Jefferson Lab Hall A Beamline Instrumentation and Calibration for GMP experiment

Thir Gautam
Hampton University

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Thomas Jefferson National Accelerator Facility

Outline

- Introduction to GMP Experiment: Proton Magnetic Form Factor:

  (I) Physics motivation

  (ii) Requirements on systematic uncertainties

- Hall A beamline instrumentation:

  (I) Beam Position Measurement/Calibration

  (II) Beam Charge Measurement/Calibration

- Conclusion

Introduction to GMP Experiment: Proton Magnetic Form Factor

- Form factors encode electric and magnetic structure of the target

  → At low Q^2, form factors characterize the spatial distribution of electric charge and magnetization current in the nucleon

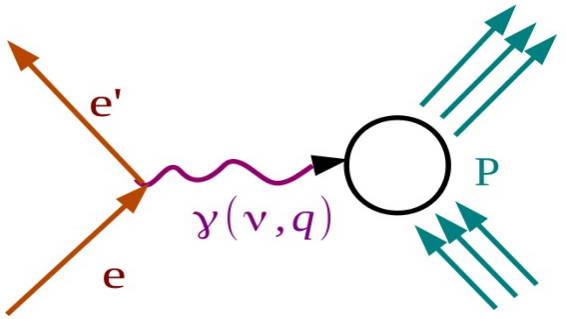
$$|\text{Form Factor}|^2 = \frac{\sigma(\text{Structured object})}{\sigma(\text{Point like object})}$$

$$\mathcal{J}_{\text{proton}} = e\bar{N}(p')\left[\gamma^{\mu}F_1(Q^2) + \frac{i\sigma^{\mu\nu}q_{\nu}}{2M}F_2(Q^2)\right]N(p)$$

$$G_E = F_1 - \tau F_2 \qquad G_M = F_1 + F_2$$

- In one photon exchange approximation the cross-section in *ep* scattering when written in terms of G_M^p and G_E^p takes the following form:

$$\frac{d\sigma}{d\Omega} = \sigma_{Mott}\frac{\epsilon(G_E^p)^2 + \tau(G_M^p)^2}{\epsilon(1+\tau)}, \qquad \sigma_{Mott} = \frac{\alpha^2\cos^2\frac{\theta}{2}}{4E^2\sin^4\frac{\theta}{2}}\frac{E'}{E}$$



Where,

$$\tau = \frac{Q^2}{4M^2}, \qquad \epsilon = \left[1 + 2(1+\tau)\tan^2\left(\frac{\theta}{2}\right)\right]^{-1}$$

ϵ - Virtual photon polarization

GMP Experiment at Hall A JLab

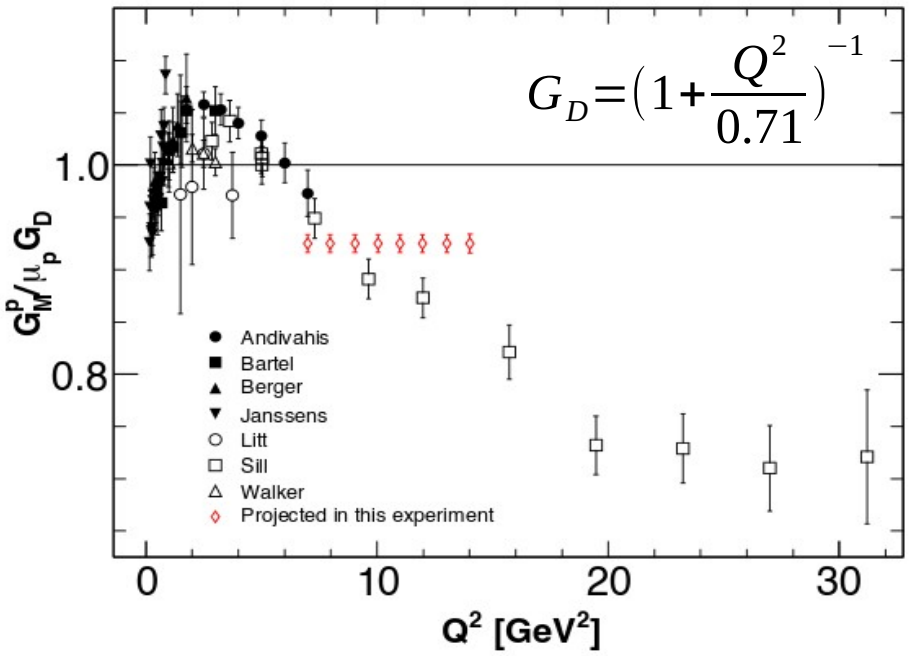
- Accurate measurement of the elastic *ep* cross-section in the Q^2 range of 7-14 GeV^2 and extraction of proton magnetic form factors
  - To improve the precision of the previous experiment
  - To provide insight into scaling behavior of the form factors at high Q^2
  - To understand two photon exchange contribution in *ep* elastic scattering

Goal: 2% or less total uncertainty

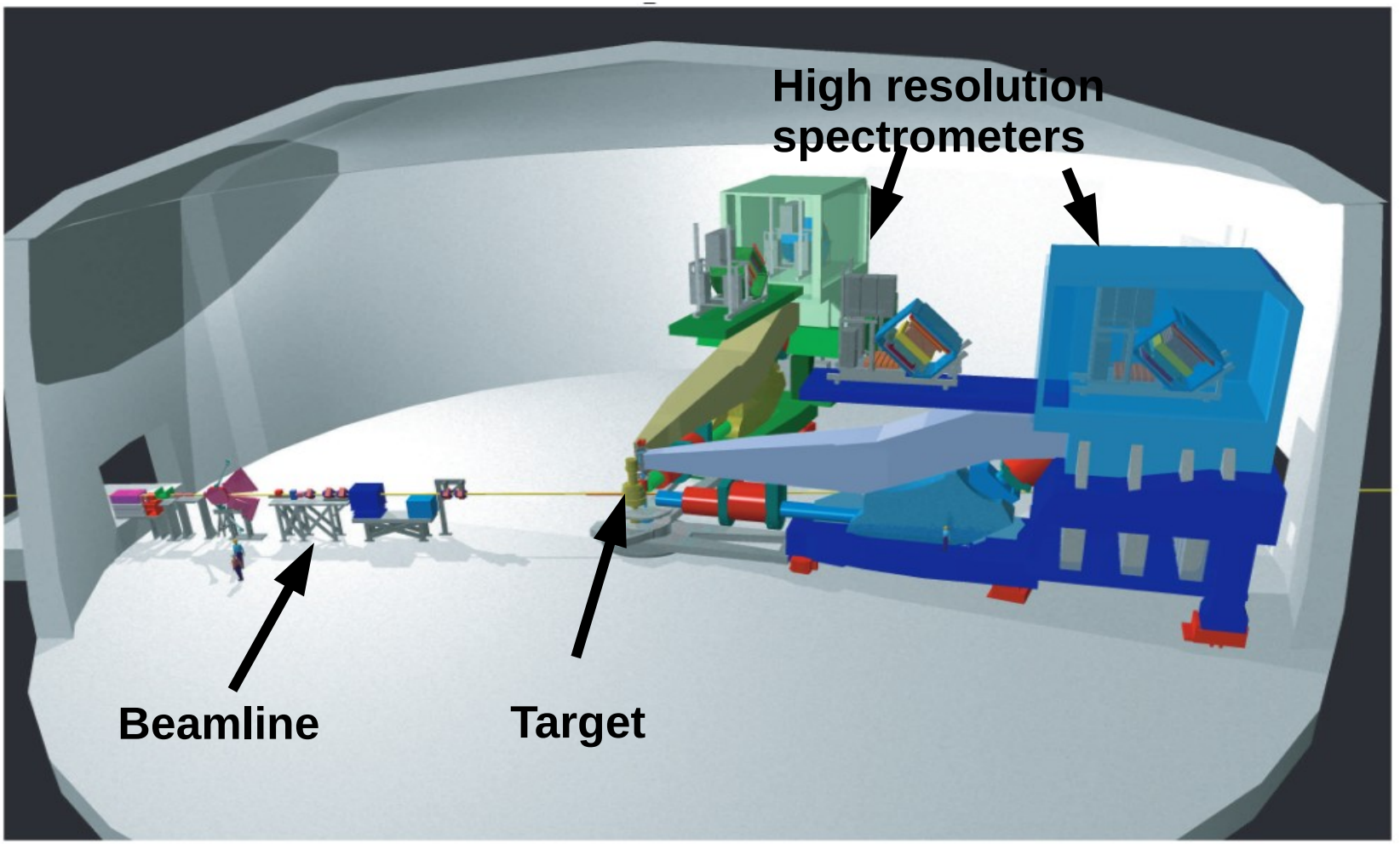
Syst: 0.5-0.8%
Point to point: 0.8-1.1%

Need a good control on:

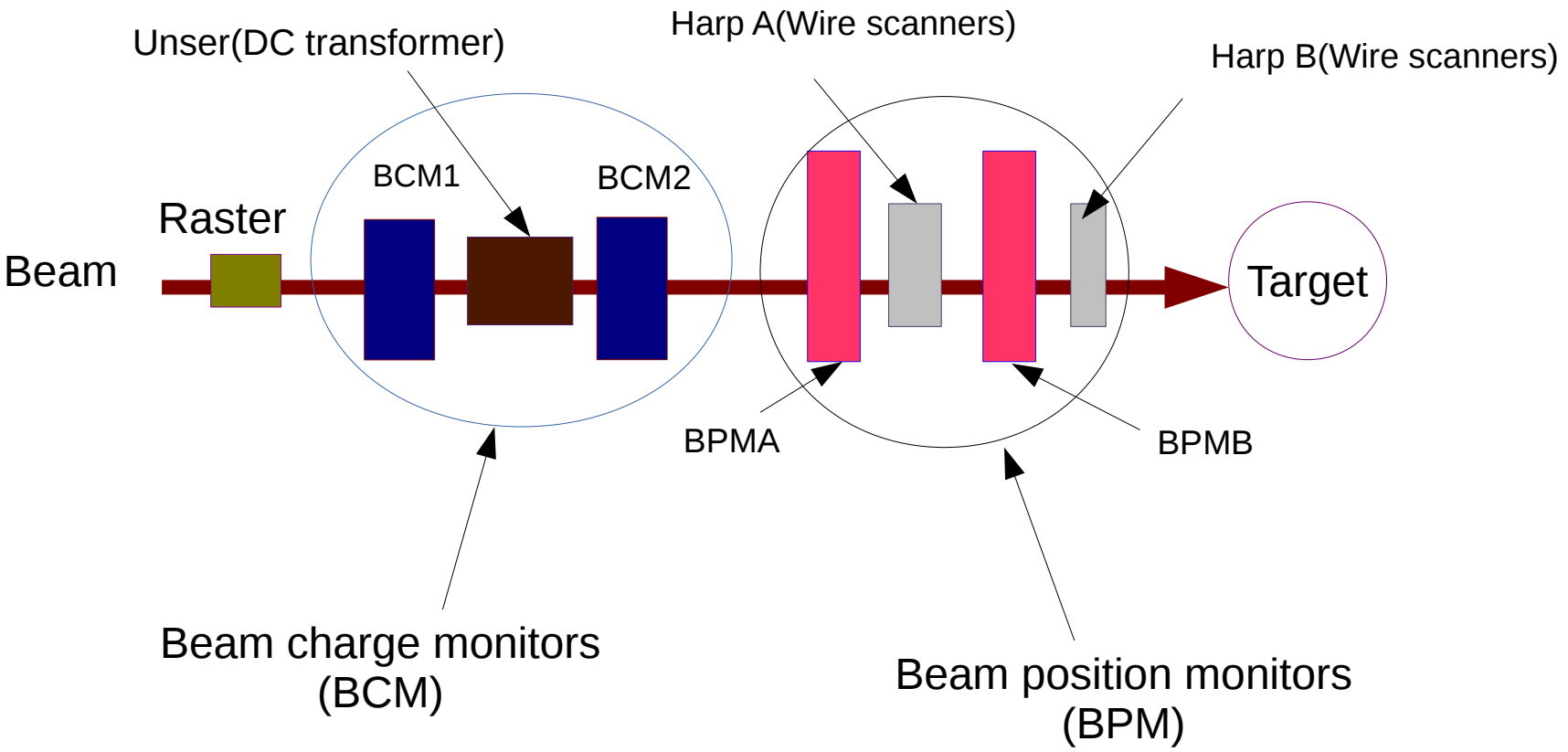
- Beam charge
- Beam position
- Scattering angle, target density, ...



Hall A arms and beamline transport

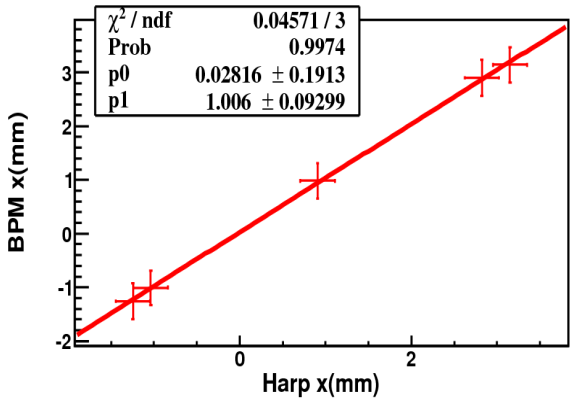


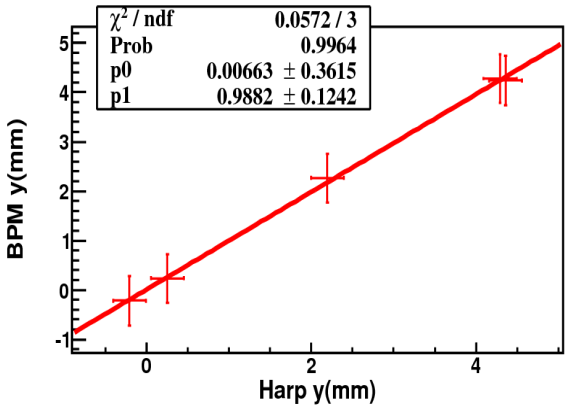
Hall A Beamline instrumentation



Beam Position Calibration

- The main components of beam position monitoring system are two BPMs and two Harp
- BPM is a cavity with four wire antennas whose signal is proportional to the distance from the beam and Harp is a system of three wire use to measure the beam profile
- Difference over sum technique is used to find relative beam position
- The relative position from BPM is calibrated to match the absolute beam position known from the Harp





BPM Relative coordinates(x',y')

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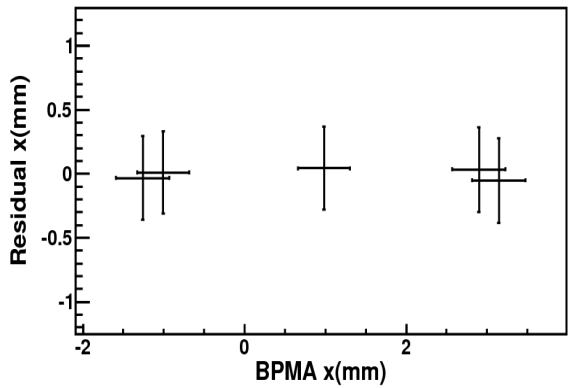
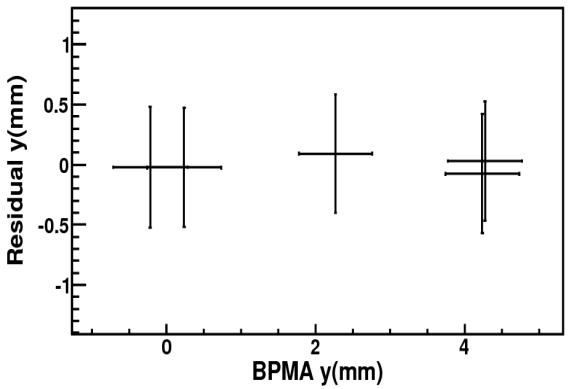
Hall coordinates (x,y)

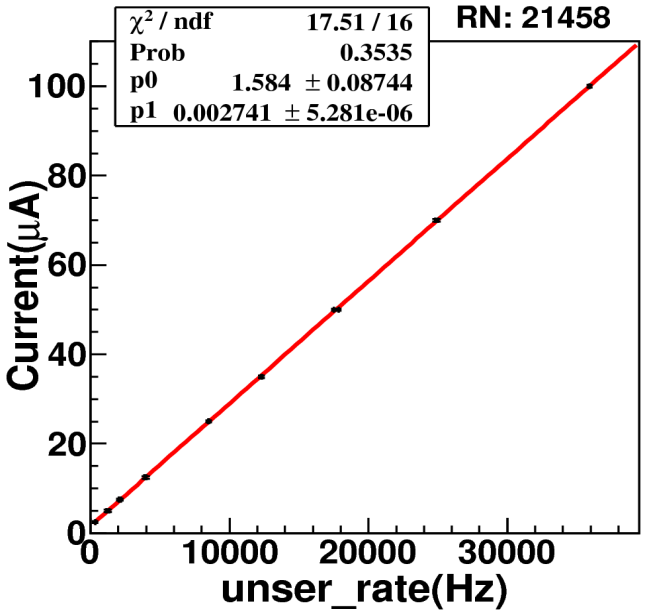


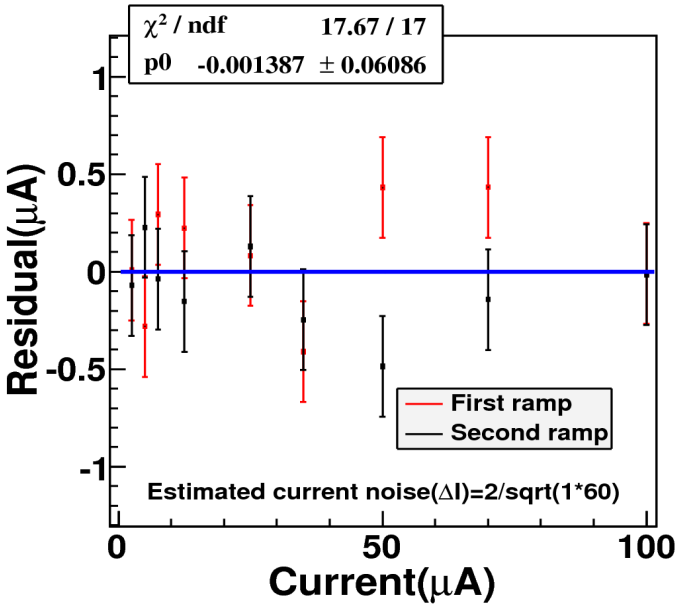


$$\begin{pmatrix} x \\ y \end{pmatrix}_{Abso} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \begin{pmatrix} x' \\ y' \end{pmatrix} + \begin{pmatrix} x_{of} \\ y_{of} \end{pmatrix}$$

Beam Current Calibration (I): Unser calibration

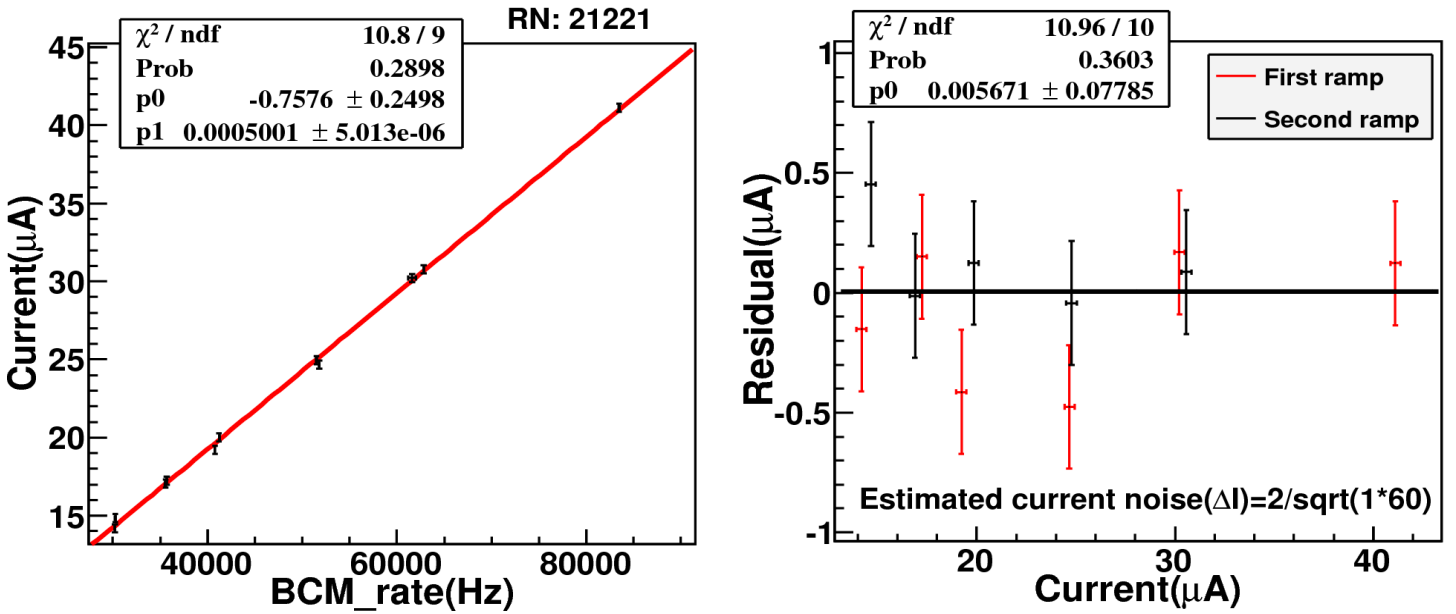
- The beam current measurement system consist of an unser monitor and two BCM cavities
- The unser monitor is a toroidal transformer sensitive to the DC currents passing through its cores
- Output signal of unser monitor drifts significantly on a time scale of several minutes and can't be used for long term beam current monitoring
- Unser is calibrated by passing high-precision current along a wire through the device
- Precise knowledge of the beam current from unser monitor is used for BCM calibration





Beam Current Calibration (II): BCM Calibration

- A BCM is a cylindrical resonant cavity whose output voltage is proportional to the beam current
- The signal from the BCM cavity is send to a V-F converter and then fed to Fastbus scalers
- BCM calibration obtains the parameters to convert the scaler counts into electron charge
  - Standardize deviation of the residual in the range of 15 to 40 uA indicates a beam current precision of 0.39%



Conclusion

- First real data from 12 GeV commissioning of GMP was done in spring 2015
- Beamline instruments were calibrated using the commissioning data
  - The beam position is determined to an accuracy of 1.5%
  - The beam current accuracy is about 0.39%
- We are going to take the production data in spring 2016