PROJECT

BEAM POSITION MONITOR AND ENERGY ANALYSIS

MEPAS SCHOOL 2015

DATE 16-NOV.

STUDENT DAVID PAVEL JUAREZ LOPEZ

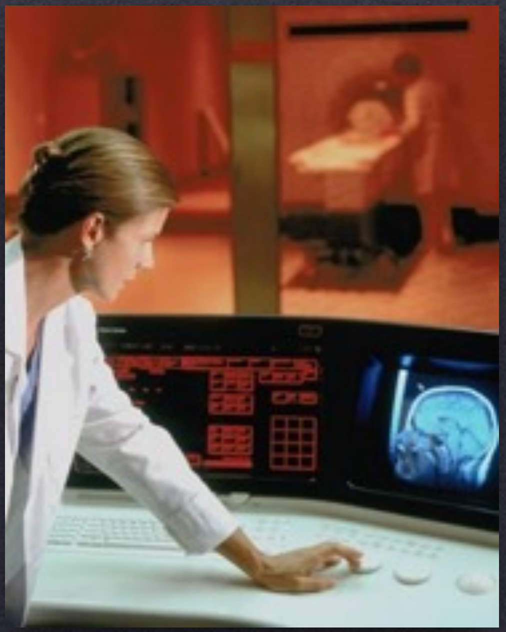
Fermilab

TALKING POINTS

- Motivation
- Introduction to FAST Facility
- Accelerator Beam Lattice
- Theory
- Measurements and Simulations
- Conclusions

MOTIVATION

* Medicine
  * Magnetic resonance imaging
  * Cancer therapy
  * Diagnostic instrumentation



* Industry
  * Power transmission
  * Transportation
  * Biomedicine

* Computing
  * The World Wide Web
  * The Grid

http://www.fnal.gov/pub/science/particle-physics/benefits/medicine.html

- Food sterilization
- Medical isotope production
- Simulation of cancer treatments
- Reliability testing of nuclear weapons
- Scanning of shipping containers
- Proposed combination of PET and MRI imaging
- Improved sound quality in archival recordings
- Parallel computing
- Ion implantation for strengthening materials
- Curing of epoxies and plastics
- Data mining and simulation
- International relations
- Nuclear waste transmutation
- Remote operation of complex facilities
- …

http://www.fnal.gov/pub/science/particle-physics/benefits/medicine.html

Pigment Discoloration
DOI: 10.1002/ange.201411691

Plumbonacrite Identified by X-ray Powder Diffraction Tomography as a Missing Link during Degradation of Red Lead in a Van Gogh Painting

*Frederik Vanmeert, Geert Van der Snickt, and Koen Janssens**

Pigments
International Edition: DOI: 10.1002/anie.201505840
German Edition: DOI: 10.1002/ange.201505840

Evidence for Degradation of the Chrome Yellows in Van Gogh's *Sunflowers*: A Study Using Noninvasive In Situ Methods and Synchrotron-Radiation-Based X-ray Techniques

Letizia Monico, Koen Janssens, Ella Hendriks, Frederik Vanmeert, Geert Van der Snickt, Marine Cotte, Gerald Falkenberg, Brunetto Giovanni Brunetti, and Costanza Miliani*

BIZARRE APPLICATIONS

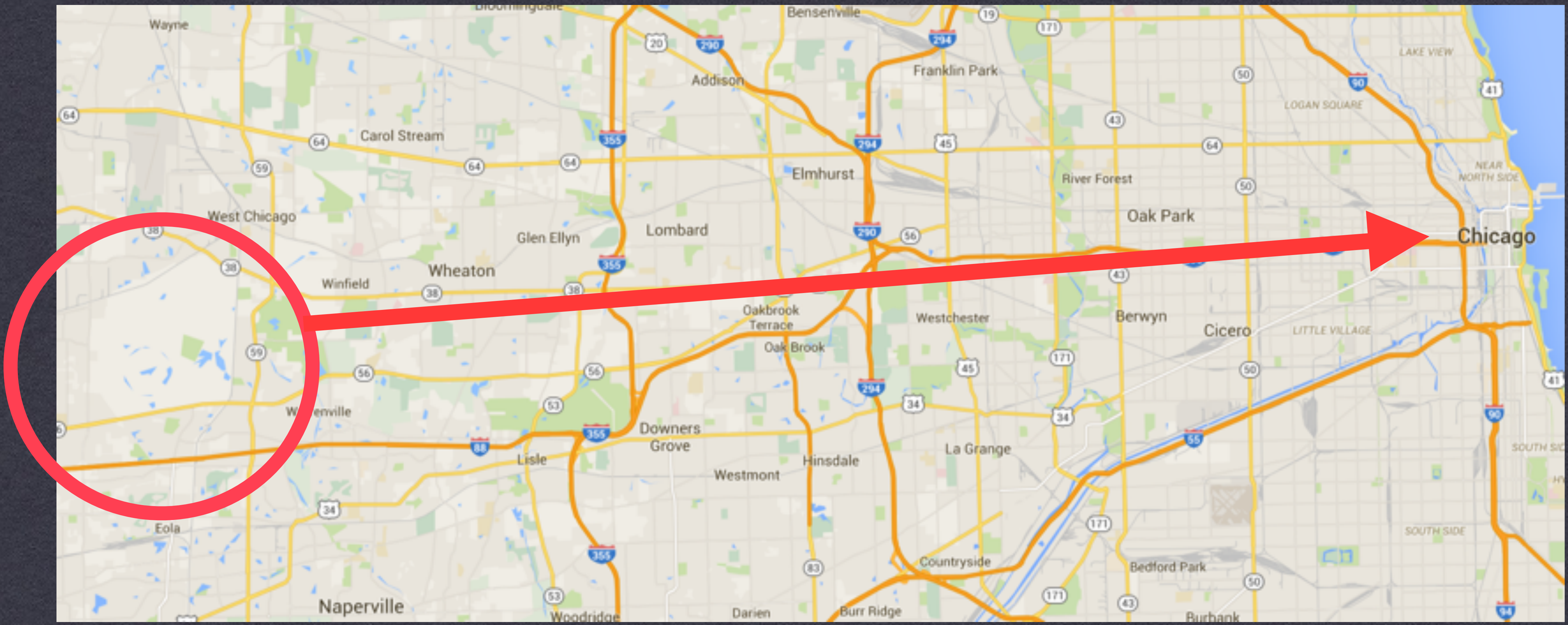
WHY VAN GOGH'S SUNFLOWERS ARE WILTING

VAN GOGH'S PIGMENT UP CLOSE: PLUMBONACRITE REVEALED AS INTERMEDIATE IN DEGRADATION OF RED LEAD

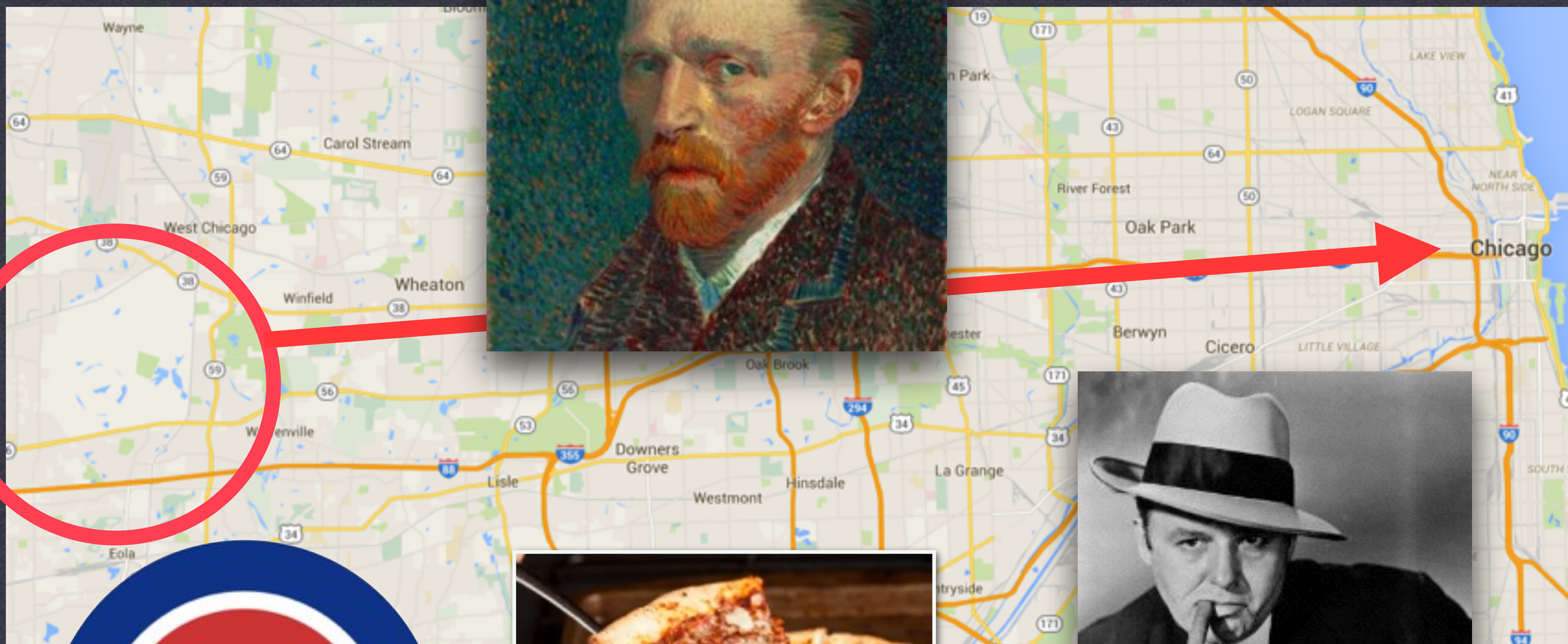
X-RAY EXAMINATION SHOWS HOW CHROME YELLOW DARKENS

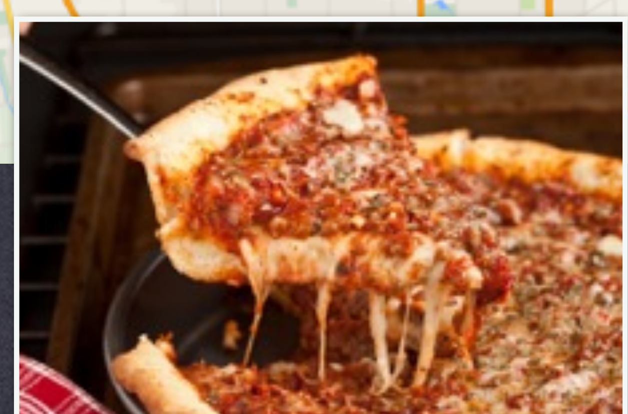
INTRODUCTION TO FERMILAB ACCELERATOR SCIENCE AND TECHNOLOGY

WHERE IS FERMILAB? - 50KM FROM CHICAGO



WHERE IS FERMILAB? - 50KM FROM CHICAGO

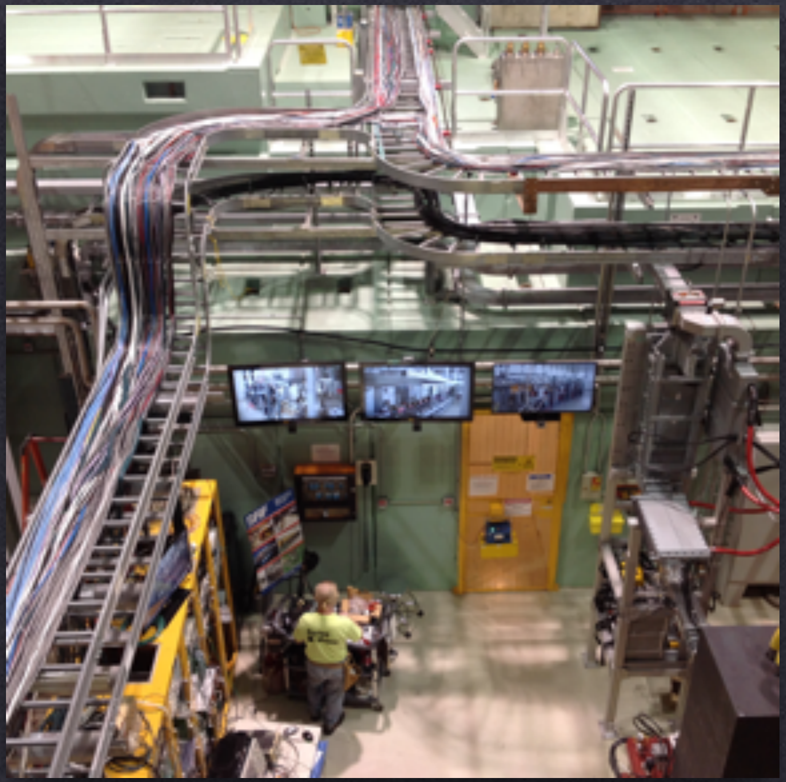


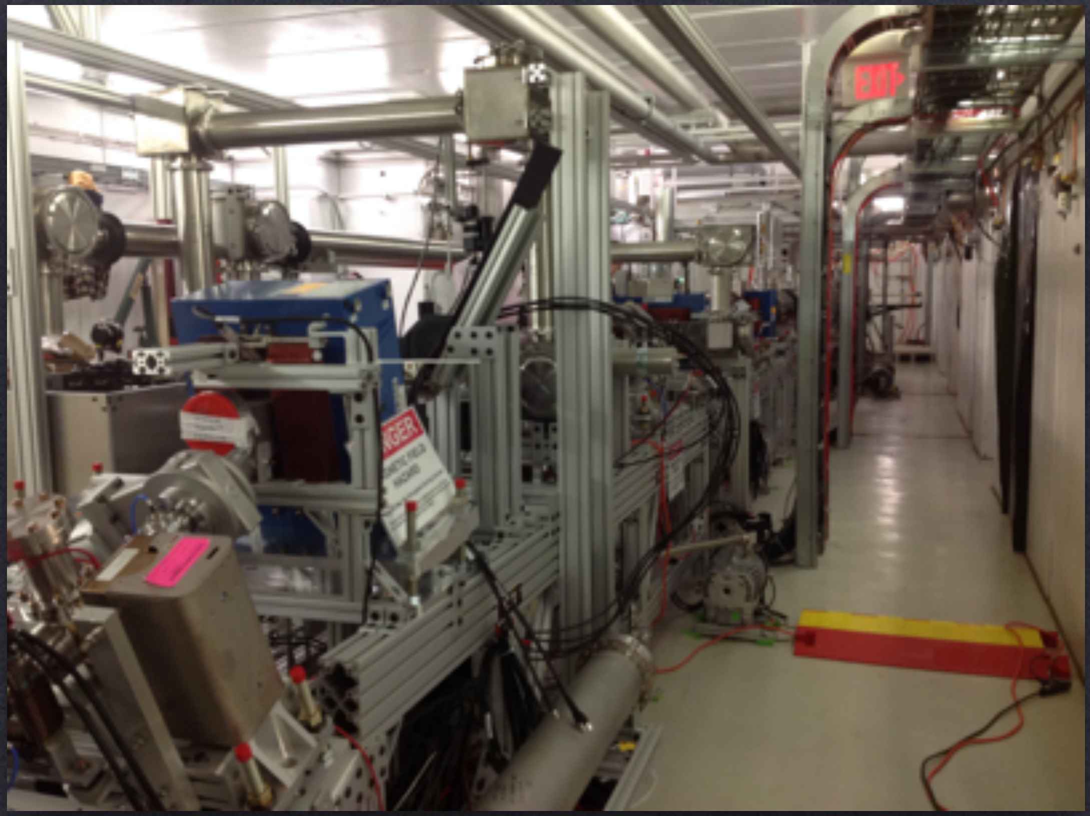


OVERVIEW OF FAST FACILITY

http://www.fnal.gov/

NML BUILDING





FAST: WHAT IS IT?

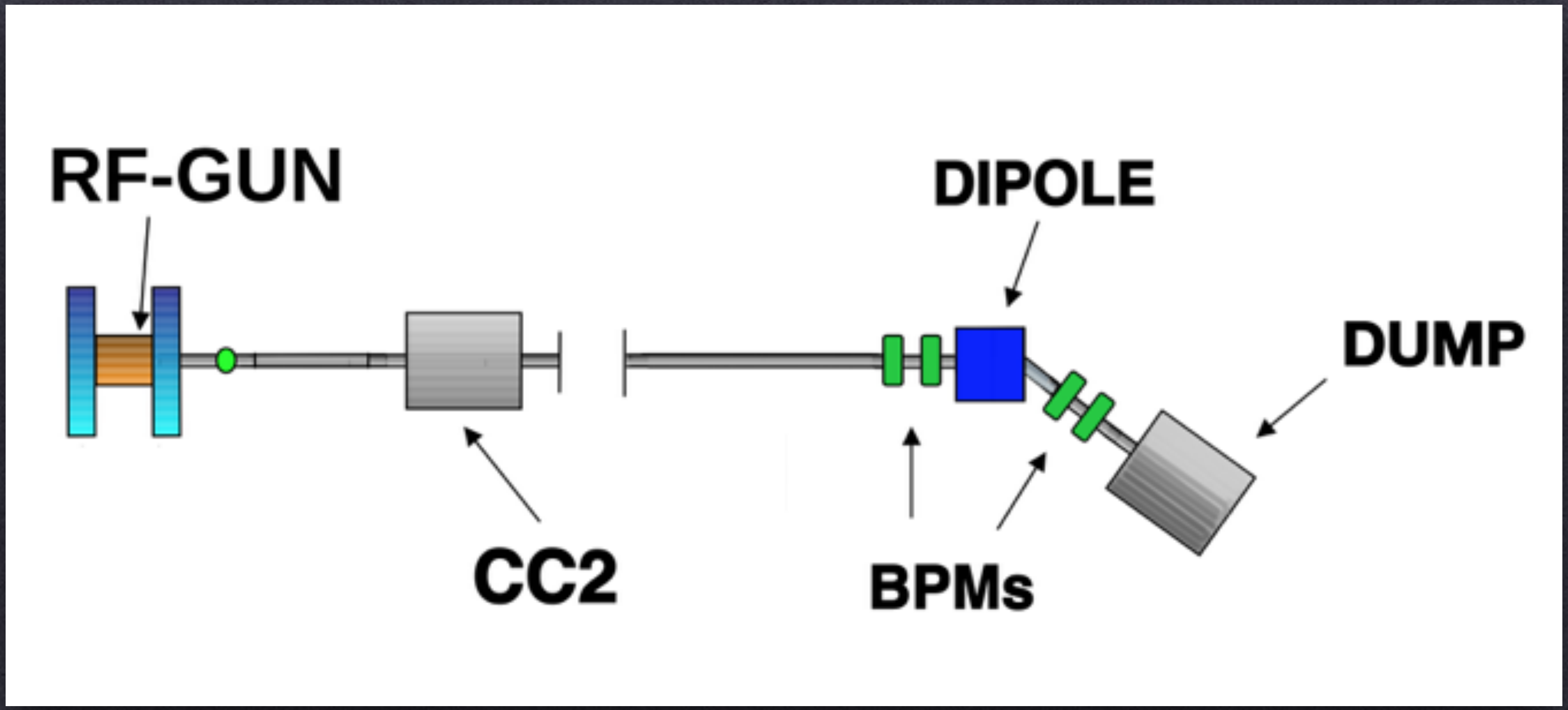
The Fermilab Accelerator Science and Technology (FAST) program is based on the capability provided by an SRF linac (which provide electron beams from 50 MeV to nearly 1 GeV) and a small storage ring to enable a broad range of beam-based experiments to **study fundamental limitations to beam intensity and to develop transformative approaches to particle-beam generation**

WHAT DO WE GOING TO DO:

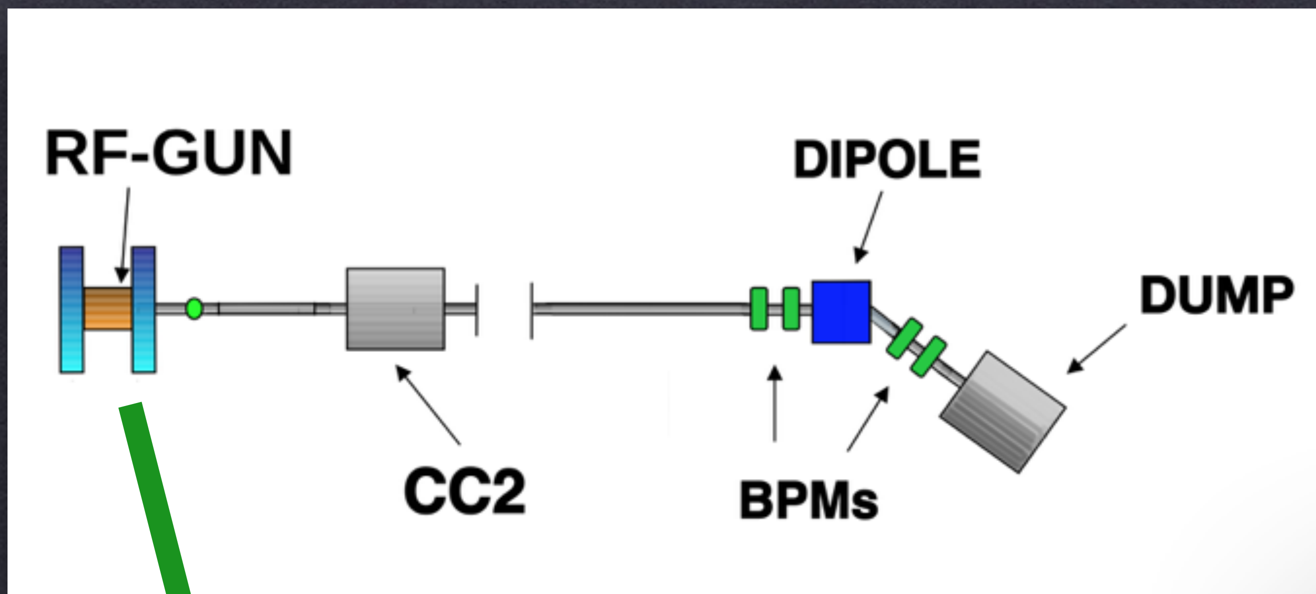
Measure the gun energy

ACCELERATOR BEAM LATTICE

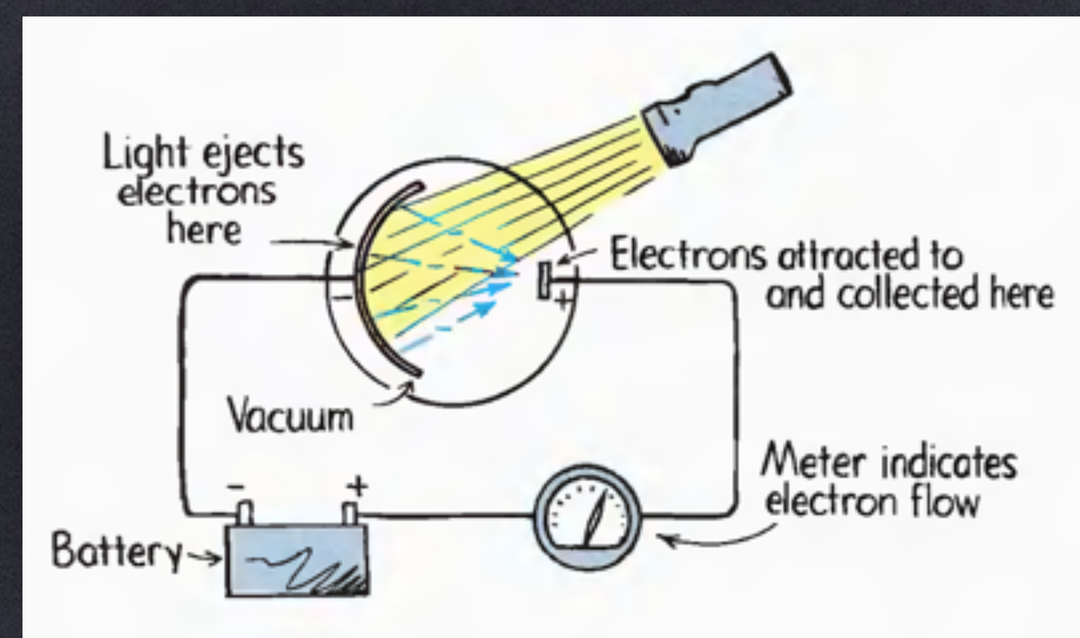
ACCELERATOR LATTICE

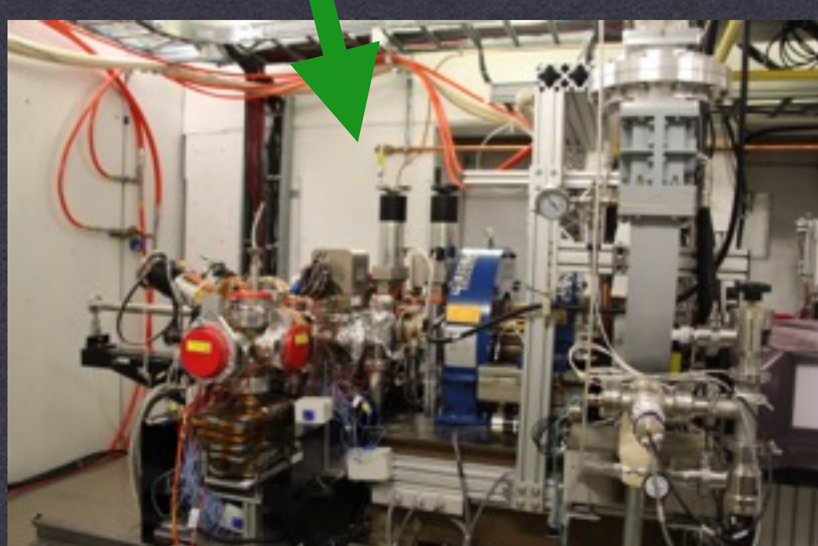


ACCELERATOR LATTICE



PHOTOELECTRIC EFFECT

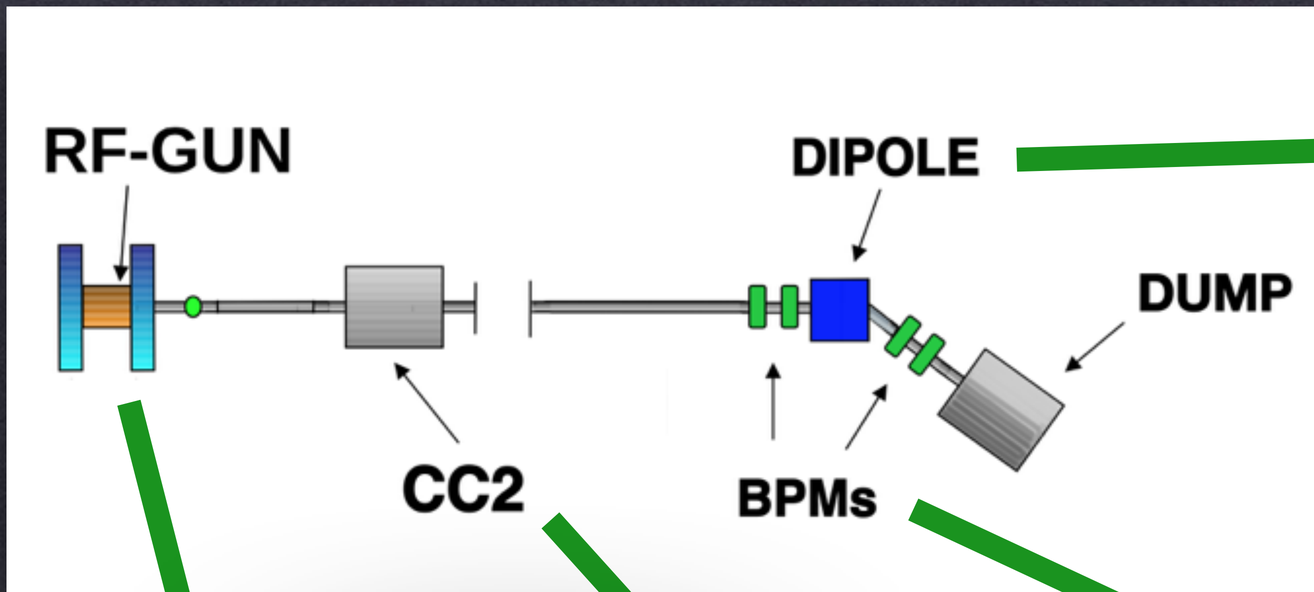


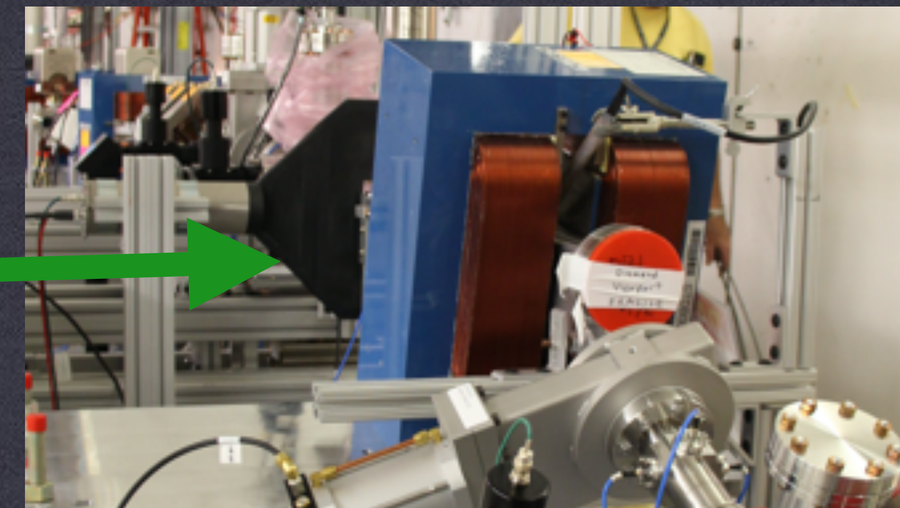


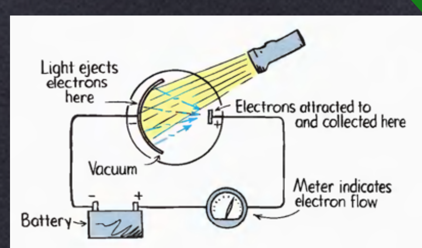
B = 1010.99844 +- 0.0014 G
L_eff = 0.2064687 m
Current of 3 A
Angle of 22.5°

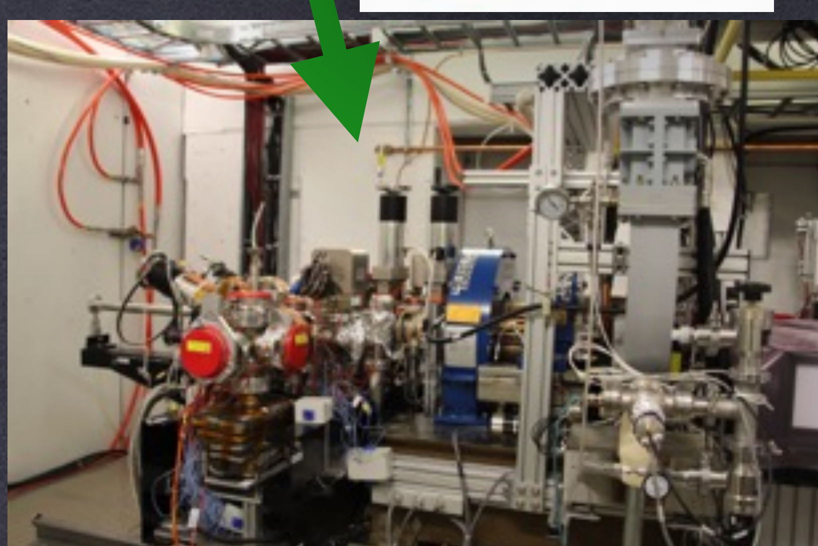
REFERENCE: CONCEPTUAL PHYSICS - P. HEWITT 10ED.

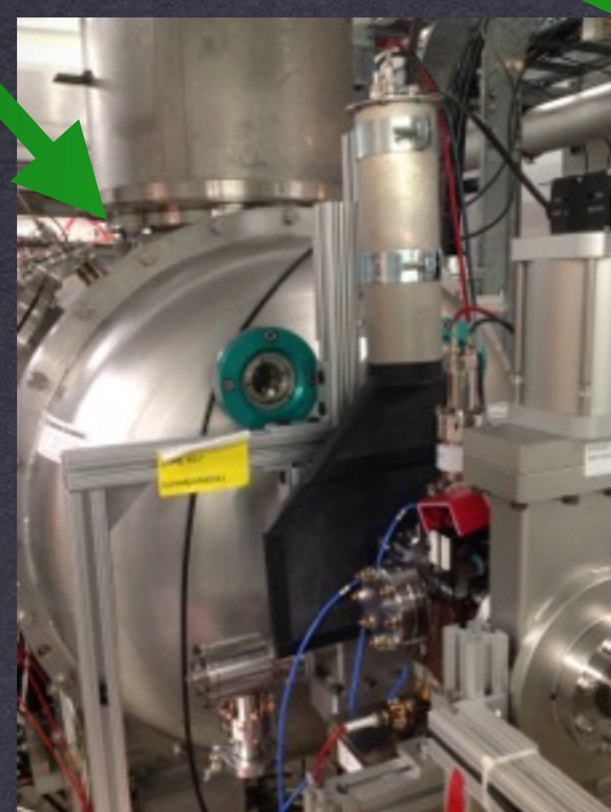
ACCELERATOR LATTICE











B = 1010.99844 +- 0.0014 G
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Current of 3 A
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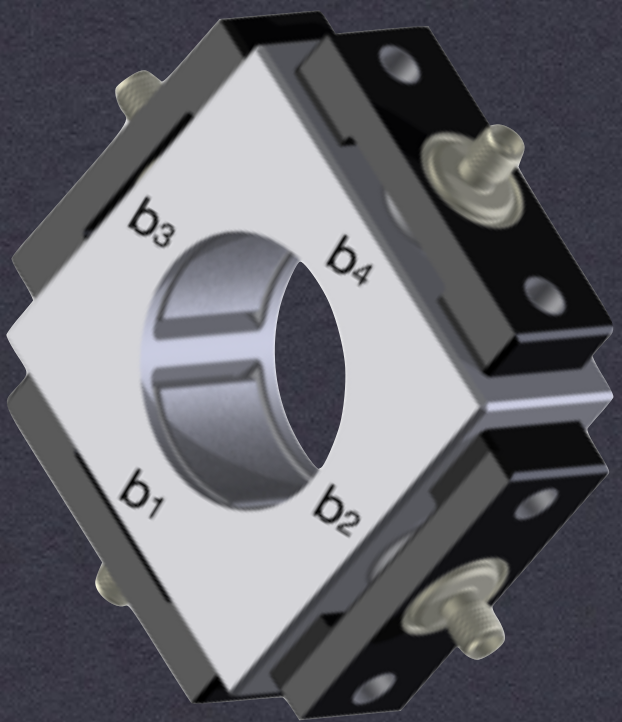
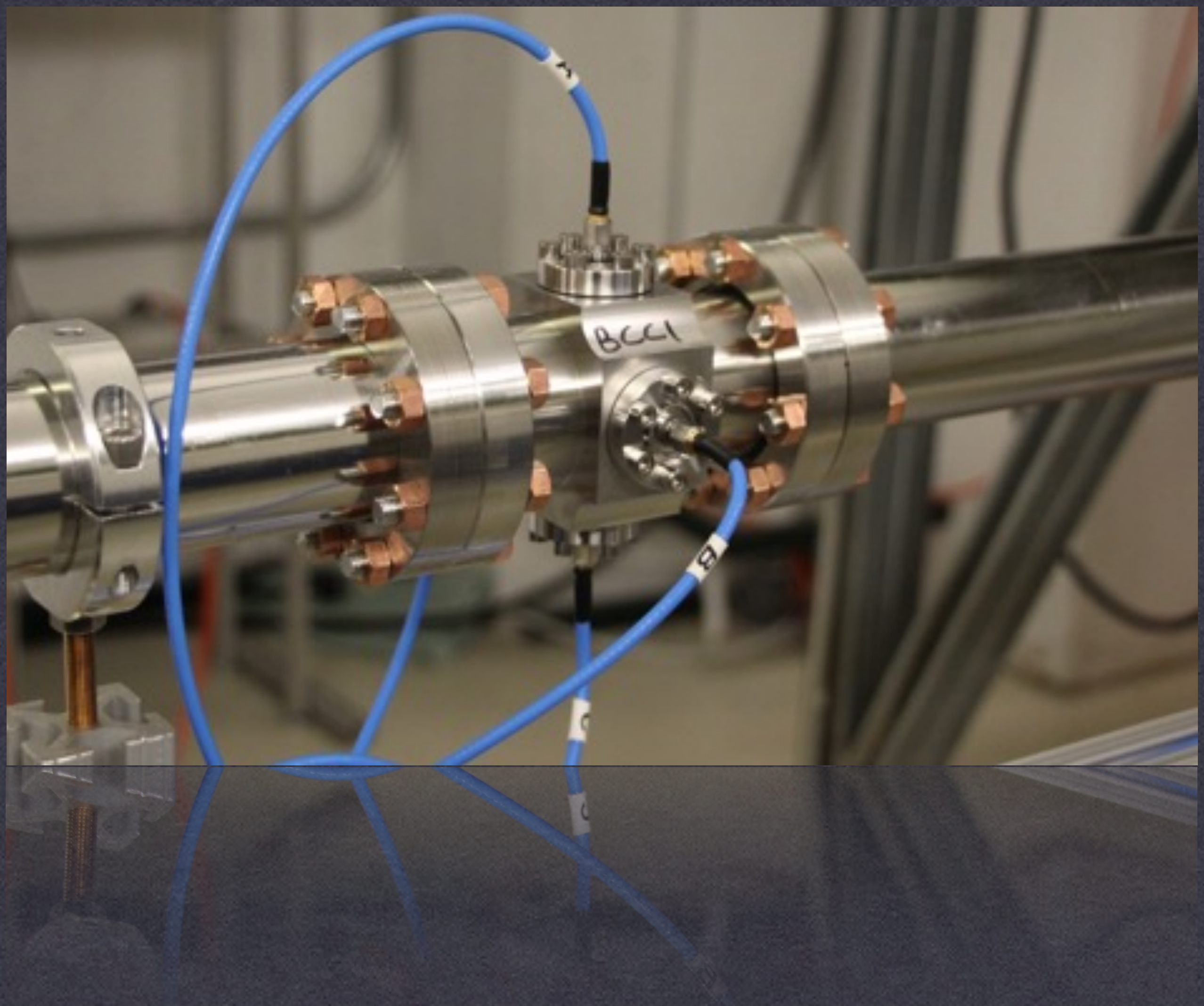
BEAM POSITION MONITOR

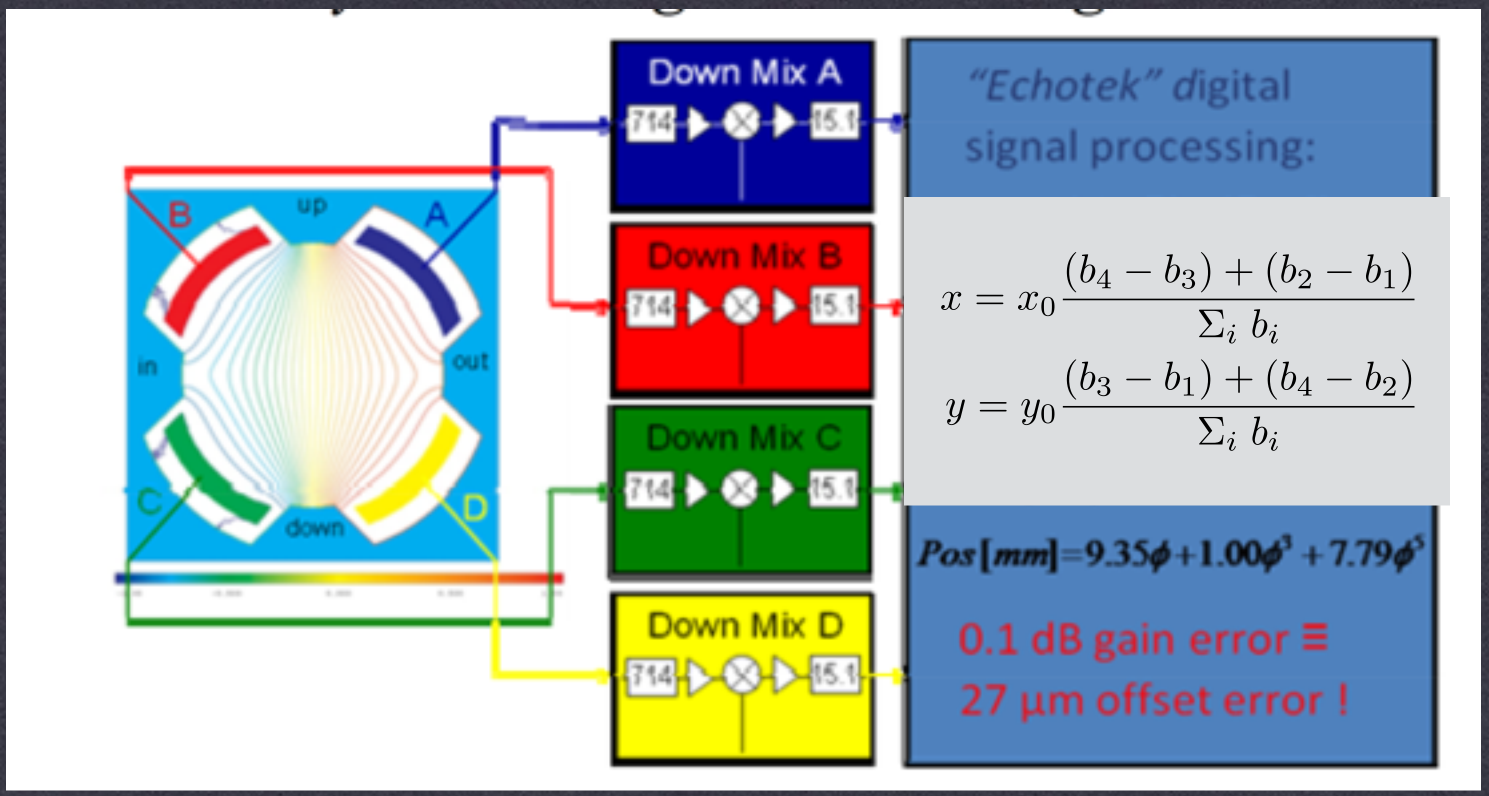




- Button Style BPM
- V(b1,b2,b3,b4) → P(x,y)
- Design Resolution of 50 μm

BEAM POSITION MONITOR

BUTTON STYLE



- Four "Button" electrodes
- Arranged symmetrically under 45°
- Design Resolution of 50 µm

Proceedings of DIPAC09, Basel, Switzerland MOPD19
HIGH RESOLUTION BPMS
WITH INTEGRATED GAIN CORRECTION SYSTEM

SOME OF THE PICKUP NON-LINEARITIES ARE TAKEN INTO ACCOUNT BY APPLYING A 5TH ORDER POLYNOMIAL TO FIT THE CALCULATED EQUIPOTENTIALS.

THEORY

From Lorentz

$$\mathbf{F} = q\left(\mathbf{E} + \frac{1}{c}\mathbf{v}\times\mathbf{B}\right)$$

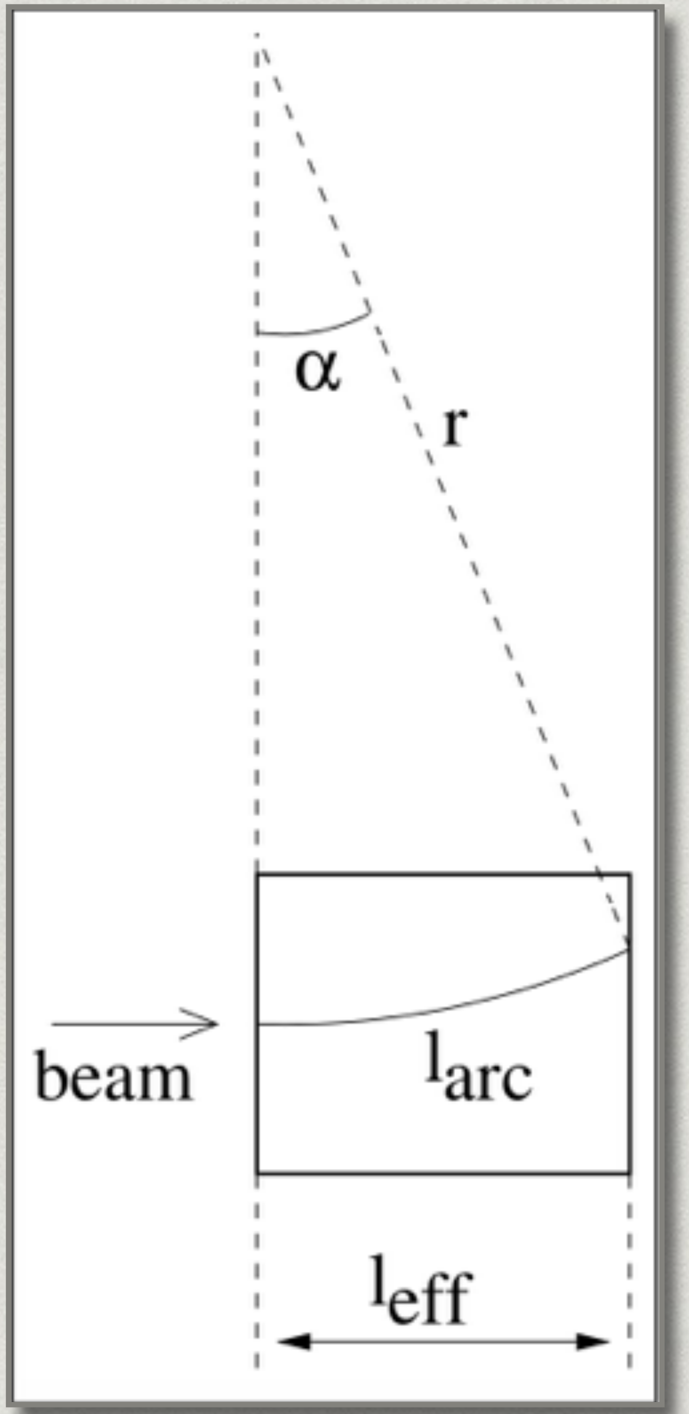
$$\mathbf{F} = \frac{\mathrm{d}\mathbf{p}}{\mathrm{d}t} = \frac{e}{c}\left(\mathbf{v}\times\mathbf{B}\right)$$

Integrating and substituting v=r/t

$$p = \frac{e}{c}\,B\,r$$

For a rectangular magnet

$$l_{arc} = \alpha\, r = l_{eff} \cdot \frac{\alpha}{\sin\alpha}$$



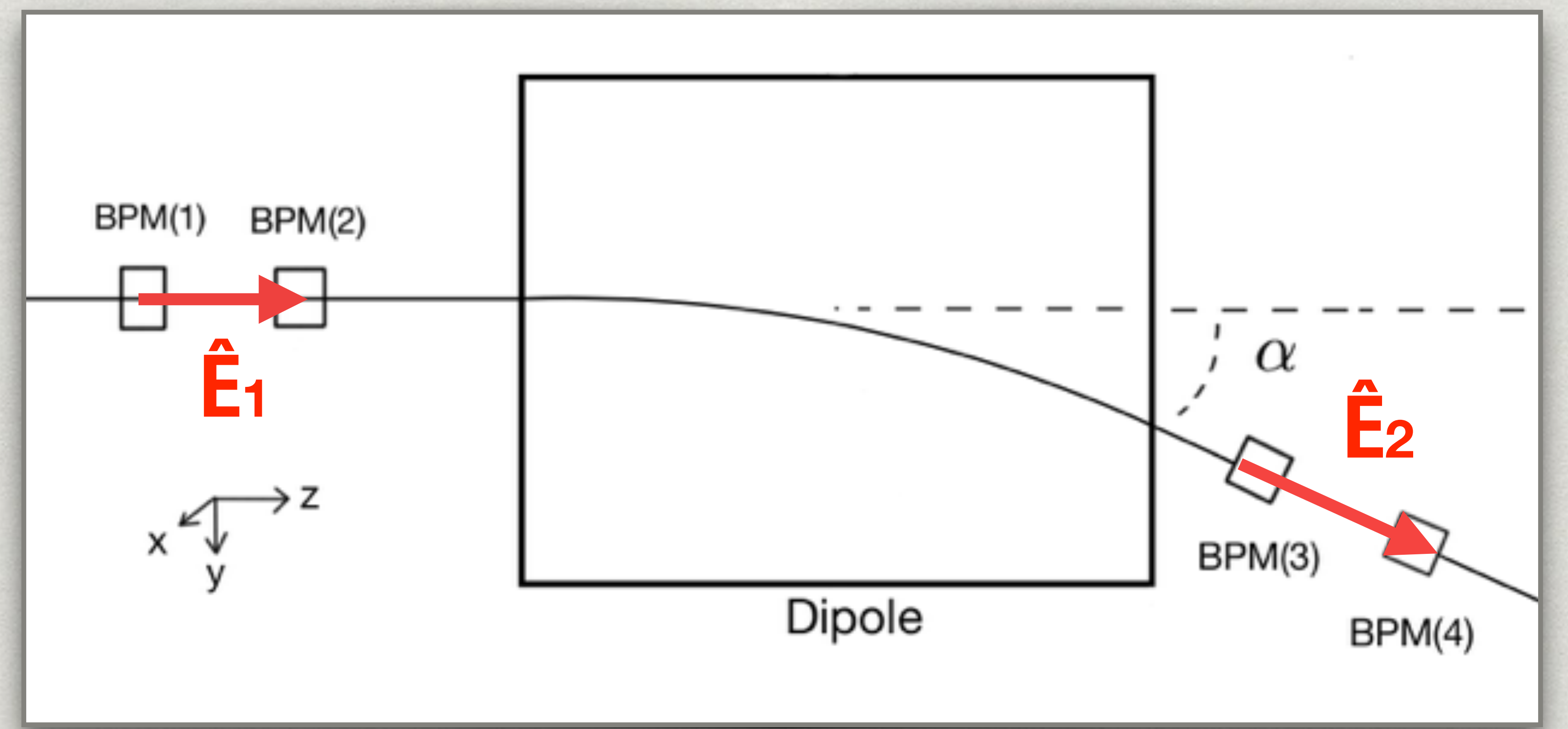
The field integral along the trajectory inside the dipole

$$\int \mathbf{B} \cdot d\mathbf{s} = B \cdot l_{arc}$$

The energy for an ultra-relativistic particle $E = cp$

$$E = e \cdot \frac{B}{\sin\alpha} \cdot l_{eff}$$

$$0 < \alpha < \pi/2$$



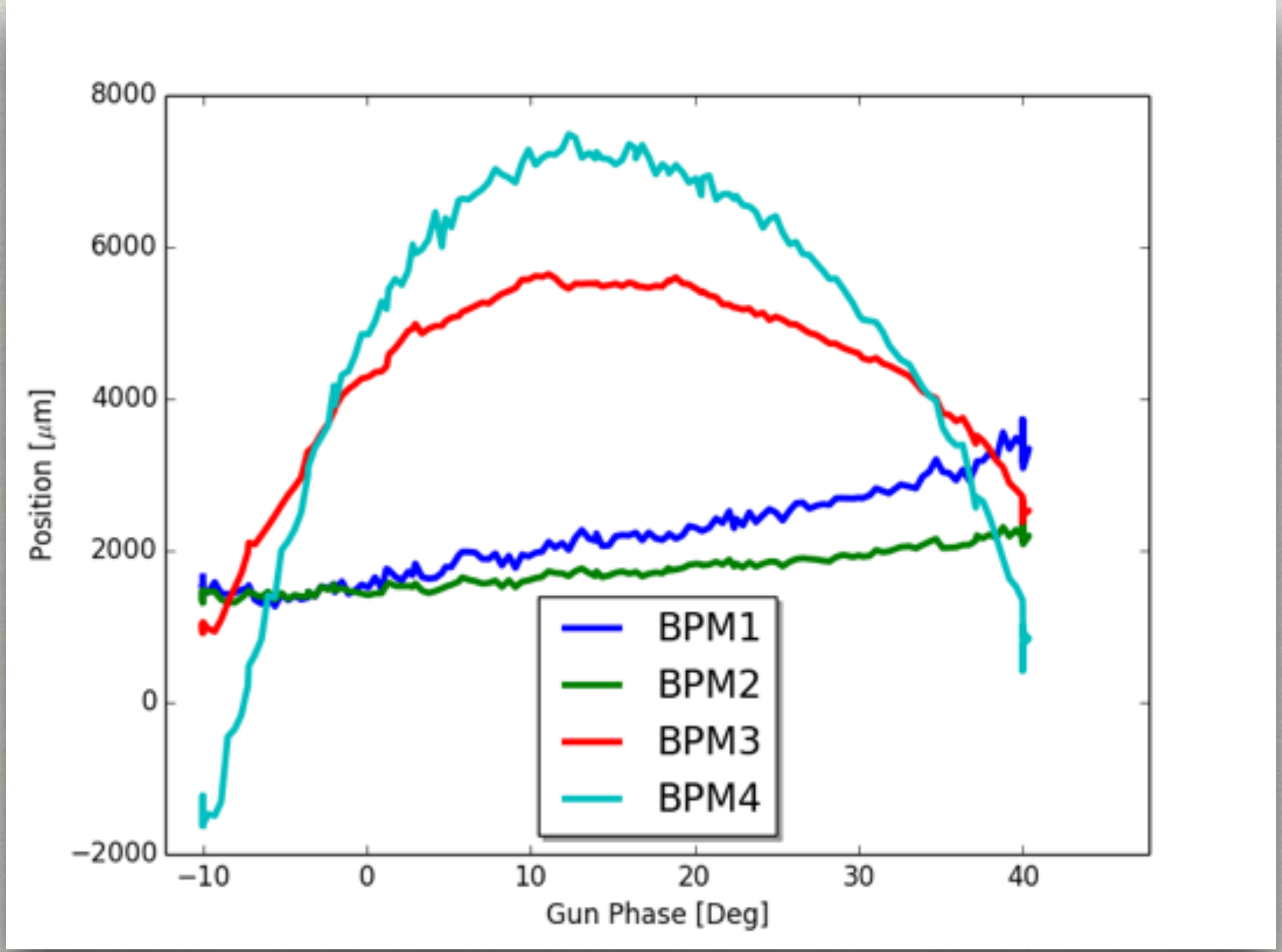
$$\mathbf{P}_1 = (X_1, Y_1, Z_1)$$
$$\mathbf{P}_2 = (X_2, Y_2, Z_2)$$
$$\mathbf{P}_3 = (X_3, Y_3, Z_3)$$
$$\mathbf{P}_4 = (X_4, Y_4, Z_4)$$

$$\hat{\mathbf{E}}_1 \times \hat{\mathbf{E}}_2 = |\hat{\mathbf{E}}_1||\hat{\mathbf{E}}_2| \sin\alpha \; \hat{\mathbf{i}}$$

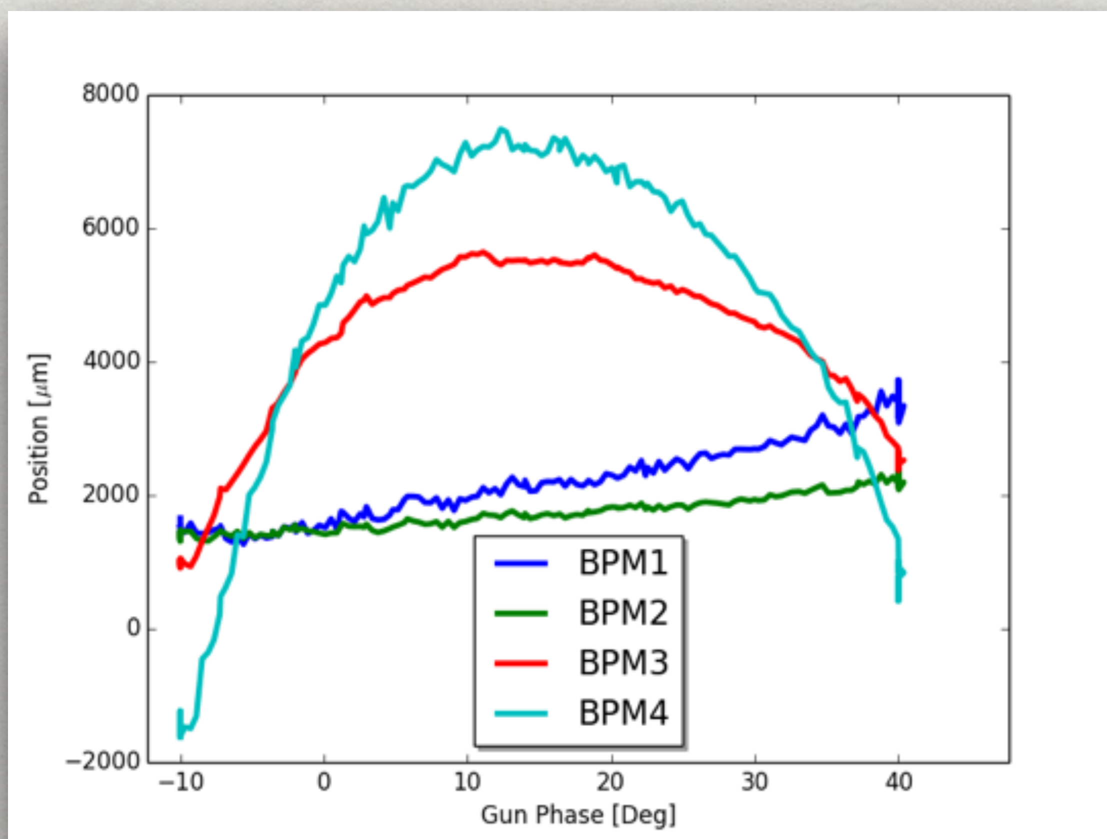
$$E = e \left(\frac{\hat{\mathbf{E}}_1 \times \hat{\mathbf{E}}_2}{|\hat{\mathbf{E}}_1||\hat{\mathbf{E}}_2|} \right)^{-1} B \cdot \; l_{eff}$$

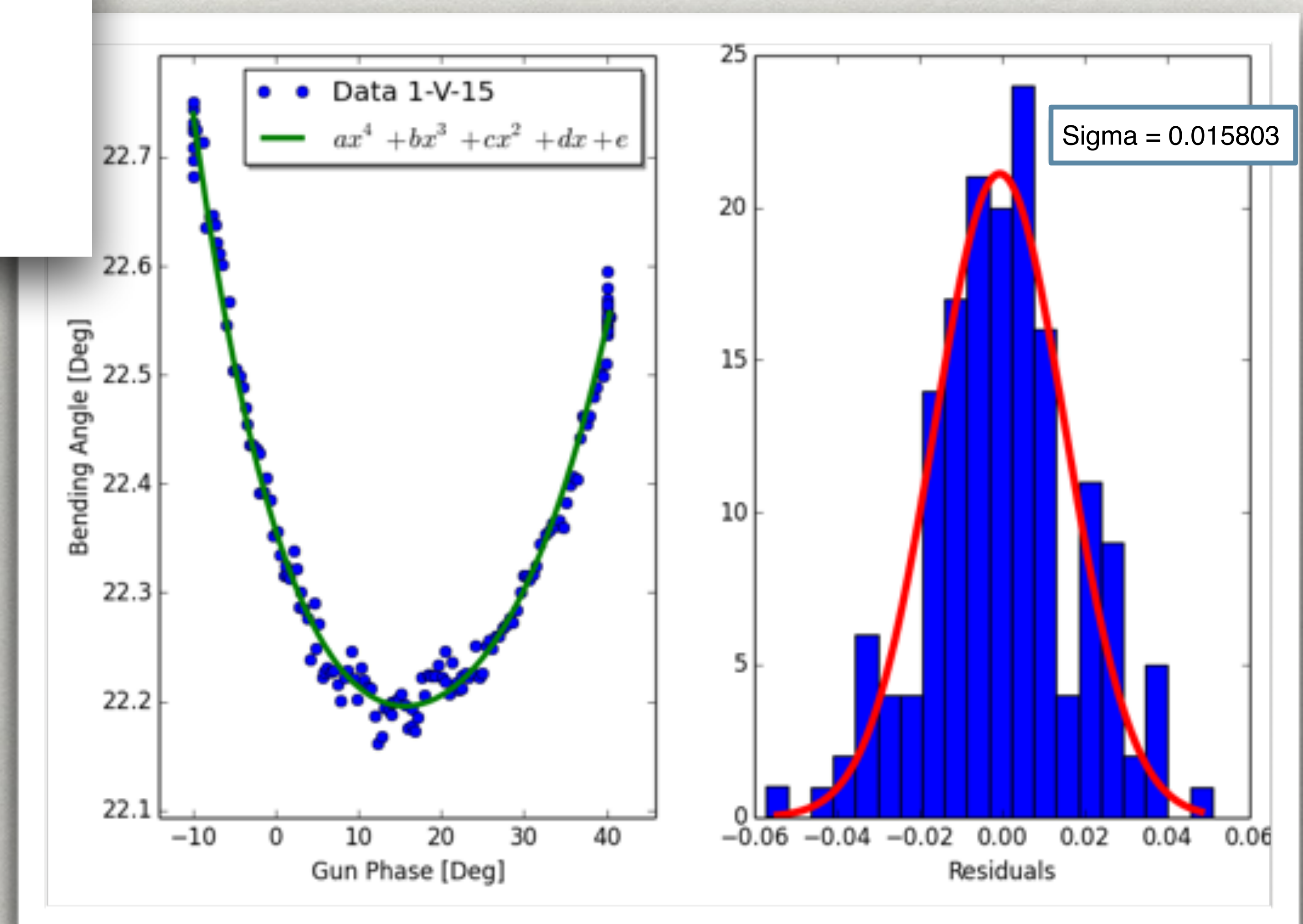
MEASUREMENTS AND CALCULATIONS

FROM THE DATA TOOK ON 1 MAY 2015



FROM THE DATA TOOK ON 1 MAY 2015

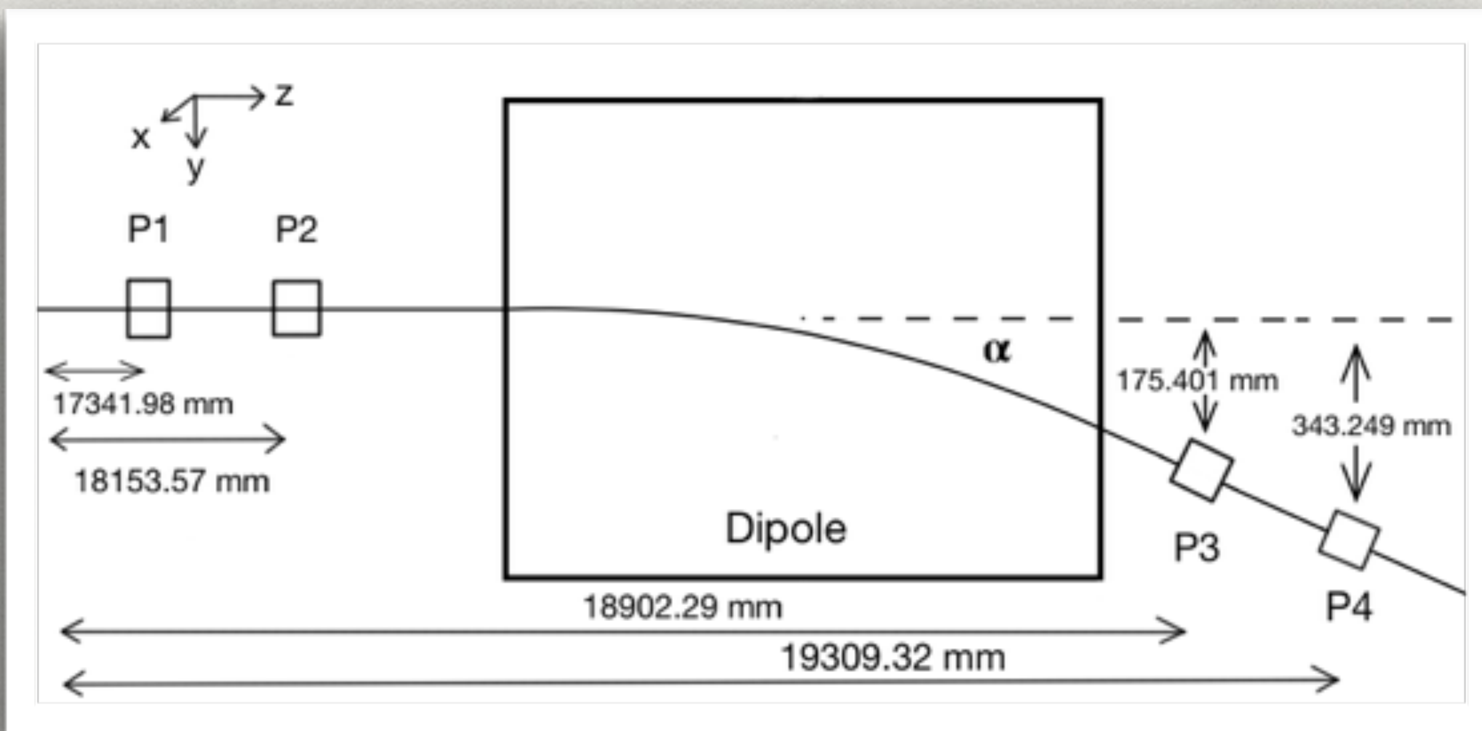




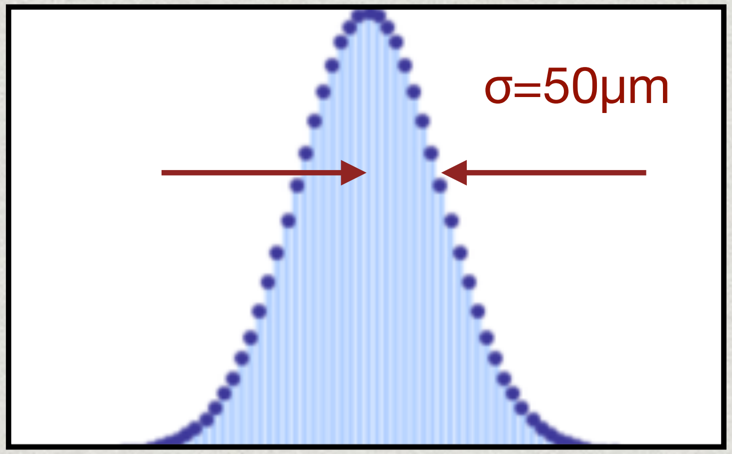
a = 3.00270739e-07,
b = -2.32514143e-05,
c = 1.16676811e-03,
d = -2.40022927e-02,
e = 2.23567900e+01

SIMULATING ERRORS ON THE BPMS

ACCELERATOR LATTICE

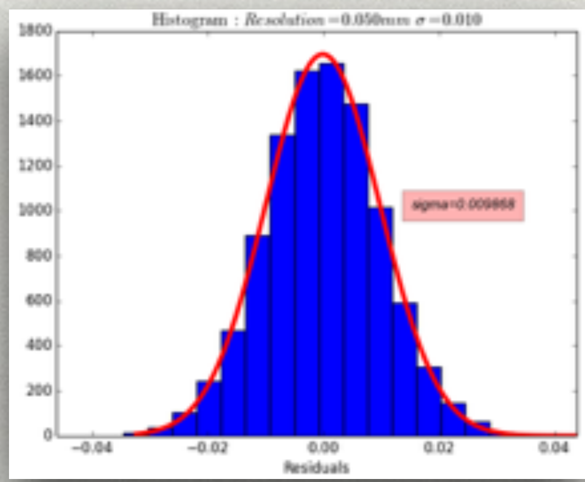


Making an error



$$\mathbf{P1} = [x1 \pm \epsilon_1, y1 \pm \epsilon_1, z1]$$
$$\mathbf{P2} = [x2 \pm \epsilon_2, y2 \pm \epsilon_2, z2]$$
$$\mathbf{P3} = [x3 \pm \epsilon_3, y3 \pm \epsilon_3, z3]$$
$$\mathbf{P4} = [x4 \pm \epsilon_4, y4 \pm \epsilon_4, z4]$$

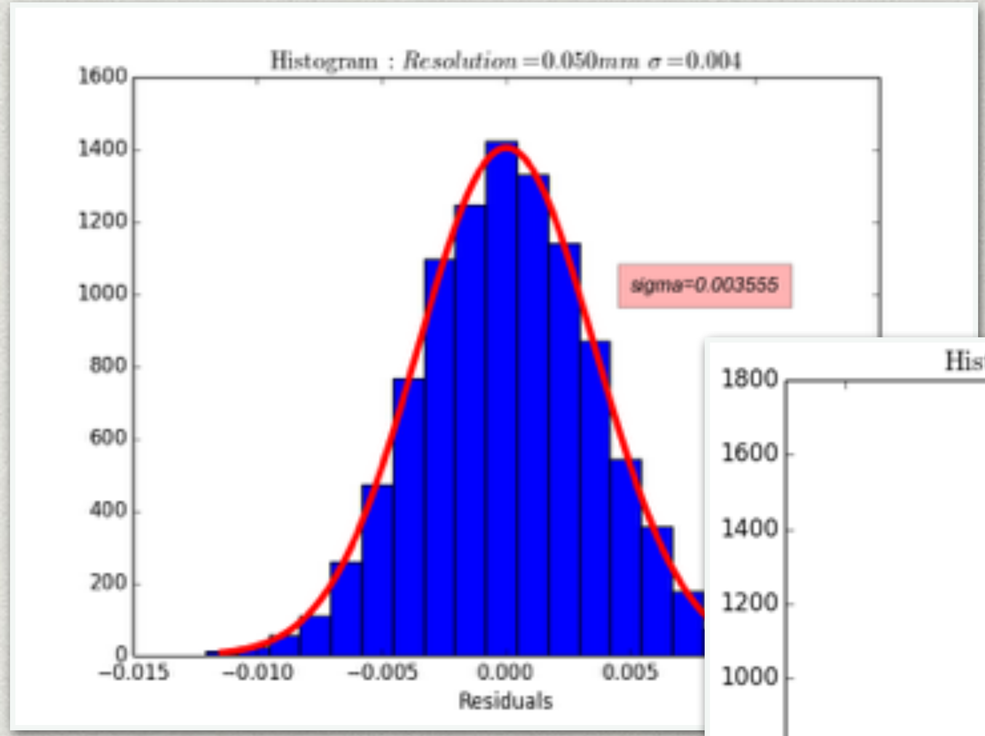
Residuals Histogram



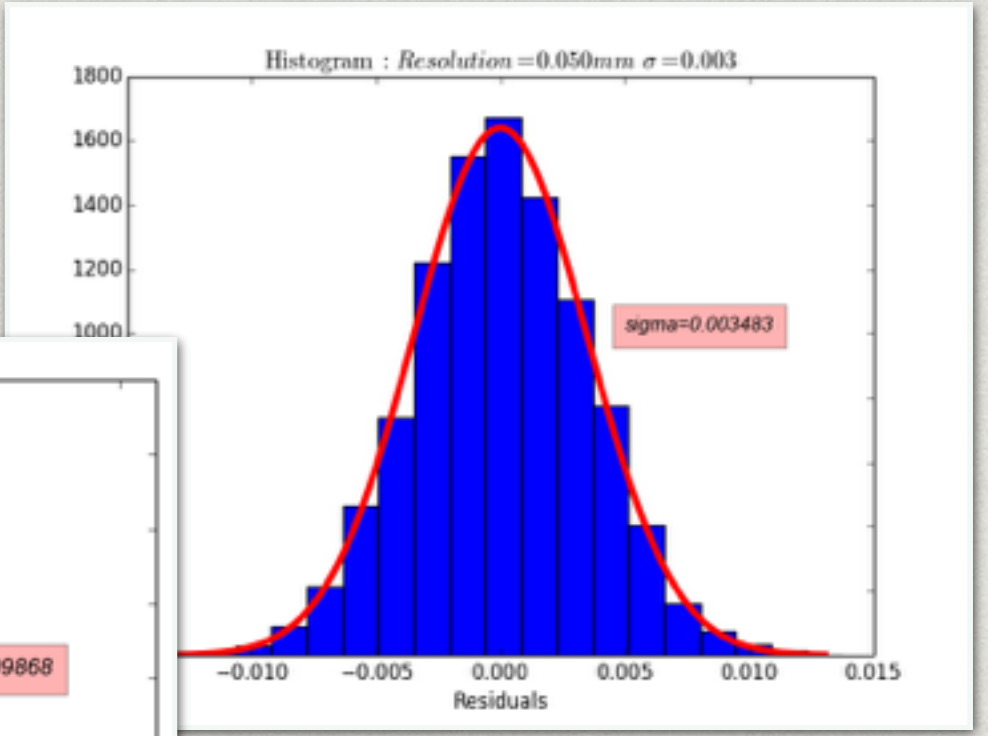
- Making errors with Normally-Distribution Random Numbers
- Calculate the Bending Angle
- Compute the residuals
- Make a histograms and fit a Gaussian

BPM ERROR USING NORMALLY-DISTRIBUTION RANDOM NUMBERS

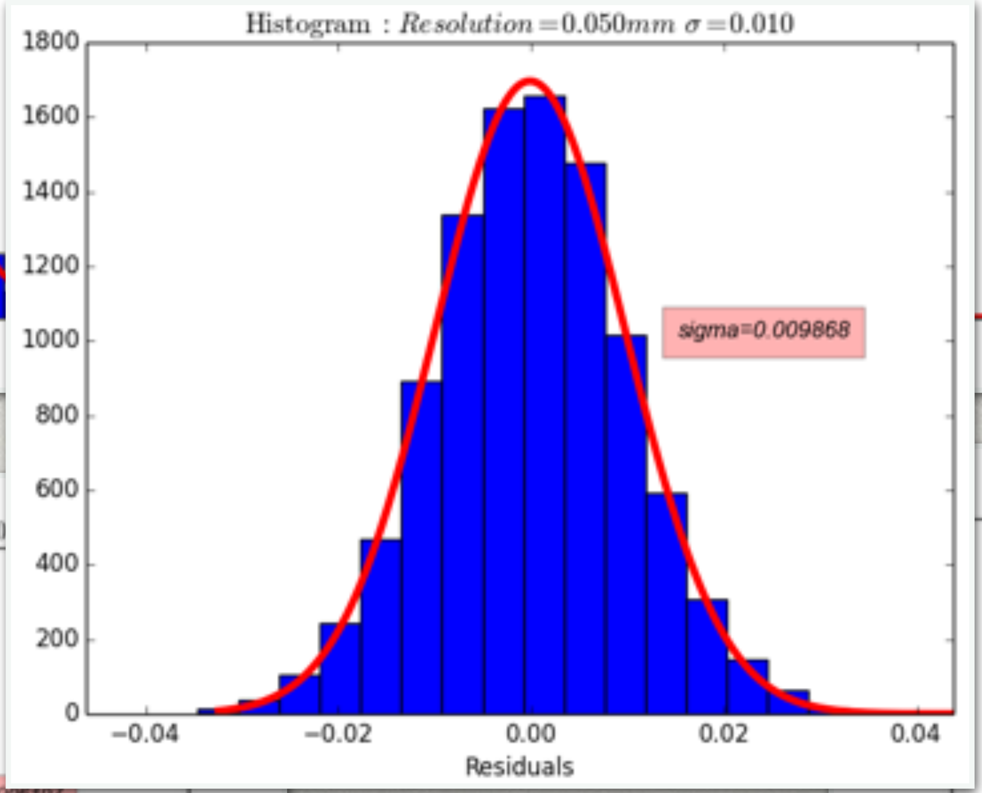
BPM1

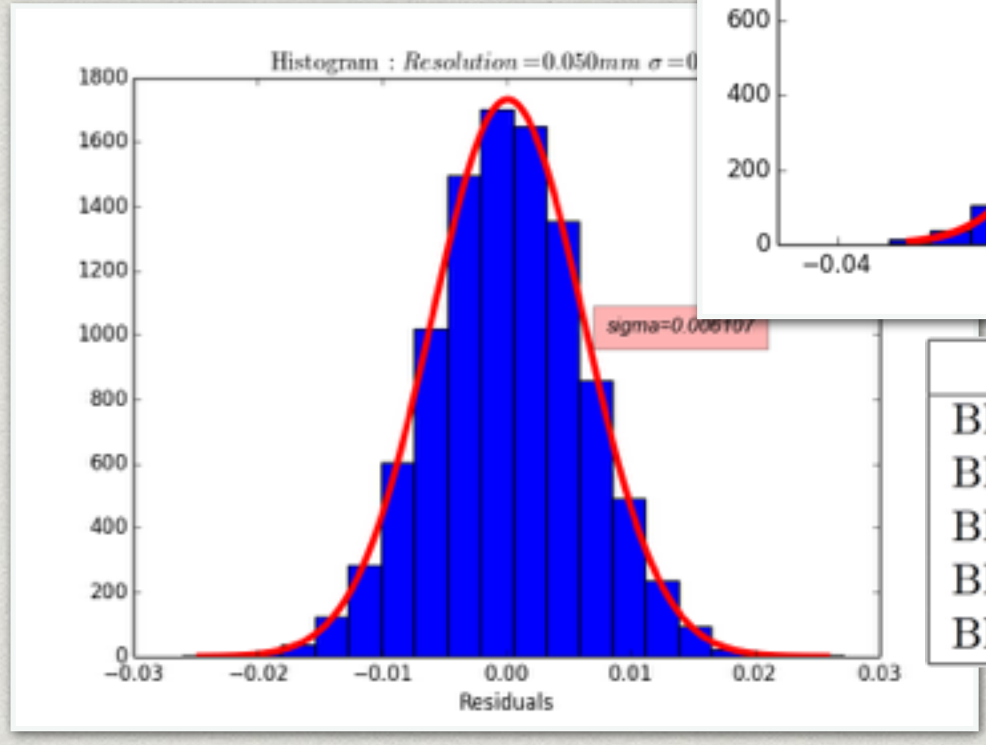


BPM2

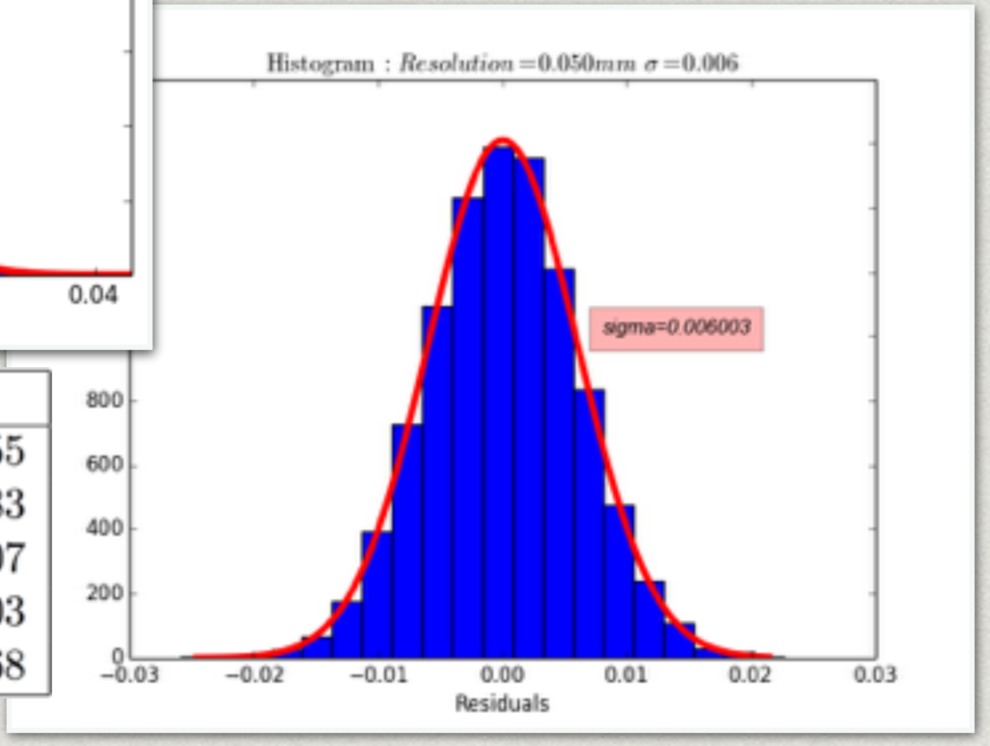


BPMs





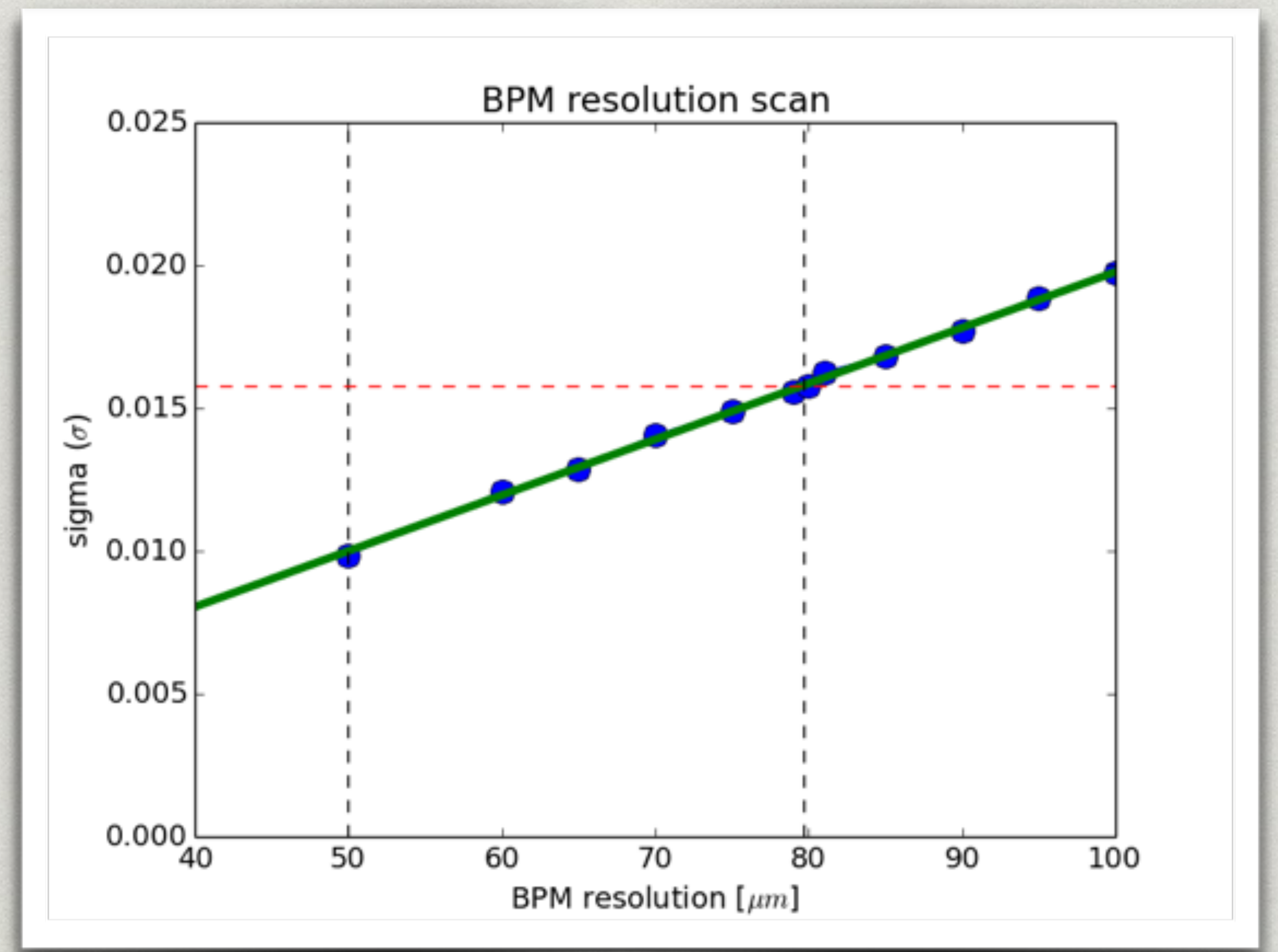
BPM Resolution = $50\mu m$	
BPM1	$\sigma_{RBA} = 0.003555$
BPM2	$\sigma_{RBA} = 0.003483$
BPM3	$\sigma_{RBA} = 0.006107$
BPM4	$\sigma_{RBA} = 0.006003$
BPMs (all)	$\sigma_{RBA} = 0.009868$



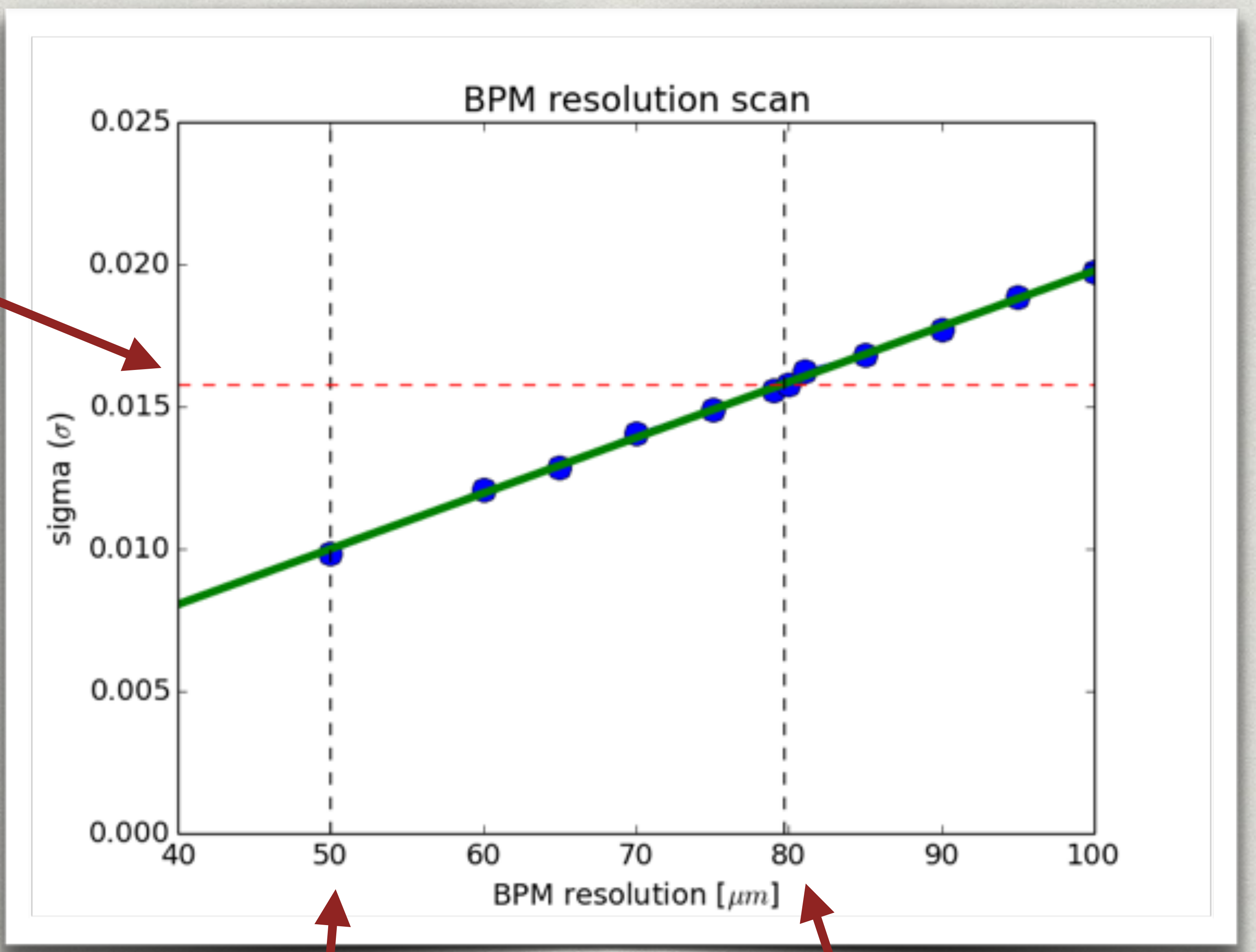
BPM3

BPM4

VARIATING THE BPM RESOLUTION



VARIATING THE BPM RESOLUTION

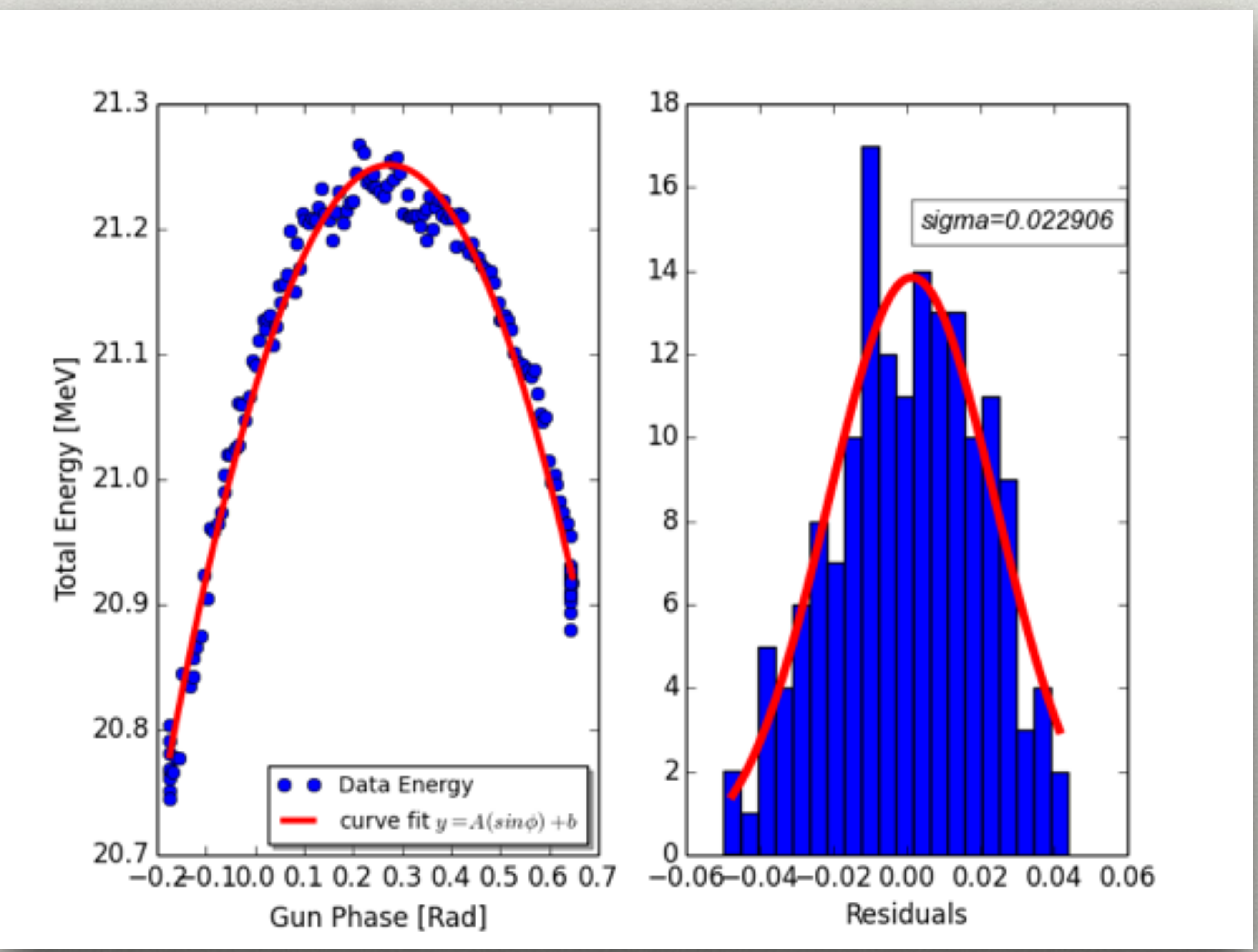


DATA

BPM DESIGN RESOLUTION

BPM ACTUAL RESOLUTION

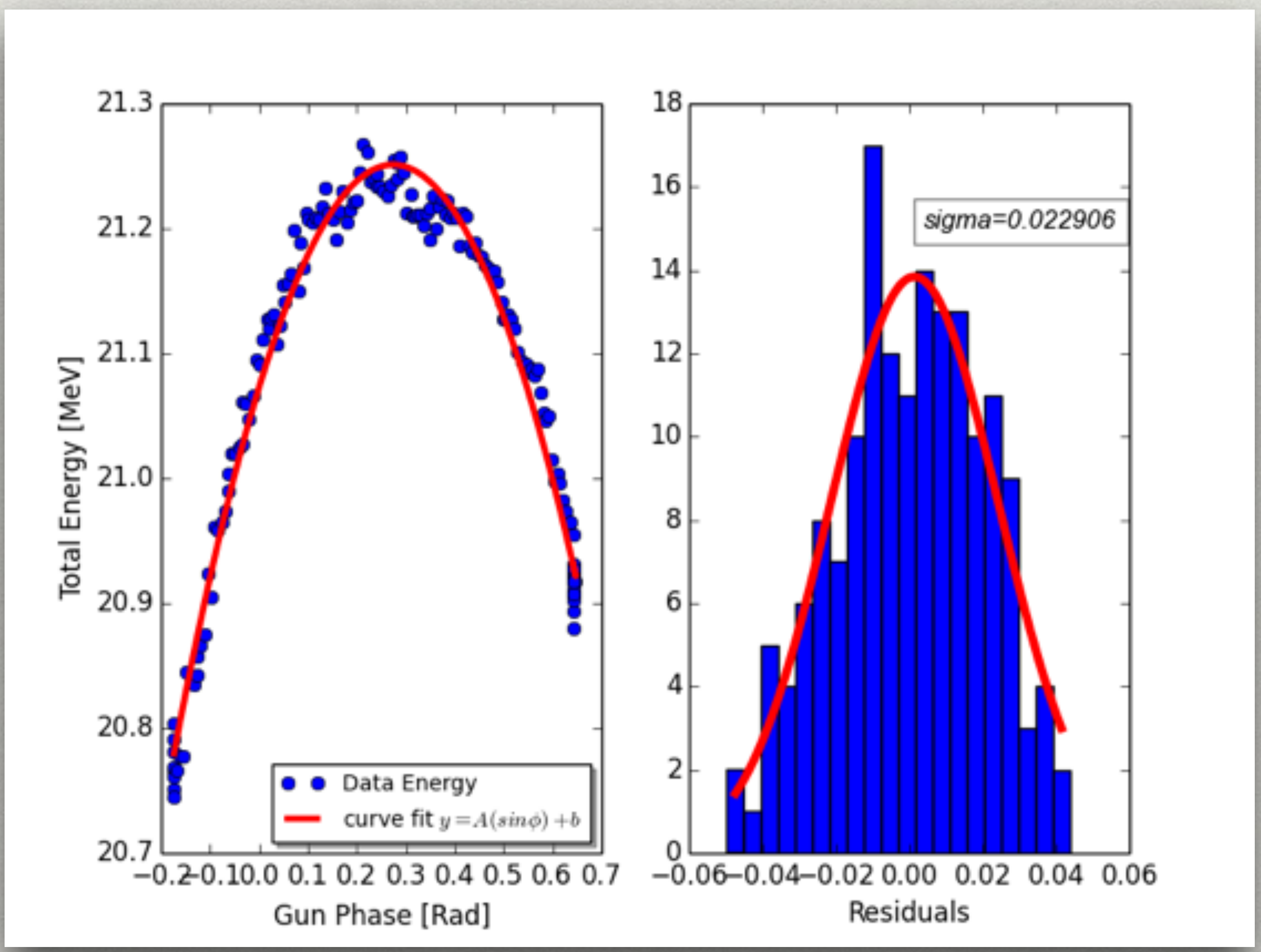
ENERGY OF THE BEAM



A = 4.77736446 b = 16.47368479

y = A e-(x-b)^2/2c

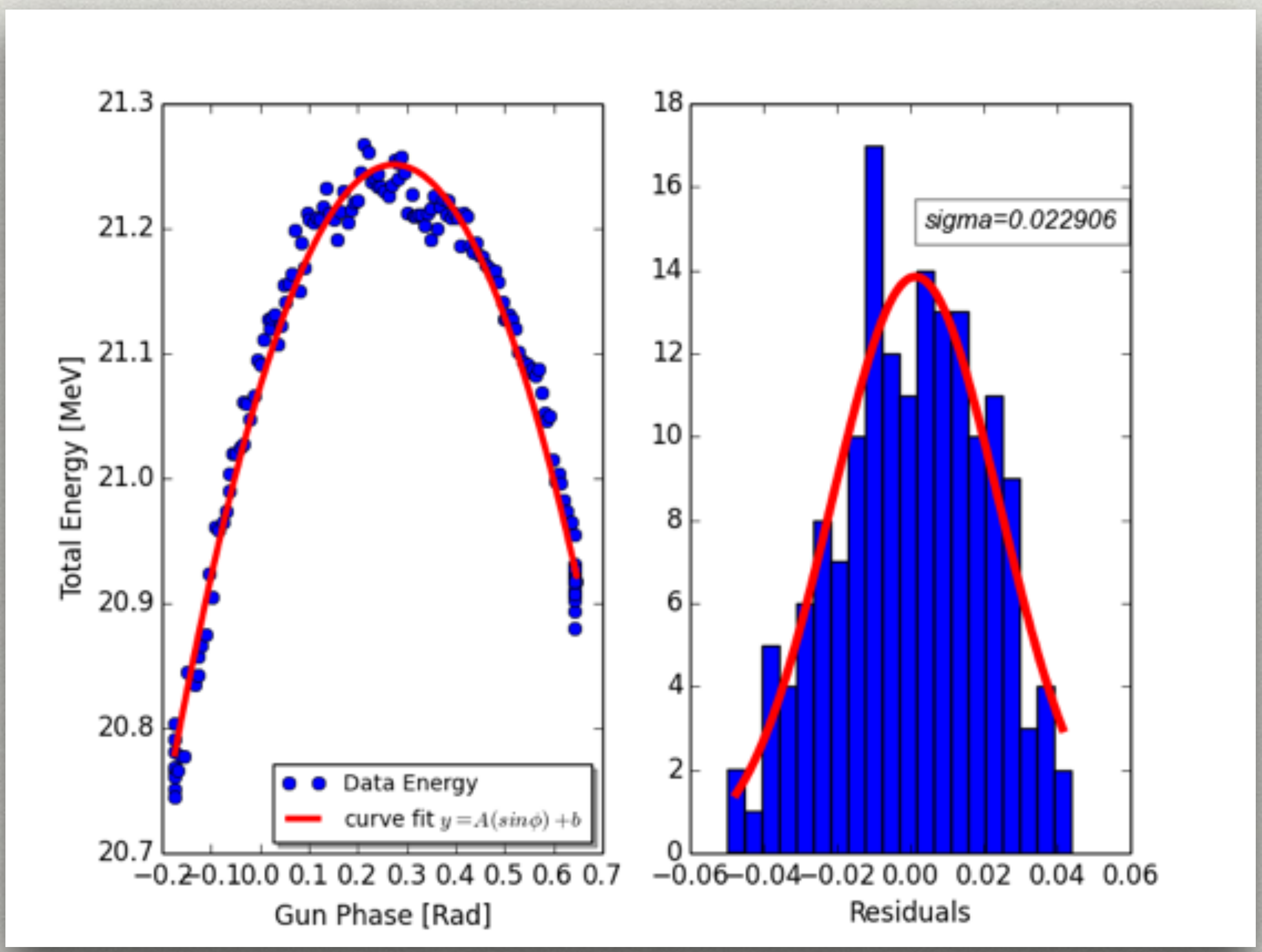
ENERGY OF THE BEAM



A = 4.77736446 b = 16.47368479

$$E_{Total} = E_{Gun} \cdot \sin\phi + E_{CC2}$$

ENERGY OF THE BEAM



A = 4.77736446 b = 16.47368479

$$E_{Total} = E_{Gun} \cdot \sin\phi + E_{CC2}$$

CONCLUSIONS

CONCLUSIONS:

We measured the read-back from the BPMs and we calculated the bending angle in function of the gun phase, did a curve fit and calculated the residuals to get the standard deviation.

We did a simulation to compute the bending angle with and without an error created with normally-distribution random numbers and calculated the residuals to get the standard deviation.

We compared the standard deviations between the data and the simulation the get the actual BPMs resolution, **that is 80μm rather than the design resolution that is 50μm**

We calculate the **Total energy = 21.251049 ± 0.024585 MeV the Gun energy = 4.777364 ± 0.024585 MeV and the CC2 energy = 16.473684 ± 0.024585 MeV**

QUESTIONS