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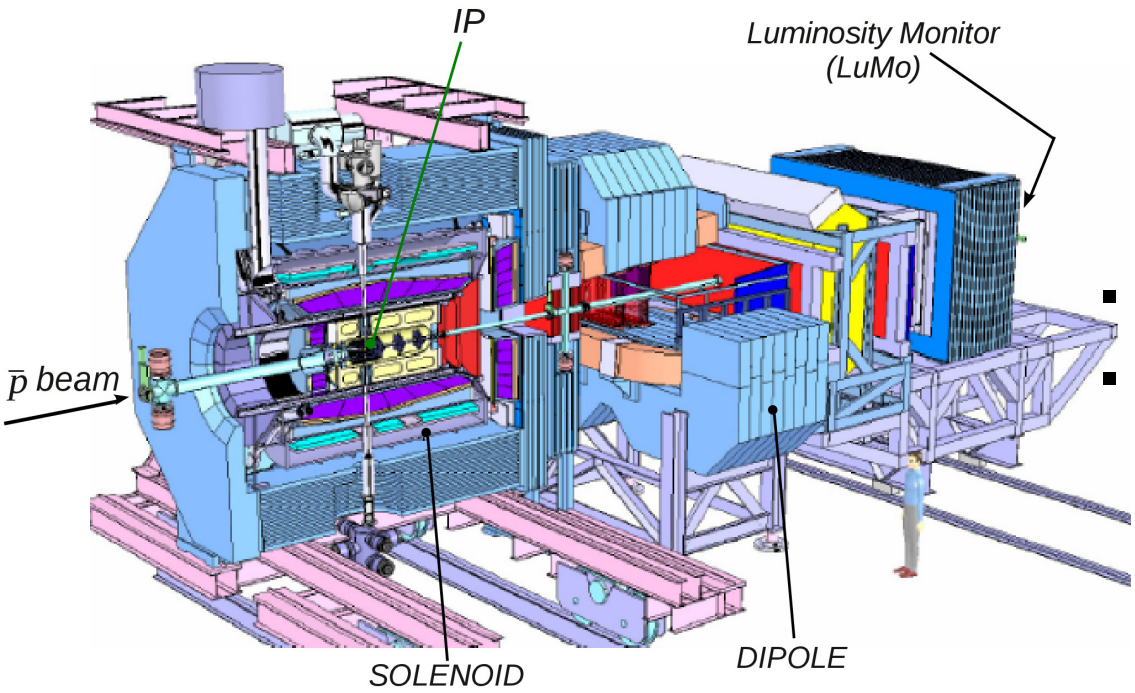
Simulation of the Luminosity Measurement for $\bar{\text{P}}$ANDA

March 6, 2012 | Tsitohaina Randriamalala

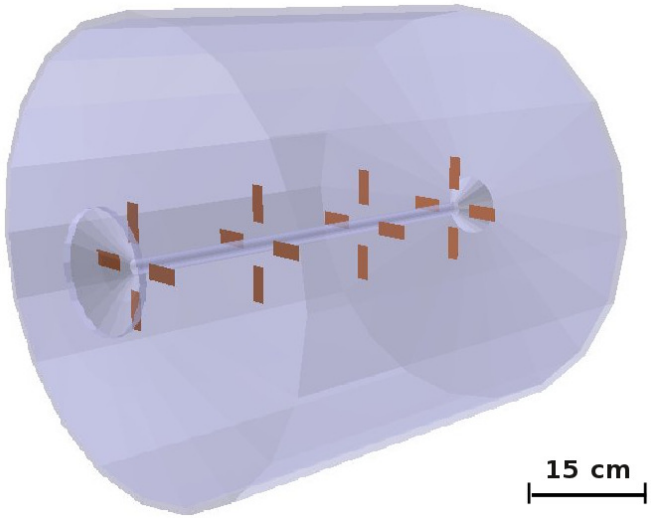
Outline

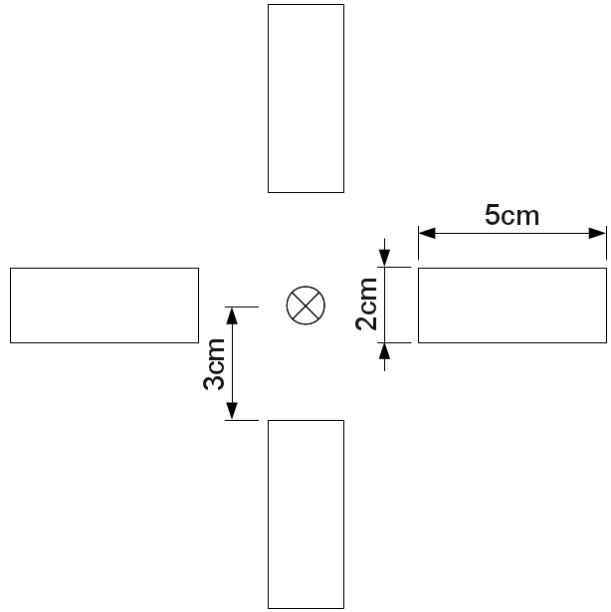
Introduction



- Distance IP-LuMo : 10.5 m
- LuMo: Measure of the elastically scattered $\bar{p}$ from the IP.

LuMo - Rectangular Sensors





- Double-sided silicon strip sensor of 50 μm pitch and 300 μm thick,
- Distance between adjacent planes: 20 cm,
- Polar angle coverage: $3 < \theta < 8\, mrad \Rightarrow$ measurement of the $\bar{p}p$ elastic scattering in *Coulomb-nuclear* interference region,
- *Goal*: Measure the luminosity with a precision of about 3%.

Simulation Setup

- *Event generator*: $d\sigma_{el}/dt$ implemented in DPM generator

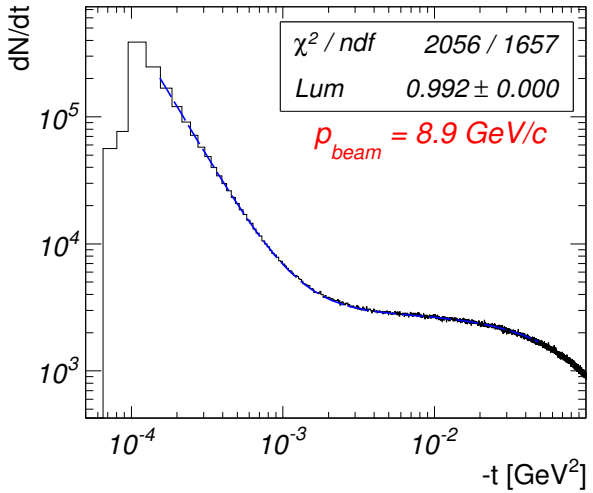
Parameter	Beam momentum $[GeV/c]$				
	1.5	4.06	8.9	11.91	15
$\theta_{min}[^\circ]$	0.20	0.21	0.29	0.25	0.22
$-t_{min}[GeV^2]$	$5 \cdot 10^{-6}$	$2 \cdot 10^{-5}$	$1 \cdot 10^{-4}$	$1 \cdot 10^{-4}$	$1 \cdot 10^{-4}$
ρ	-0.138	-0.061	-0.072	-0.080	-0.085
$b\,[GeV^2]$	13.442	12.253	11.729	11.656	11.619
$\sigma_{tot}[mb]$	80.818	73.066	56.123	50.374	47.217
$\sigma_{had}[mb]$	26.23	21.61	13.53	11.02	9.74
$\sigma_{coul}[mb]$	72.55	13.46	2.62	2.60	2.61

Simulation Setup (2)

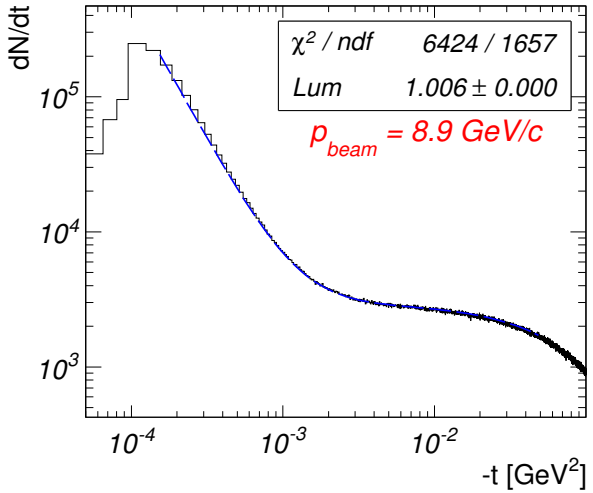
- Expected HESR beam emittance ($\varepsilon = 1\,mm \cdot mrad$) taken into account,
- Dipole magnetic field switched on,
- $n_{ev} = 10^7$, $\mathcal{L} = 10^{31}\,cm^{-2}s^{-1}$.

(Only $\mathcal{L}$ set free)

Generated $t-$spectrum



$t-$spectrum including beam emittance



Fit function:

$$\frac{dN}{dt} = \mathcal{L} \times \frac{d\sigma_{el}}{dt} \times \Delta\tau$$

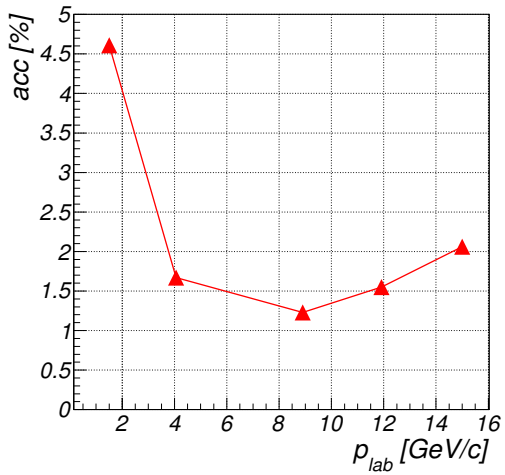
$\Longrightarrow$ 5 parameters: $\mathcal{L}$, ρ, b, σ_{tot} and $\Delta\tau$

$$\Delta\tau = \frac{n_{had}}{\mathcal{L} \times \sigma_{had}}$$

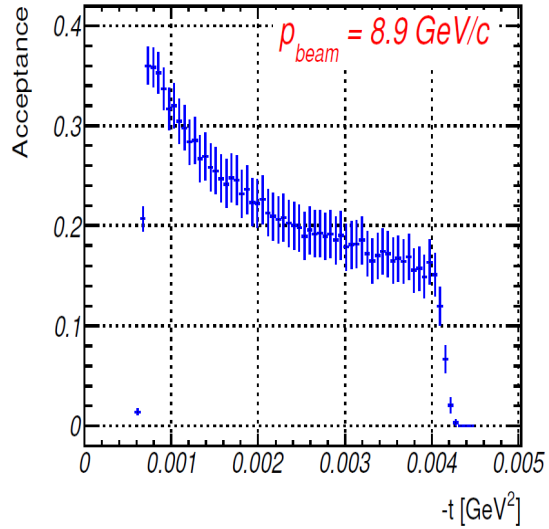
$$n_{had} = n_{ev} \frac{\sigma_{had}}{\sigma_{had} + \sigma_{coul}}$$

Detector Acceptance

- Ratio of the generated tracks which hit all four planes

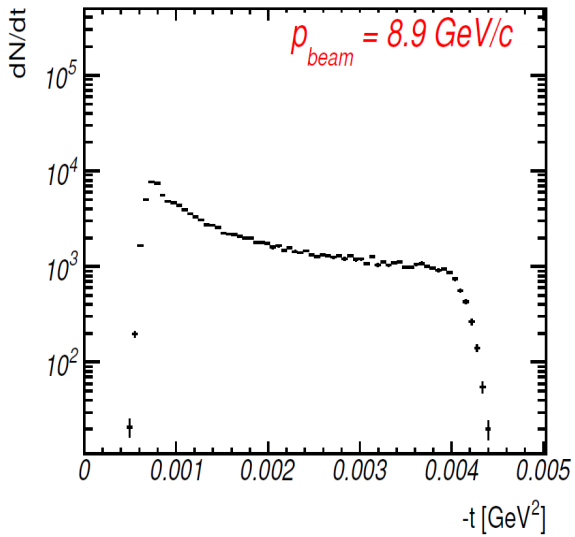


- Acceptance as function of t: Divide the dN/dt within the detector acceptance by the generated $t-$spectrum.



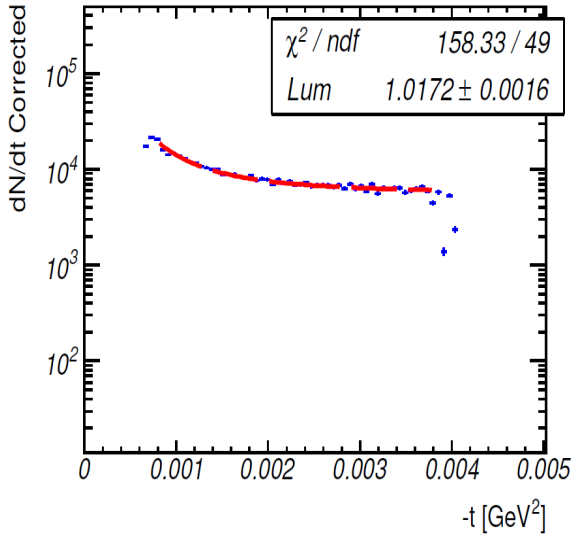
Luminosity Measurement

- Reconstructed dN/dt at the LuMo



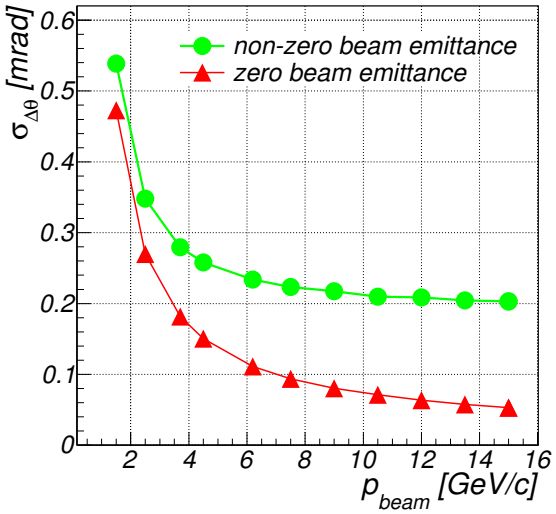
- $t-$spectrum corrected by the acceptance distribution
- Fit by $dN/dt = \mathcal{L} \times d\sigma_{el}/dt \times \Delta\tau$
  1. **Only $\mathcal{L}$ set free:**

  (systematic errors due to the detector resolution and the beam emittance)



Luminosity Measurement (2)

- Angular resolution:

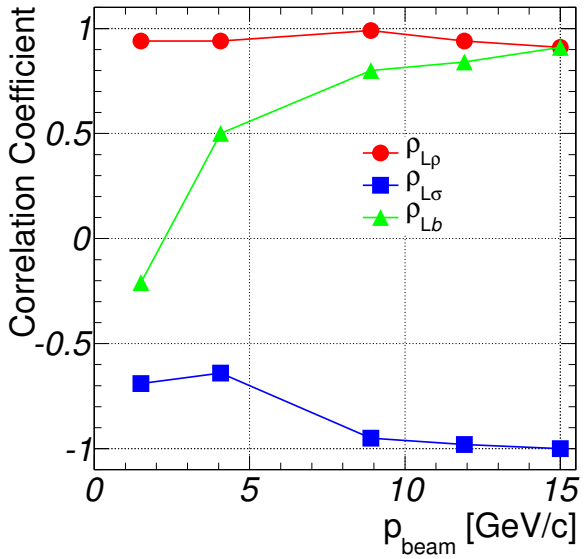


	Beam momentum $[GeV/c]$				
	1.5	4.06	8.9	11.91	15
$\mathcal{L}$ $[10^{31} cm^{-2} s^{-1}]$	0.9547	1.0205	1.0172	1.0146	1.0133
$\Delta\mathcal{L}/\mathcal{L}$ [%]	4.53	2.05	1.72	1.46	1.33

Luminosity Measurement (3)

2. Systematic errors due to ρ, b and σ_{tot}

- Correlation coefficients, $\rho_{\mathcal{L}p}$, between the luminosity and the cross section parameters $p = \{\rho, b, \sigma_{tot}\}$.

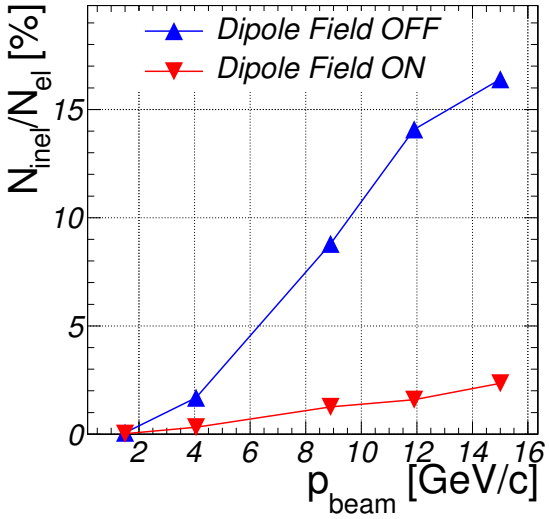


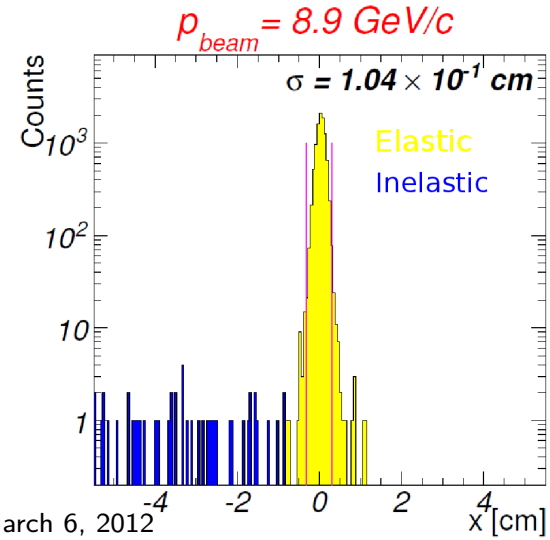
	Beam momentum $[GeV/c]$				
	1.5	4.06	8.9	11.91	15
$\rho \to \rho + 0.05$					
$\mathcal{L}$ $[10^{31} cm^{-2} s^{-1}]$	0.9605	1.0276	1.0242	1.0221	1.0201
$\Delta\mathcal{L}/\mathcal{L}$ [%]	0.61	0.69	0.77	0.74	0.67
$\Delta b/b = 1\%$					
$\mathcal{L}$ $[10^{31} cm^{-2} s^{-1}]$	0.9547	1.0205	1.0172	1.0146	1.0133
$\Delta\mathcal{L}/\mathcal{L}$ [%]	$< 10^{-4}$	$< 10^{-4}$	$< 10^{-4}$	$< 10^{-4}$	$< 10^{-4}$
$\Delta\sigma_{tot}/\sigma_{tot} = 1\%$					
$\mathcal{L}$ $[10^{31} cm^{-2} s^{-1}]$	0.9549	1.0223	1.0311	1.0325	1.0326
$\Delta\mathcal{L}/\mathcal{L}$ [%]	0.02	0.27	1.37	1.76	1.90
Total systematic error [%]	4.57	2.18	2.27	2.40	2.41

Luminosity Measurement (5)

3. Physical background: $\bar{p}p$ inelastic scattering process

- $\bar{p}p$ inelastic events generated by DPM,
- Inelastic events rate in the LuMo strongly suppressed by the dipole magnetic field,
- Reconstructed tracks are pointed back to the IP





Cut within the elastic region
$\Longrightarrow$ negligible inelastic events rate in the relevant $t-$range for the LuMo.

Luminosity Measurement (6)

4. Statistical error

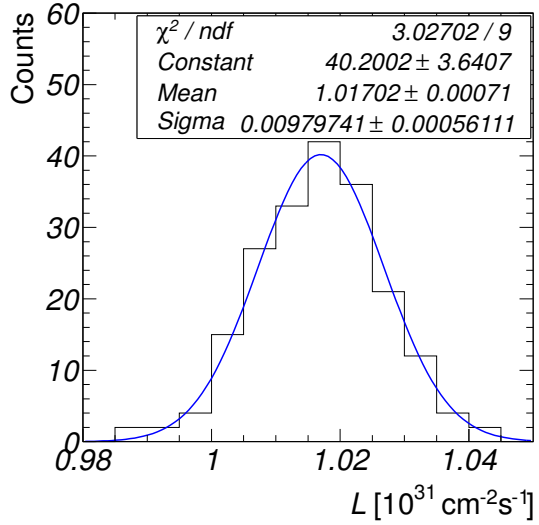
- Generate $N = 200$ data sets of n_{ev} $\bar{p}p$ elastic scattering events
  - fit reconstructed $t-$spectrum
  - plot measured luminosity
- Statistical error less than 1% achieved after about 25 seconds.

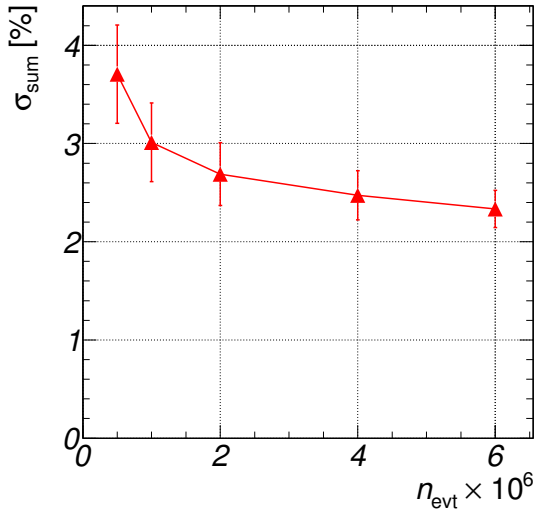
5. Summary

- $\sigma^2_{sum} = \sigma^2_{stat} + \sigma^2_{syst}$

(Case where the cross section parameters are known with high precision)

$p_{beam} = 8.9\ GeV/c,\ n_{ev} = 4 \times 10^6$





Conclusion

- Simulation of the luminosity measurement was performed using the DPM event generator.
- Systematic errors were estimated by:
  - considering the effect of the detector resolution and the beam emittance,
  - considering the effect of systematic uncertainties on the ρ, b and σ_{tot},
  - investigating the rate of $\bar{p}p$ inelastic events in the LuMo.
- Statistical error of less than 1% can be easily achieved.
- The goal of 3% uncertainty on the luminosity measurement is feasible if ρ, b and σ_{tot} are accurately known ($< 1\%$).

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Thank you

- Differential cross section:

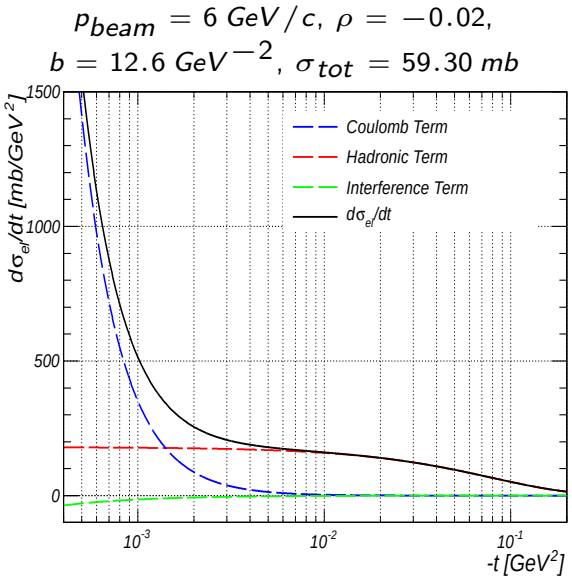
$$\frac{d\sigma_{el}}{dt} = \frac{d\sigma_{coul}}{dt} + \frac{d\sigma_{had}}{dt} + \frac{d\sigma_{int}}{dt};$$

where:

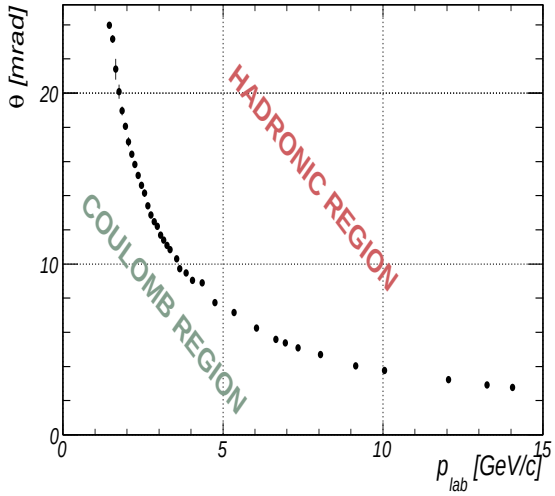
$$\frac{d\sigma_{coul}}{dt} = \frac{4\pi(\hbar c)^2\alpha_{em}^2 G^4}{\beta^2 t^2},$$

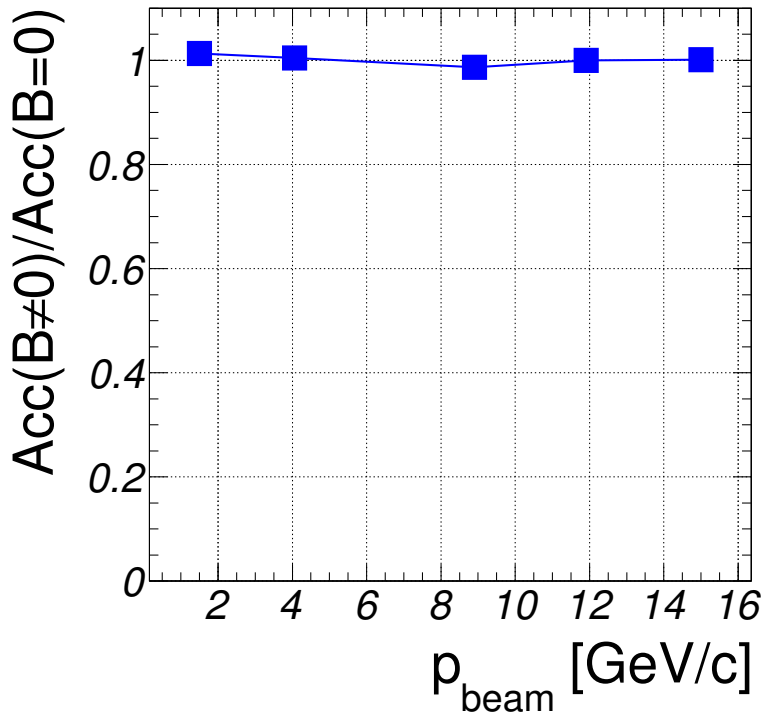
$$\frac{d\sigma_{had}}{dt} = \frac{(1+\rho^2){\sigma_{tot}}^2}{16\pi(\hbar c)^2} e^{-b|t|},$$

$$\frac{d\sigma_{int}}{dt} = -\frac{\sigma_{tot}\alpha_{em}G^2}{\beta|t|}(\rho+\delta)e^{-\frac{b}{2}|t|}.$$



- Coulomb-nuclear interference region: $3 < \theta < 25\ mrad$.




Acc(B≠0)/Acc(B=0)
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
16
p_beam [GeV/c]