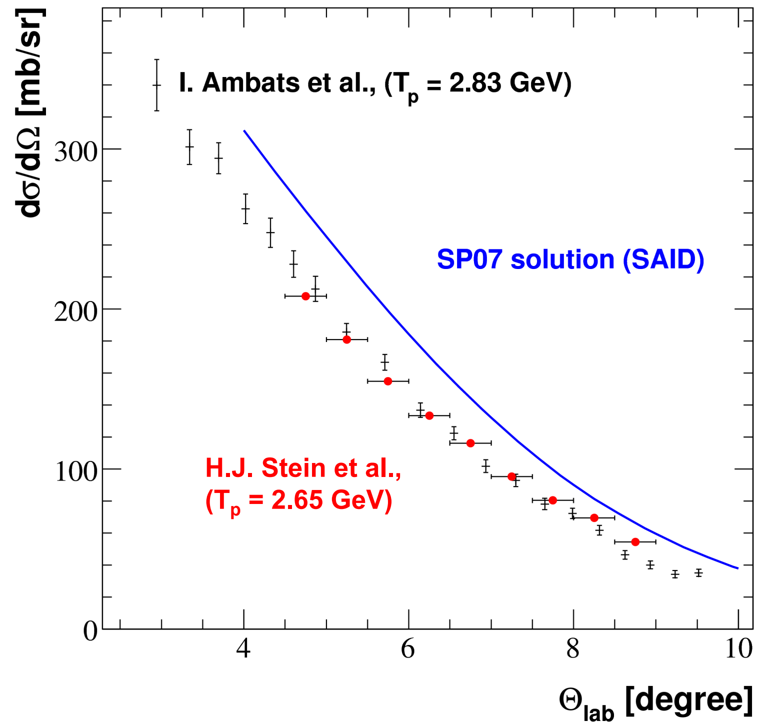


In order to deduce information on np system it is necessary to have equally <u>robust pp data</u> in the <u>same</u> angular range.

Motivation

- There are severe problems with the small angle predictions from SAID above 2.5 GeV.
- But SAID predictions and experimental data do agree for larger angles.





Above 2.5 GeV SAID does not reproduce simultaneously small and large angle data

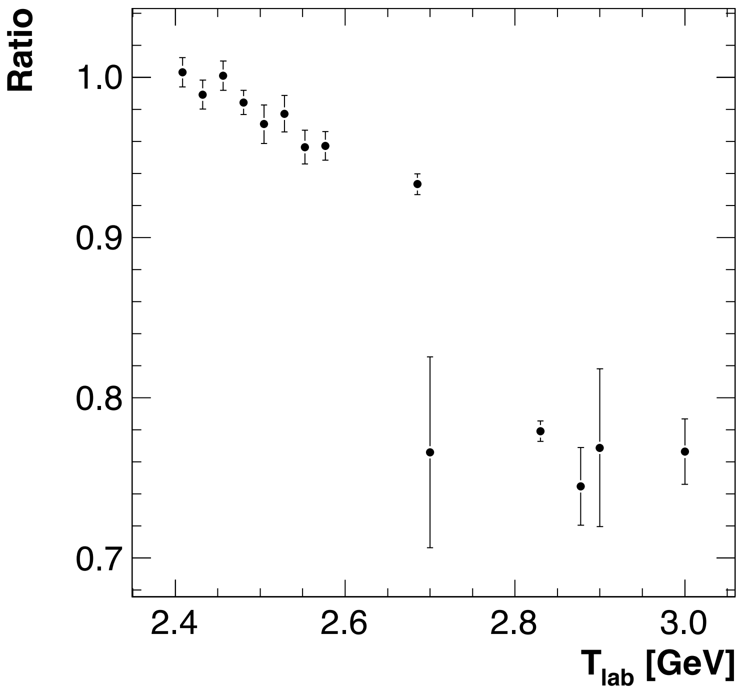
Motivation

- The discrepancy between SAID and experiment is about 25 % above 2.6 GeV for the angular range 10° < θ_{cm} < 30°

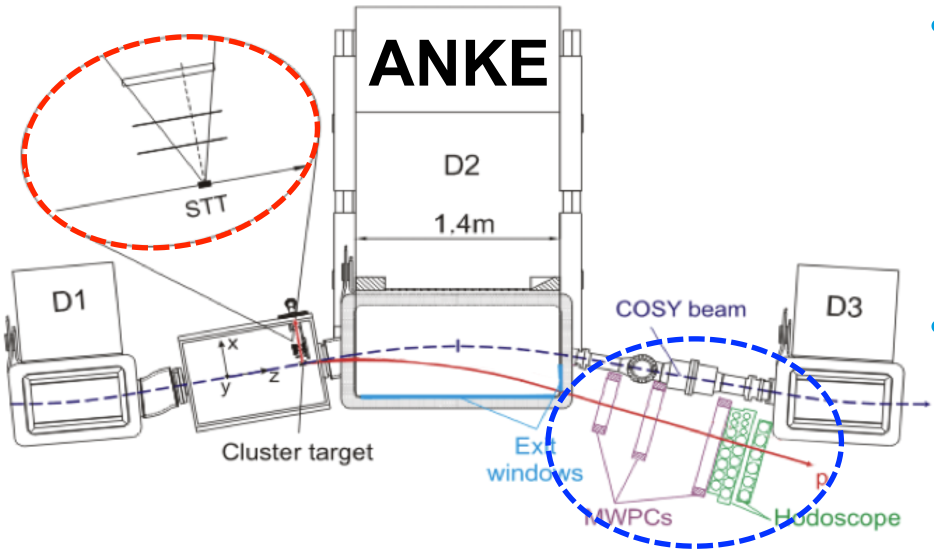
- Arndt / Strakovsky:
  "Our solution should be considered at best qualitative between 2.5 and 3 GeV"

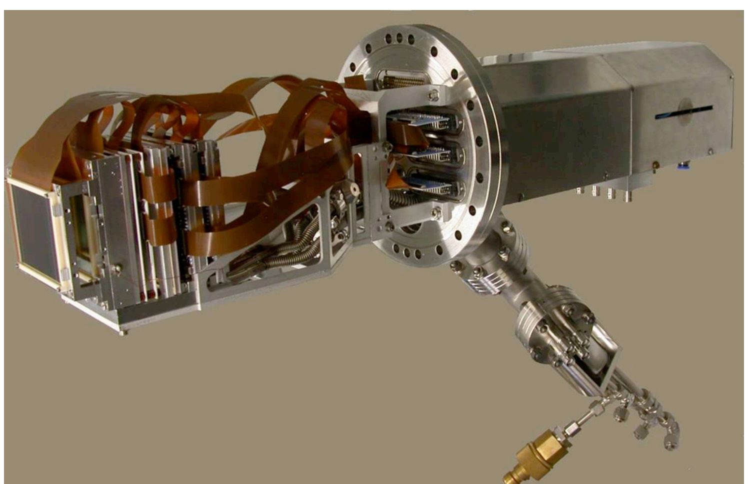
- Further precise measurements are required at the upper end of the COSY energy range.

Ratio of the experimental data to the SAID predictions averaged over angular range: 10° < θ_{cm} < 30°



Experimental Setup





- dσ/dΩ measurement in the angular range: 5°< θ_{cm}<30° for the energies: T_p = 1.0, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8 GeV.
- Proton detection either with **FD**, or with **STT**, or with both in coincidence.
  - Three Multi-wire Chambers with two layers of Scintillation hodoscopes. (10°< θ_{cm}<30°)
  - Three layers of double-sided silicon strip detectors. (5°< θ_{cm}< 15°)

Measurement Technique

- Cross section σ of given physical process is related to its event R rate by luminosity:

$$\sigma = \frac{R}{L}$$

Accuracy 2-3%

Where: $L = n_T \cdot n_B$

  - Accurate measurement of beam intensity n_B is possible via the high precision Beam Current Transformer (BCT) device.
  - Effective target thickness n_T can be obtained via the measurement of the frequency shift of coasting beam using the Schottky device.

$$n_T \sim \frac{df}{dt}$$

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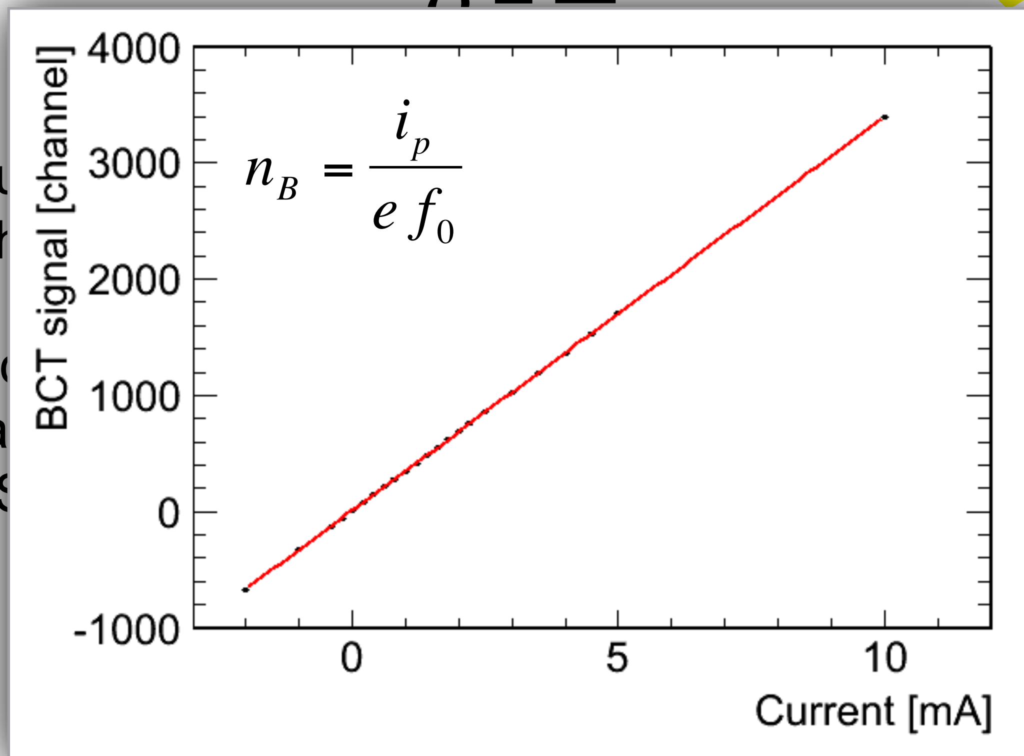


- Accu… …ossible via the h… …CT) device.
- Effe… …the mea… …beam using the S…

Target Density Determination

In general, number of target atoms per unit area can be expressed as:

$$n_T = \frac{\delta T}{(dE/dx)m}$$

In Δt time interval beam makes $f_0 \Delta t$ traversals with corresponding energy loss of ΔT

$$n_T = \frac{\Delta T}{f_0 \Delta t} \frac{1}{(dE/dx)m}$$

In terms of change in beam momentum

$$n_T = \left(\frac{1+\gamma}{\gamma}\right) \frac{T_0 \Delta p}{f_0 p_0 \Delta t} \frac{1}{(dE/dx)m}$$

In the case of closed orbit:

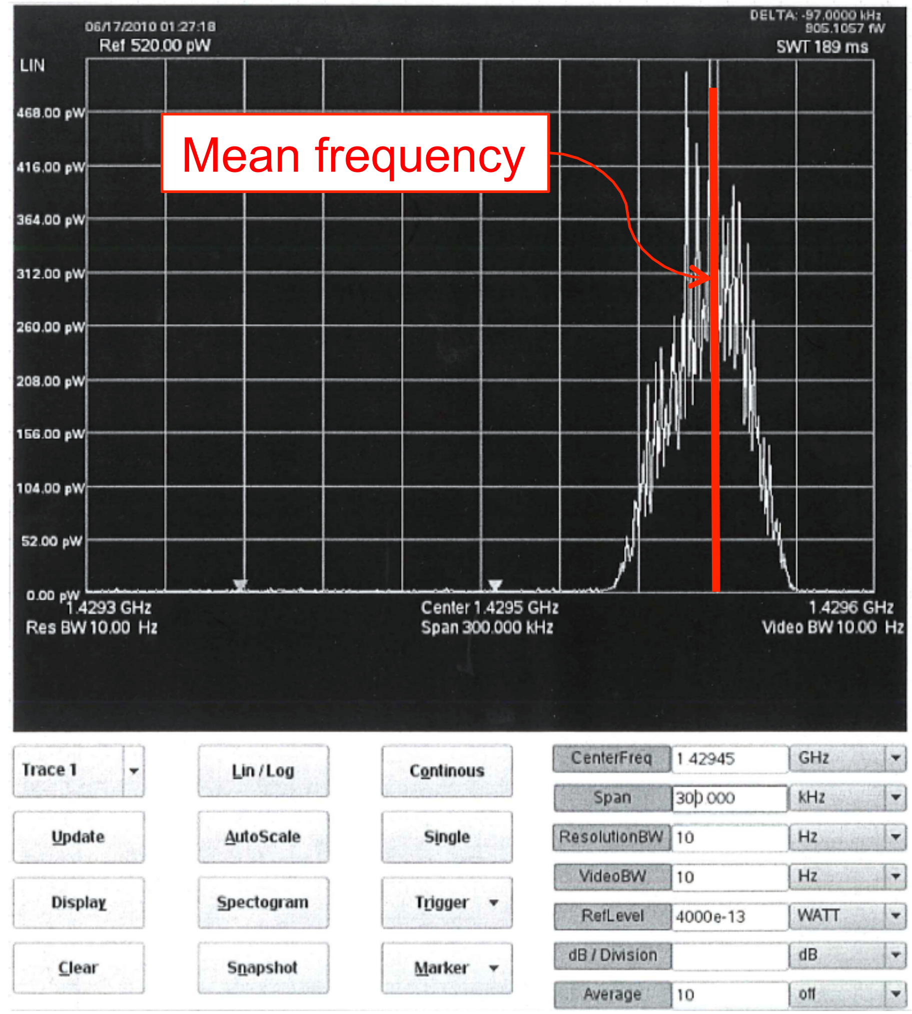
$$\frac{\Delta p}{p_0} = \frac{1}{\eta} \frac{\Delta f}{f_0}$$

η - frequency-slip parameter

$$n_T = \left(\frac{1+\gamma}{\gamma}\right) \frac{1}{\eta} \frac{1}{(dE/dx)m} \frac{T_0}{f_0^2} \frac{df}{dt}$$

Target Density Determination: Frequency Analyzer

- Frequency is measured by analyzing the Schottky noise of coasting proton beam
  (no cooling, no bunching)
- The sweep time of the analyzer was set to 189 ms. Thus Instantaneous spectra
- Mean frequency of the beam is determined as a center of mass of Schottky distribution after background subtraction.



Target Density Determination: η parameter

η parameter is connected to the momentum compaction factor α:

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

Relative frequency can be changed by:

- changing the speed of particles
- changing the trajectory

$$\frac{\Delta f}{f_0} = \frac{\Delta \beta}{\beta_0} - \frac{\Delta C}{C_0}$$

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Study of the shift of mean revolution frequency as a function of ΔB/B change in the bending magnets allows to extract the momentum compaction factor α

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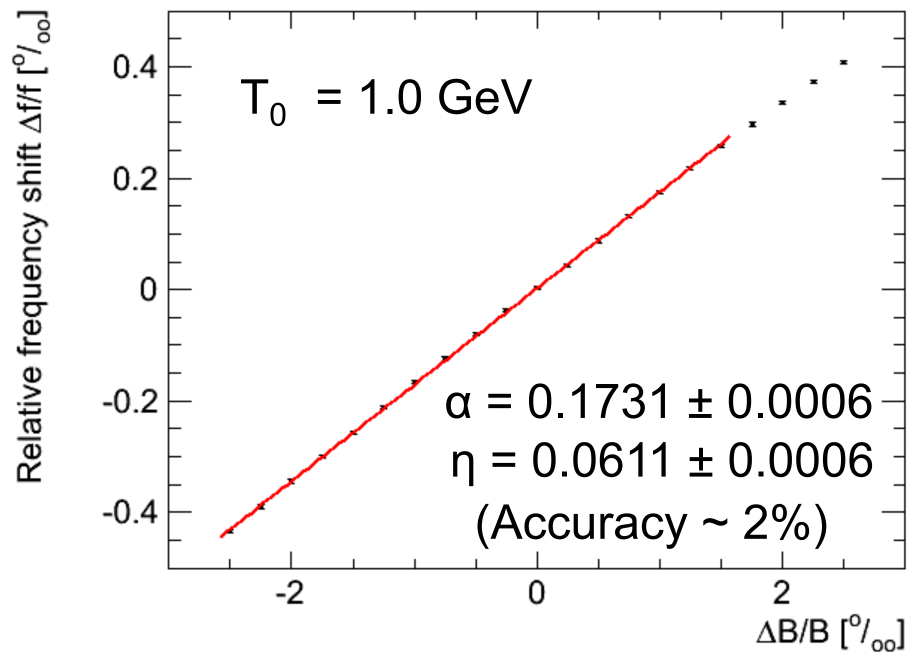

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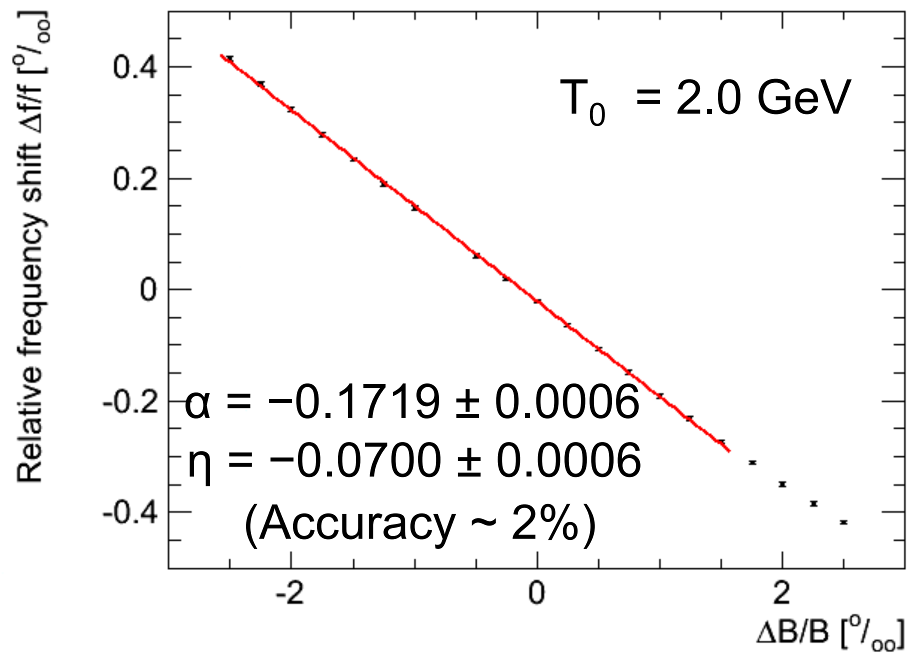

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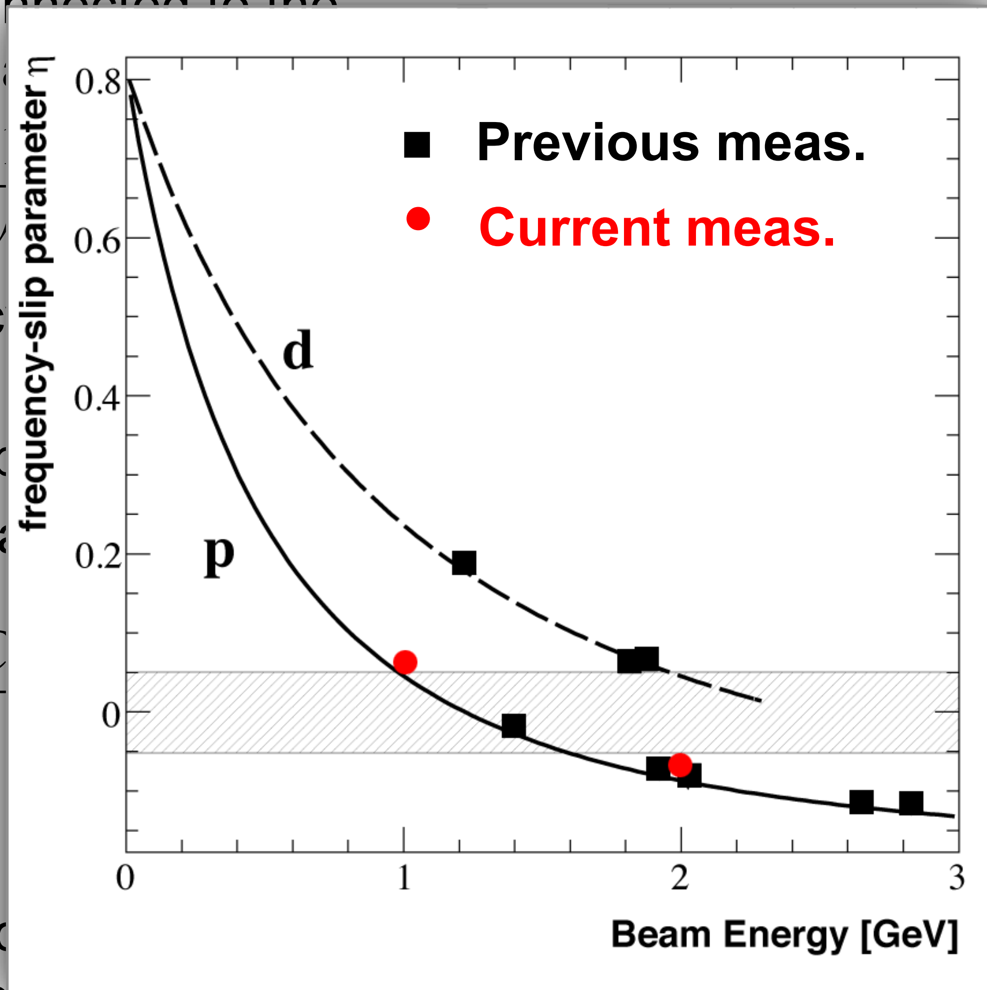

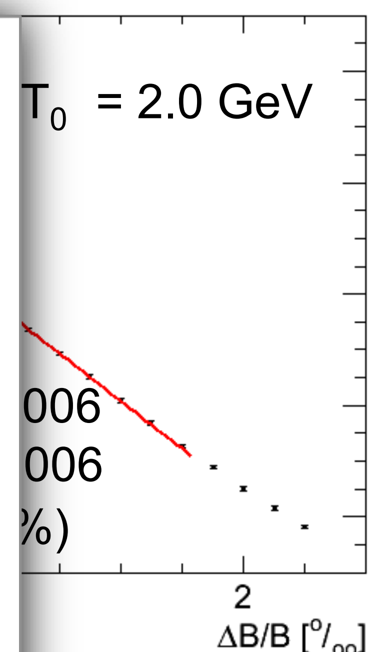

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function of ΔB/B
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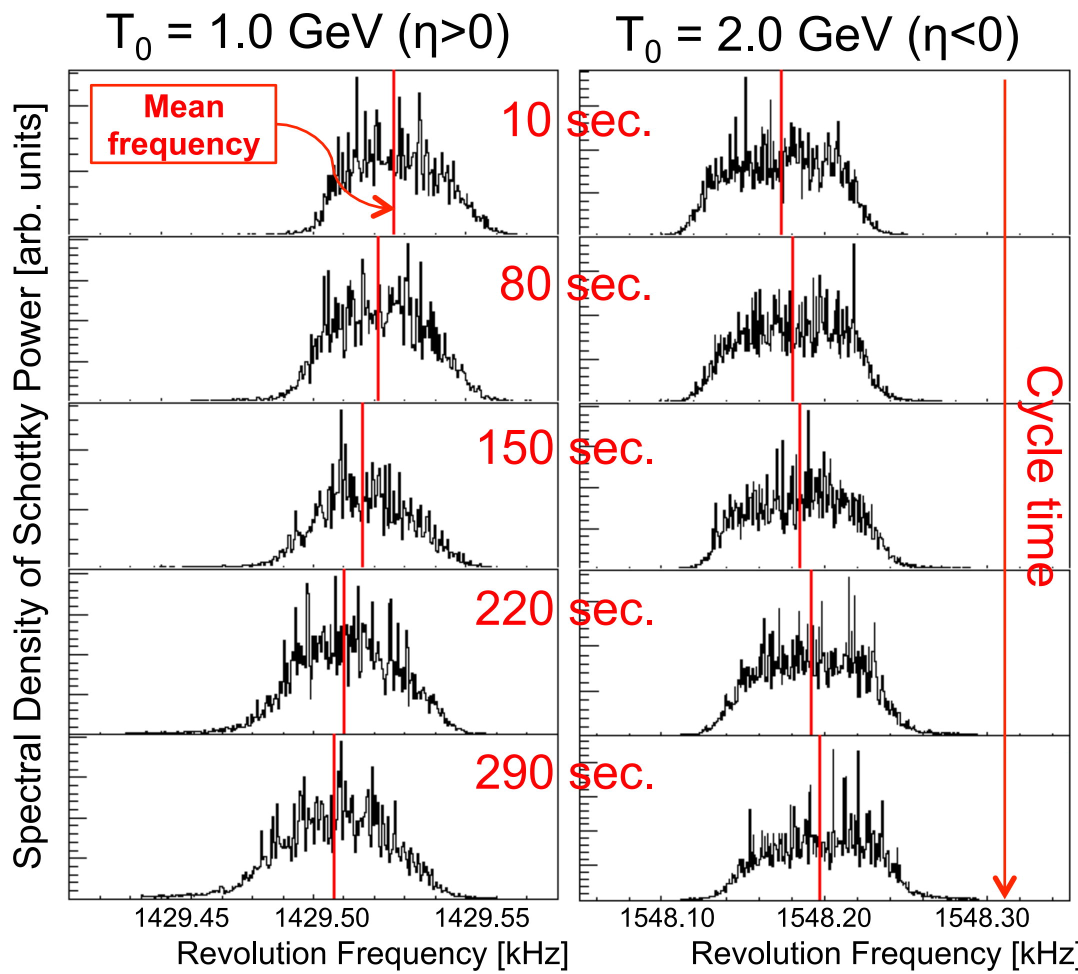
$$\frac{\Delta f}{f_0} = \alpha \frac{\Delta B}{B}$$

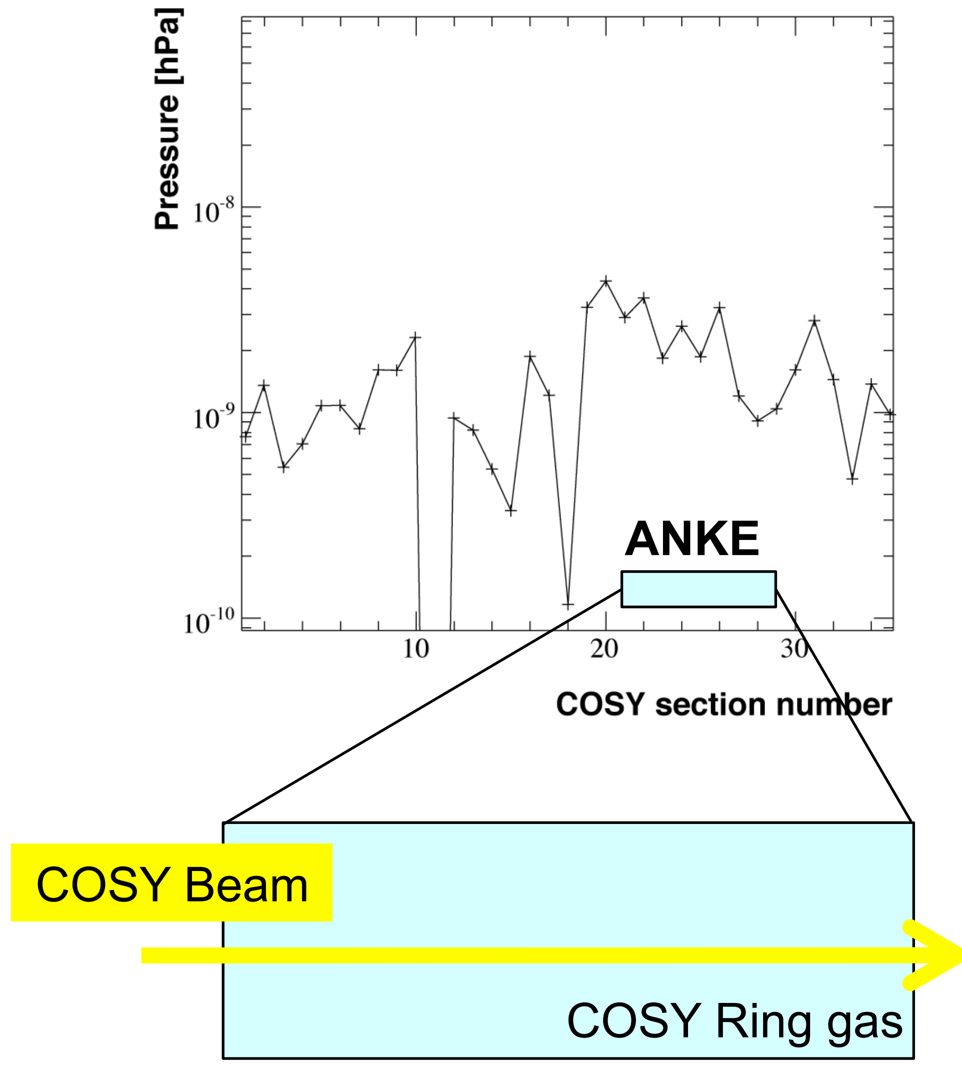
Target Density Determination: Frequency Shift

- Beam-target interaction gives energy loss that changes the machine frequency.
- Frequency change depends on η parameter
- Schottky distribution was recorded in every 10 sec. throughout the 300 sec. cycle.



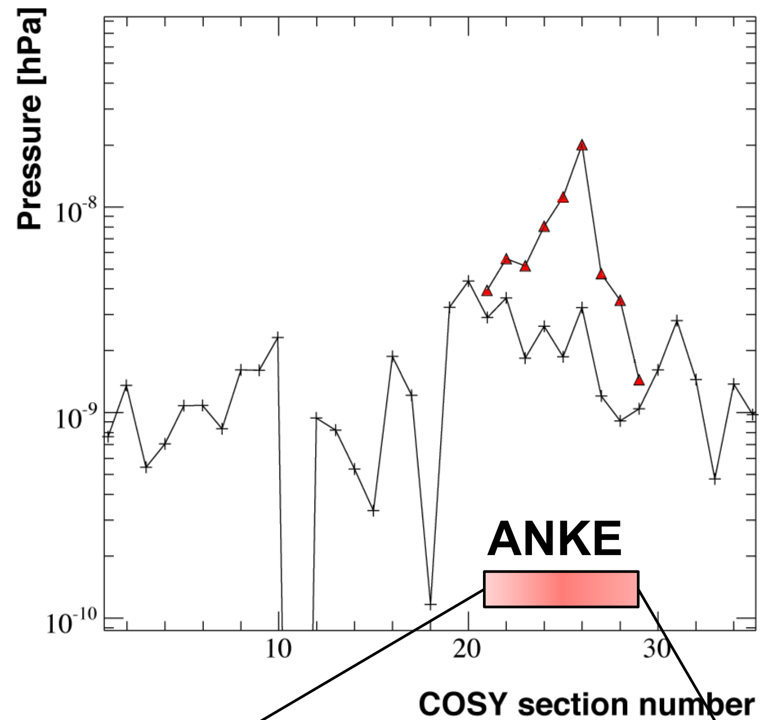
Target Density Determination: Residual Gas Effect

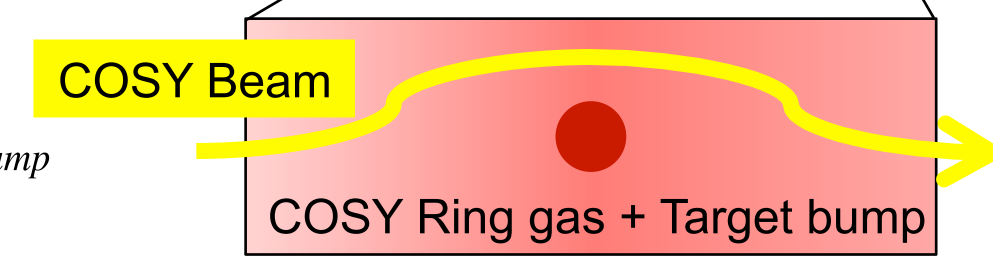
- Contribution of residual gas in the ring to the energy loss should be subtracted.



Target Density Determination: Residual Gas Effect

- Contribution of residual gas in the ring to the energy loss should be subtracted.
- Gas pressure rises in the vicinity of ANKE chamber when target is switched on
- Pressure bump was measured by steering the beam to the side of the target.
- $$\frac{df}{dt}_{target} = \frac{df}{dt}_{total} - \frac{df}{dt}_{ring+bump}$$





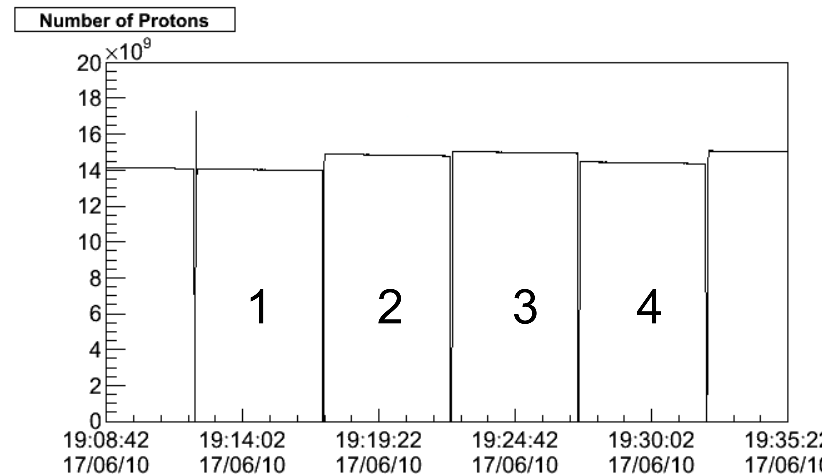
Luminosity

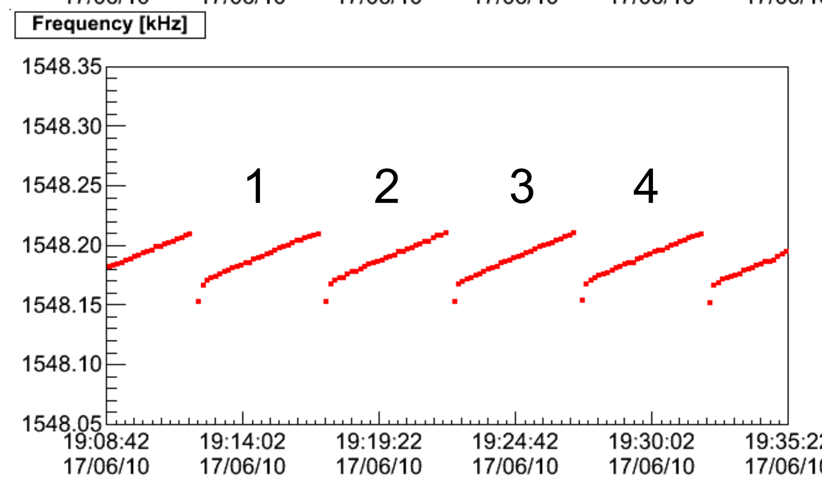
$$n_T = \left(\frac{1+\gamma}{\gamma}\right)\frac{1}{\eta}\frac{1}{(dE/dx)m}\frac{T_0}{f_0^2}\frac{df}{dt}$$

$$T_0 = 2.0\,\mathrm{GeV}$$

$$\eta = -0.07$$

$$f_0 = 1548.15\,\mathrm{kHz}$$



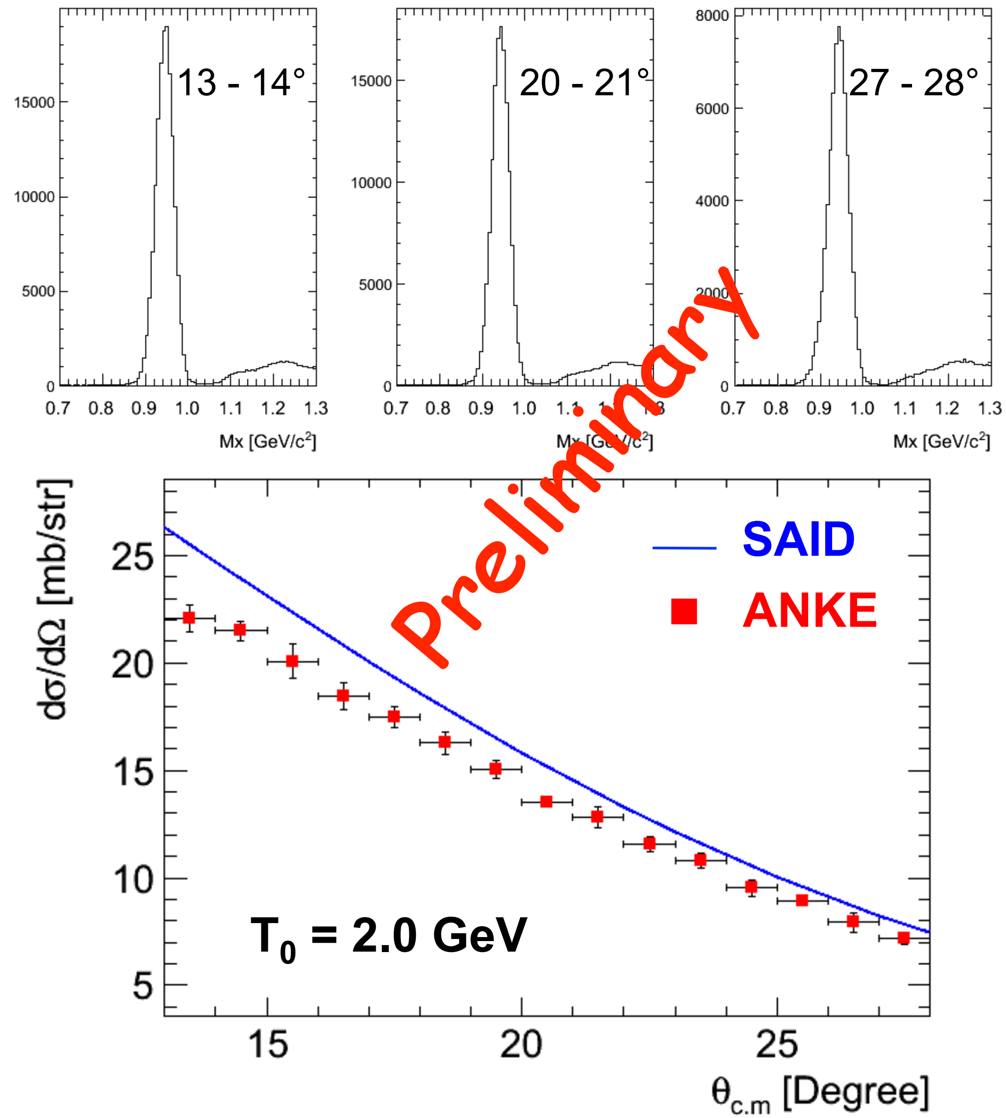


Cycle	df/dt	Target Density	Integrated Luminosity
1	0.152	2.75e+14	1.67e+33
2	0.151	2.74e+14	1.76e+33
3	0.154	2.79e+14	1.81e+33
4	0.149	2.70e+14	1.68e+33

With 2% accuracy

Preliminary Results: Cross Section

- Preliminary results of pp differential cross section in c.m. system for T_p = 2.0 GeV
- Only FD system is used.
- Clean identification of pp elastic process using the missing mass technique
- No corrections on detector efficiency yet.
- Total error expected ~ 5%.



Summary

- ANKE can provide robust pp data in energy region Tp = 1.0 – 2.8 GeV for c.m. angular range 5 – 30° (uncharted territory)
- High precision luminosity determination with schottky technique has been achieved (accuracy ~ 2 – 3%)
- Expected precision of differential cross section around 5% (analysis in progress).