Determination of the Effective Target Thickness and Luminosity from Beam Energy Losses at the ANKE Cluster-Jet Target

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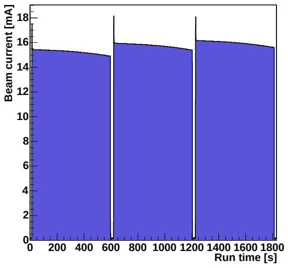
Luminosity via Schottky - Method

The thickness of a hydrogen cluster-jet target and the corresponding luminosity in an experiment at the ANKE spectrometer at the internal beam of the COSY accelerator were determined by measuring the energy loss of the circulating proton beam [1, 2]. Possible error sources of the measurement, especially residual gas influences, were carefully studied resulting in a relative accuracy better than ±10%. In parallel, the luminosity was determined by the standard technique of elastic scattering based on known cross sections. The results do compare reasonably well.

[1] H.J. Stein, D. Prasuhn, IKP Annual Report 2001. [2] K. Zapfe et. al, NIM A 368 (1996)



COSY beam current measured by a beam current transformer (BCT). Here shown for three 10 min cycles.

2.65 GeV coasting proton beam → hydrogen cluster-jet target

The luminosity is individually determined by for each cycle by multiplying the mean proton flux by the mean target density. The machine cycle time is 10 min.

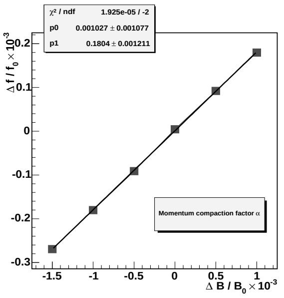
$$L = J_{beam} \cdot N_T$$

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

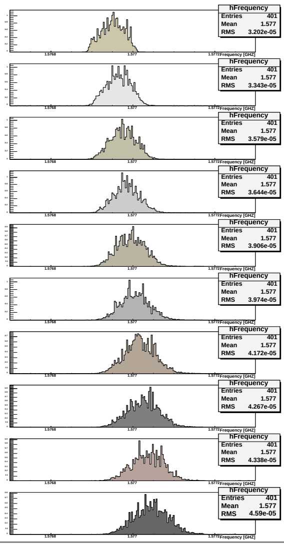
$$dT = \frac{\Delta T}{f_0 \Delta t} \qquad \frac{\Delta T}{T_0} = \frac{1+\gamma}{\gamma}\frac{\Delta p}{p_0} \qquad \frac{\Delta p}{p_0} = \frac{1}{\eta}\frac{\Delta f}{f_0}$$

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

- L - luminosity
- J_{beam} - flux of proton beam
- I_{beam} - COSY beam current
- q_p - proton electric charge (1.6×10^{-19} C)
- N_T - effective thickness of ANKE cluster target
- dT - energy loss per single target traversal
- dE/dx - stopping power of protons in hydrogen gas [NIST tables] (4.108 MeV cm² g⁻¹)
- m - proton mass (1.673×10^{-24}g)
- f_0 - revolution frequency, measured (1.577 MHz)
- T_0 - beam kinetic energy (2650 MeV)
- γ - Lorentz factor (3.824)
- p_0 - beam momentum (3463 MeV/c)
- η - off-momentum factor (- 0.115), based on measured α (0.1804)
- B_0 - COSY dipole magnetic field

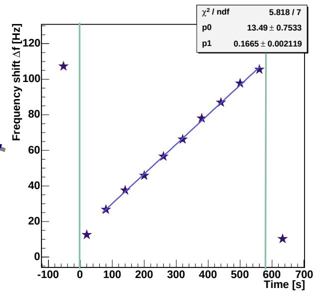


α measurement to determine η



Squared frequency distribution of the longitudinal Schottky noise measured every minute in a cycle. The squared distribution reflects the true momentum distribution.

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

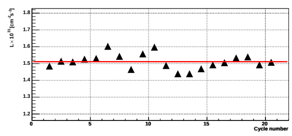


Frequency shift of the center of gravity of the Schottky spectra over one cycle.

Error estimation

1) typical frequency shift rate:	Δf/Δt = 0.167 Hz/s	σ ≤ 4%
2) eta:	η = - 0.115	σ = 2.5%
3) systematic residual gas effect:	≈ - (6 ± 3)%	
4) specific energy loss:	dE/dx	σ ≈ 1% ?
5) BCT signal:	I	σ ≤ 1%

In total we assume an error of less than 10% error.



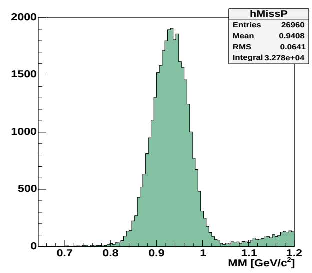
Average luminosity over the cycle's

Luminosity via *pp* elastic scattering

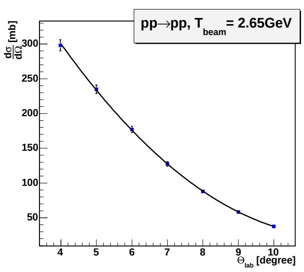
Error estimation

1) Detector Eff.	(5 ± 1)%
2) Acceptance	8.2%
3) Statistical error	2.2%
4) SAID	3%
5) BG Subtraction	2.7%

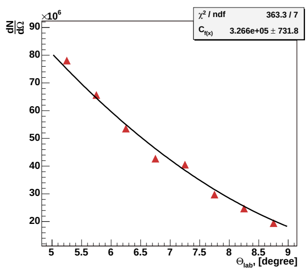
In total we assume an error of less than 16% error.



missing proton mass spectra by detecting fast proton in forward



Differential cross section from SAID database, angular range equivalent to our acceptance



Differential number of counts vs Θ_{lab} angle fitted by SAID curve

Final Results

Comparison of the luminosities determined by Schottky method ▼ and by elastic scattering ▲. Both results just coincide within the error limits, however, it is obvious that there is a constant systematic deviation of 15 % between both methods.