PHIN Photo-Injector, the first measurement results

(November 2008)

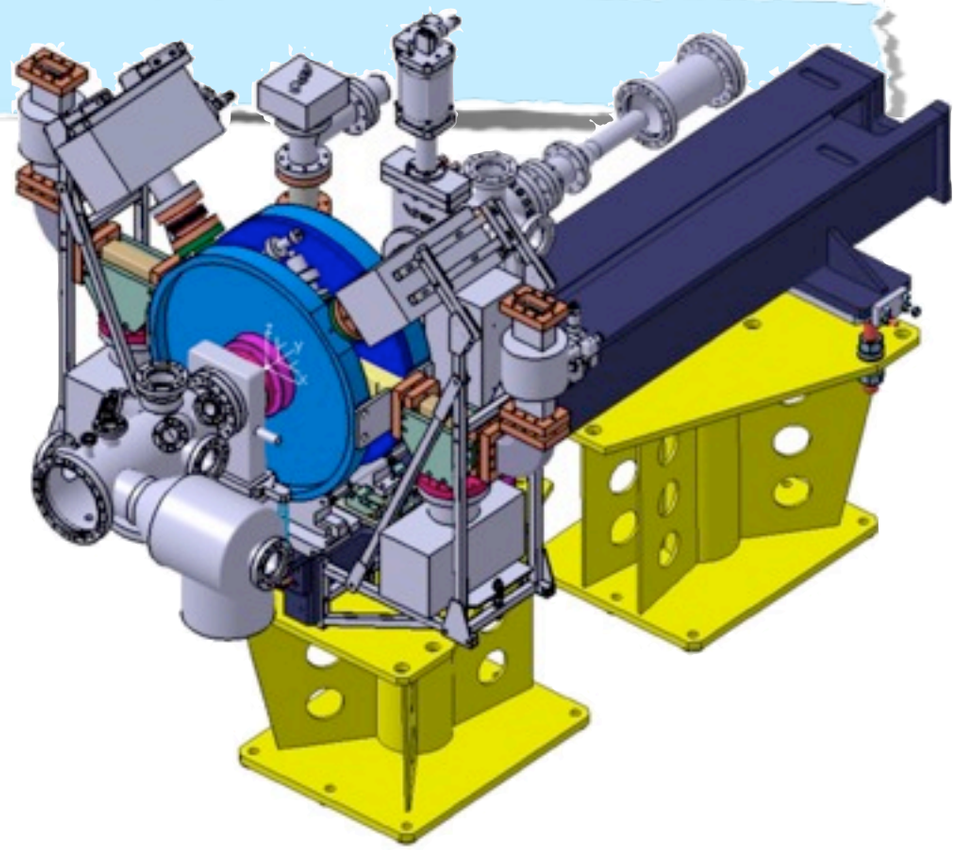
O. Mete

CERN PhD Student

CTF3 Collaboration Meeting

28.01.2009

Contents



- experimental set-up
- measurements and simulations
- conclusion and outlook

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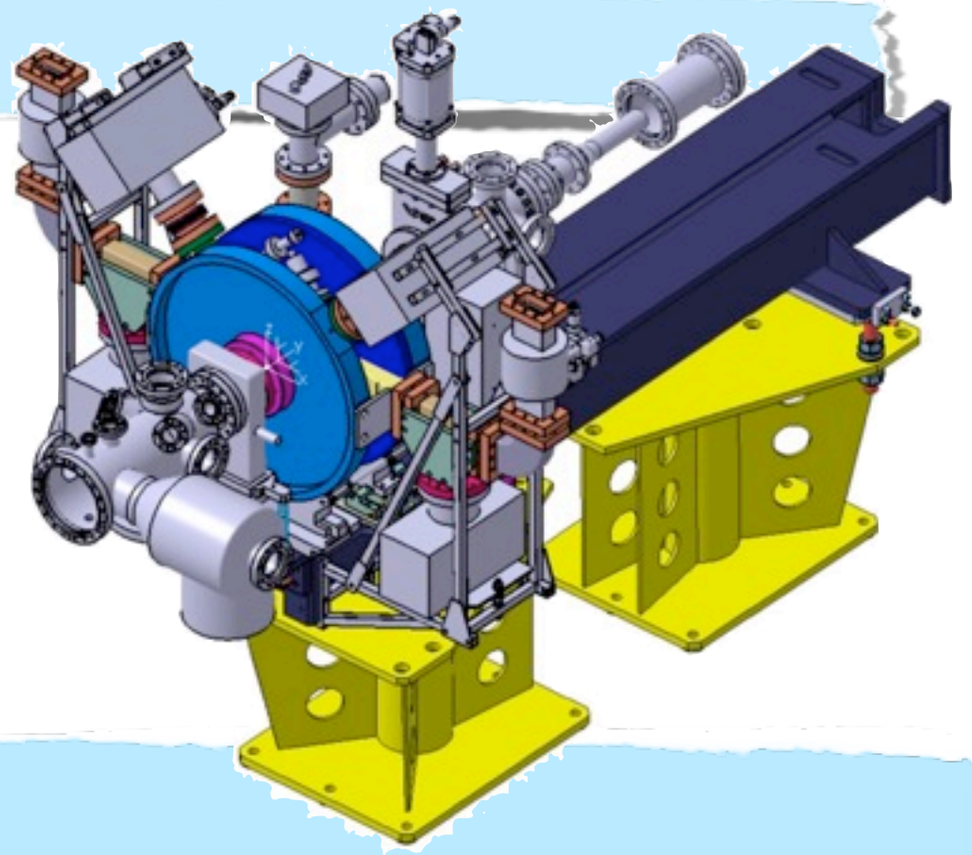
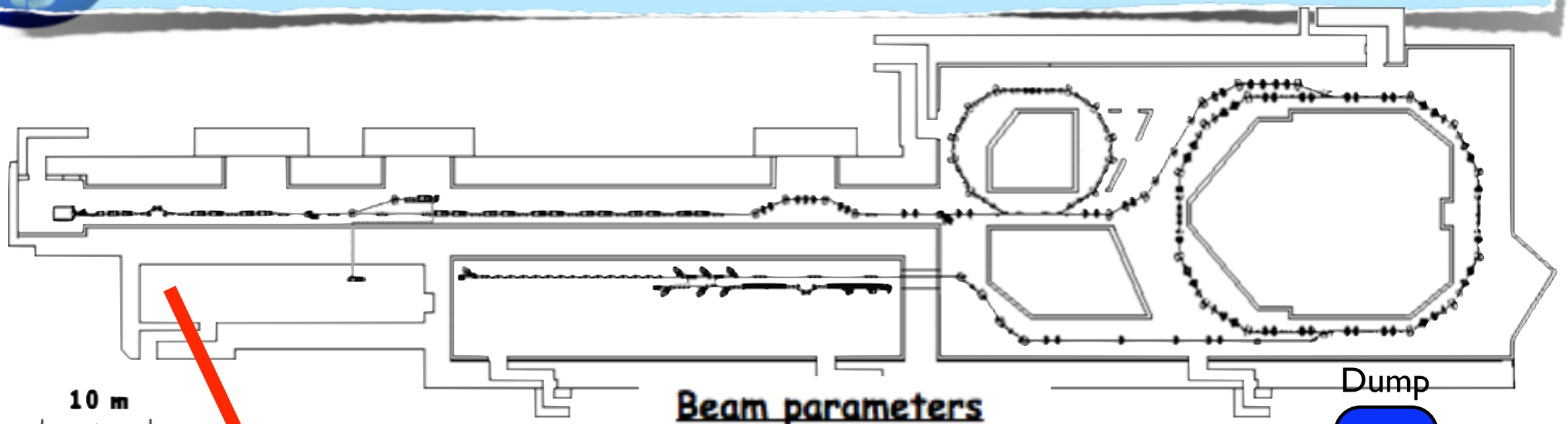


- experimental set-up
- measurements and simulations
- conclusion and outlook

- high brightness low emittance electron source with a time structure to fulfill the expectations of CTF3 and CLIC
- compensation of space charge induced emittance growth
- implementation of the multi-slits method for emittance measurement
- beam size, energy and energy spread measurements

Motivation



Beam parameters

E = 5.6 MeV

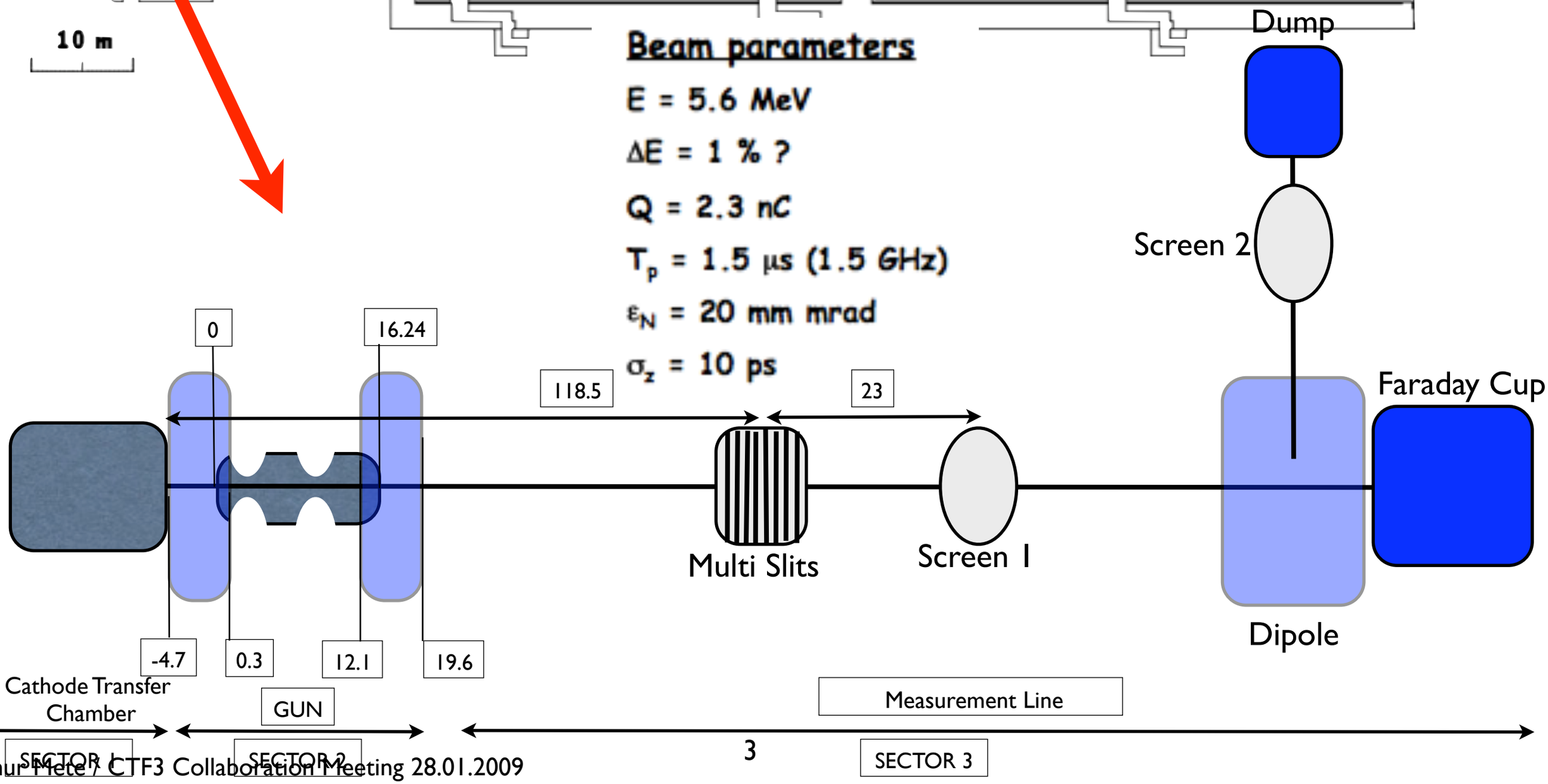
ΔE = 1 % ?

Q = 2.3 nC

T_p = 1.5 μs (1.5 GHz)

ε_N = 20 mm mrad

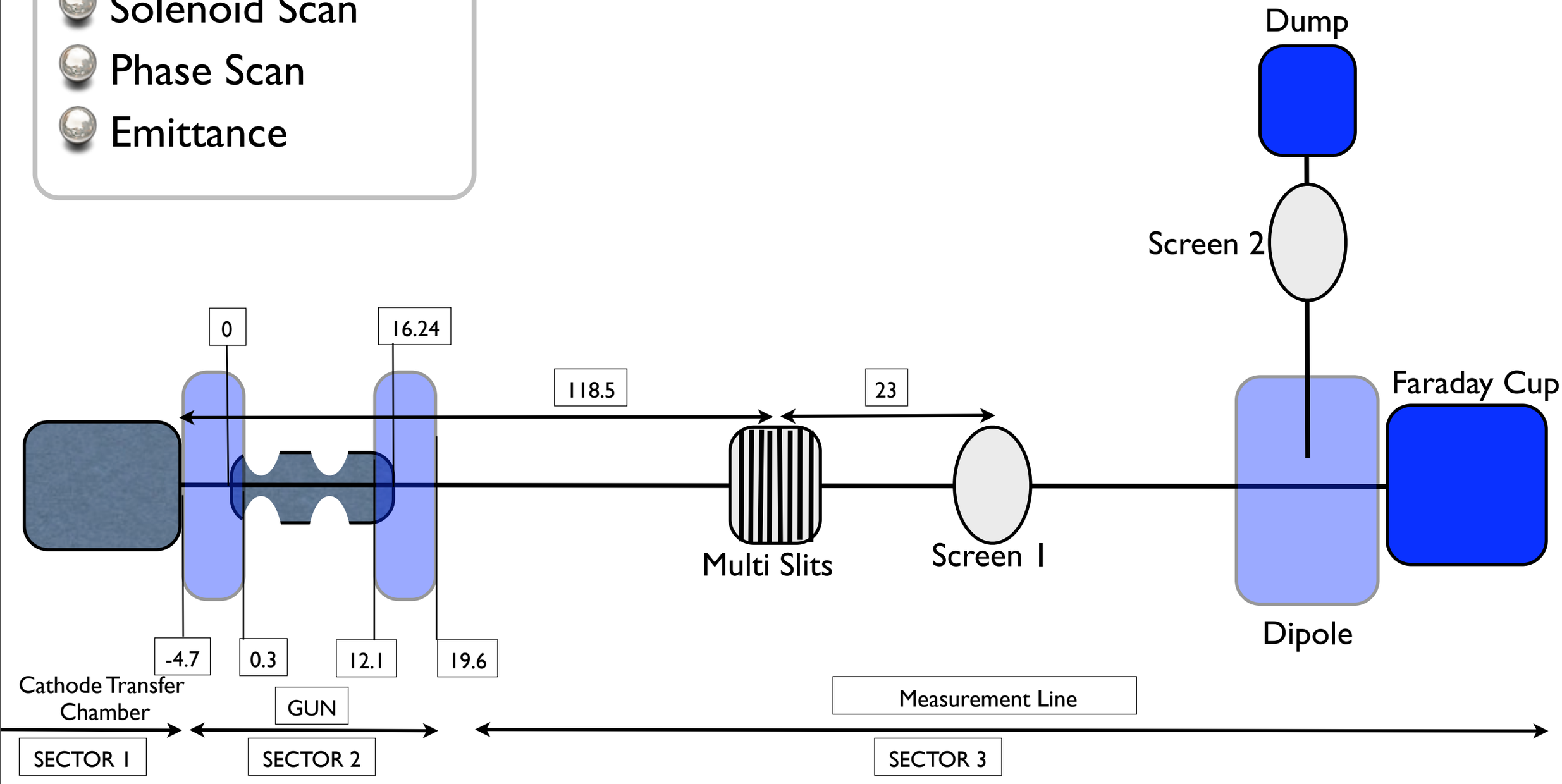
σ_z = 10 ps



Experimental Set-up

Measurements

- Solenoid Scan
- Phase Scan
- Emittance



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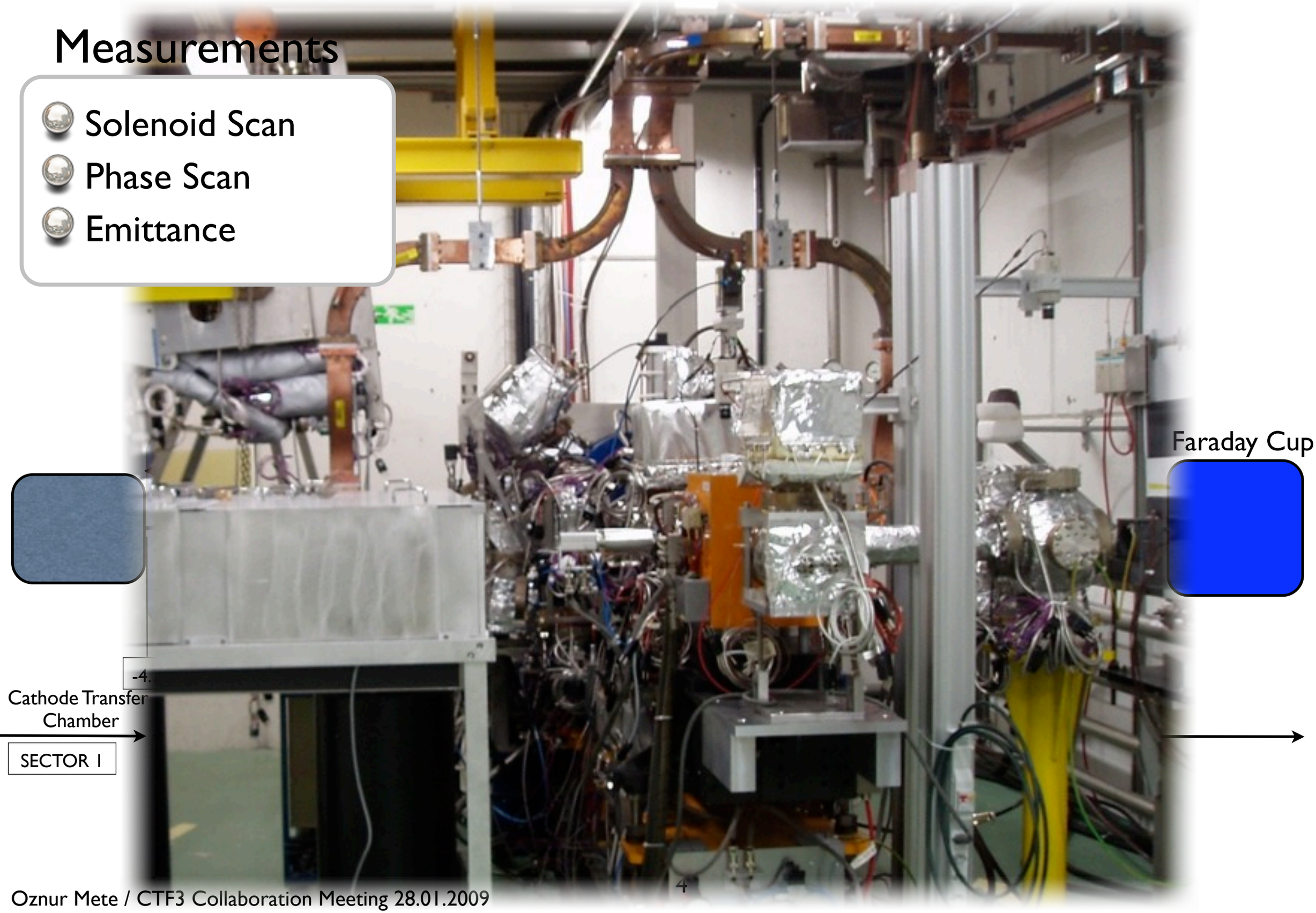
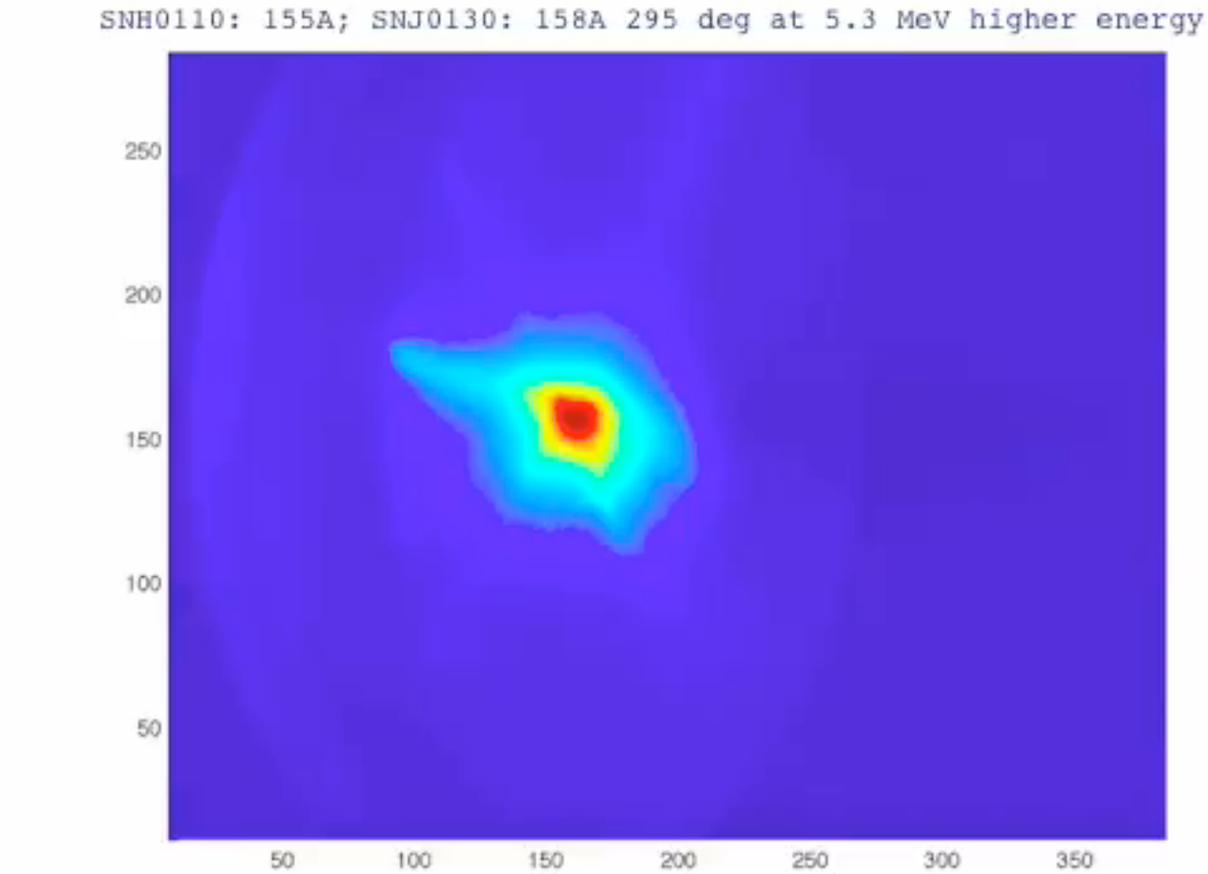
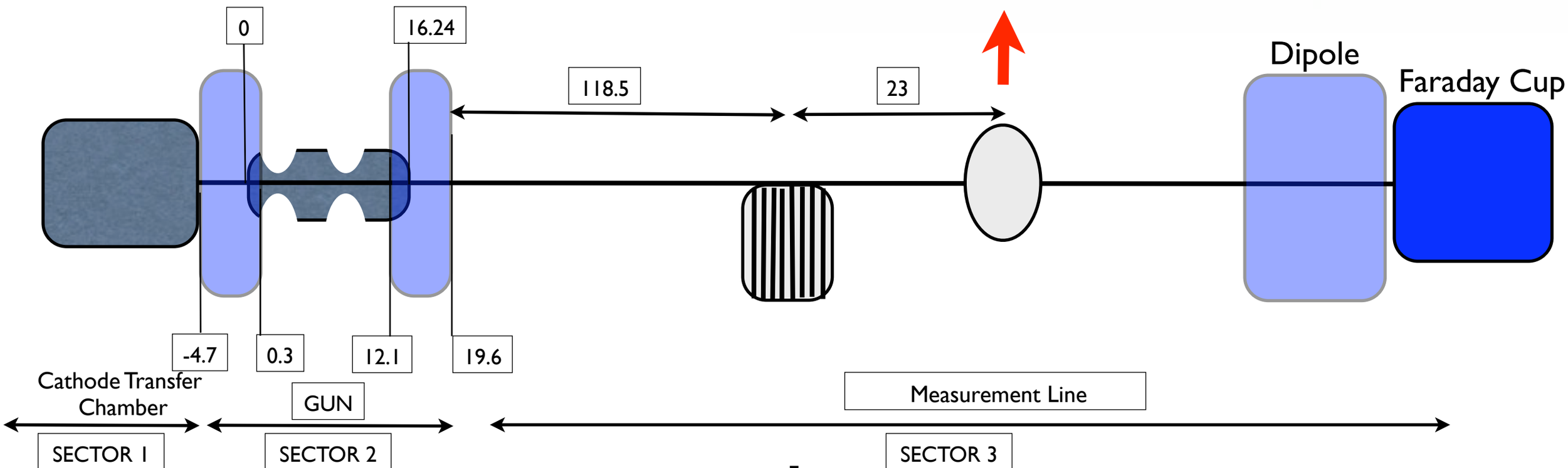


Measurements & Simulations

Measurements

- **Solenoid Scan,**
  Bucking &Focusing Solenoids
- Phase Scan
- Emittance





Measurements & Simulations

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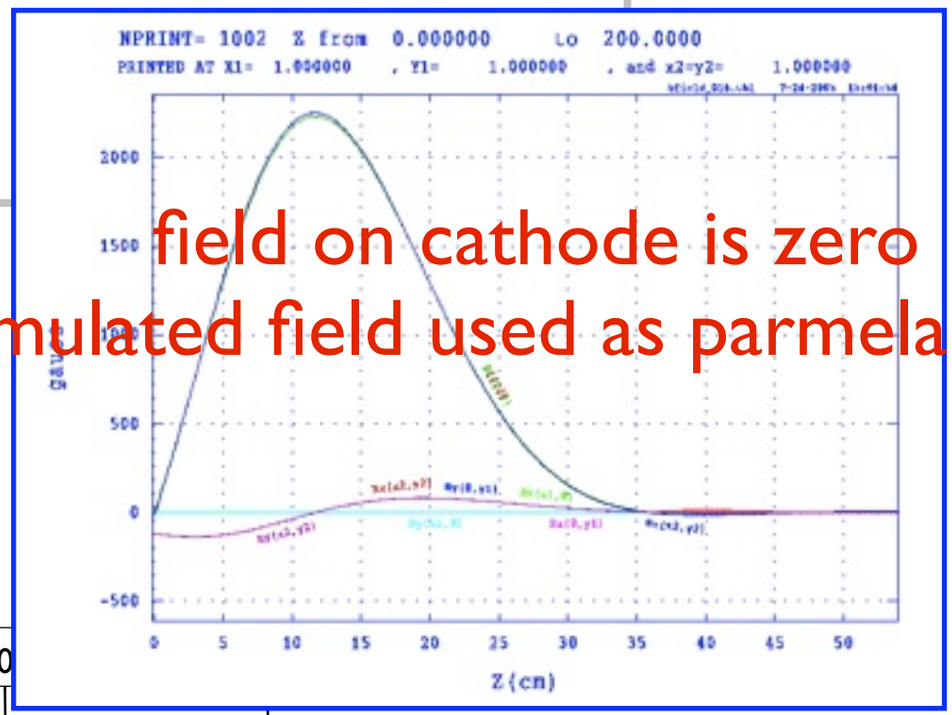
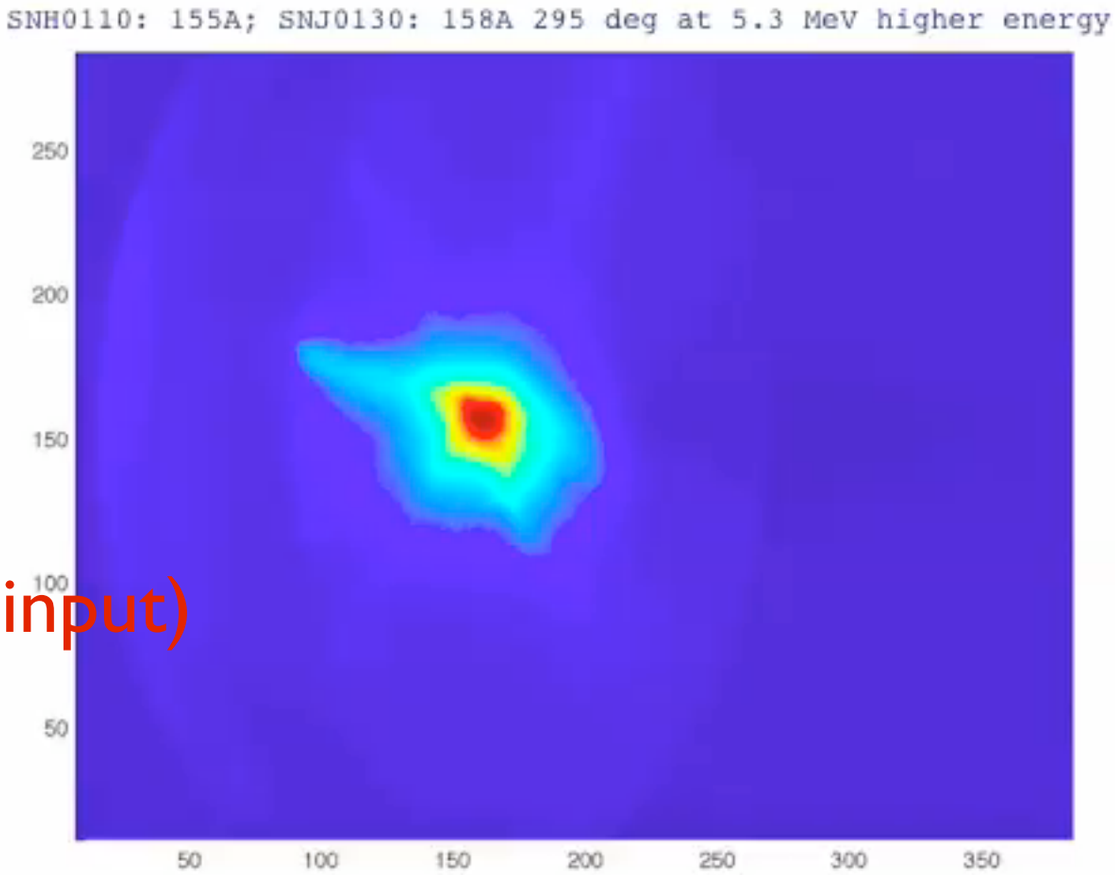
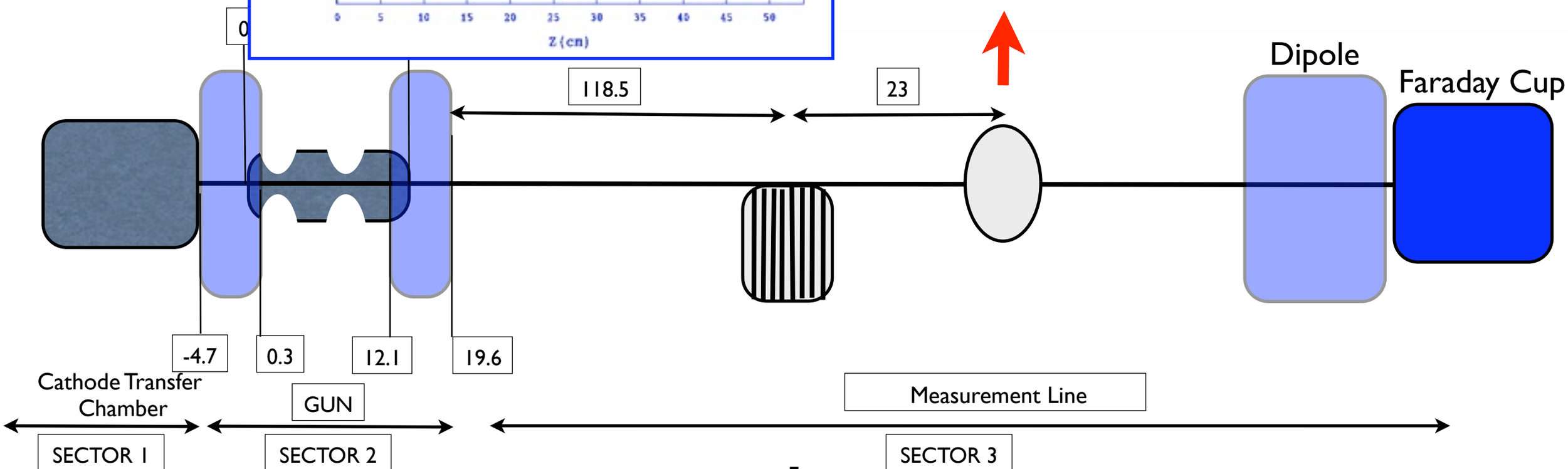


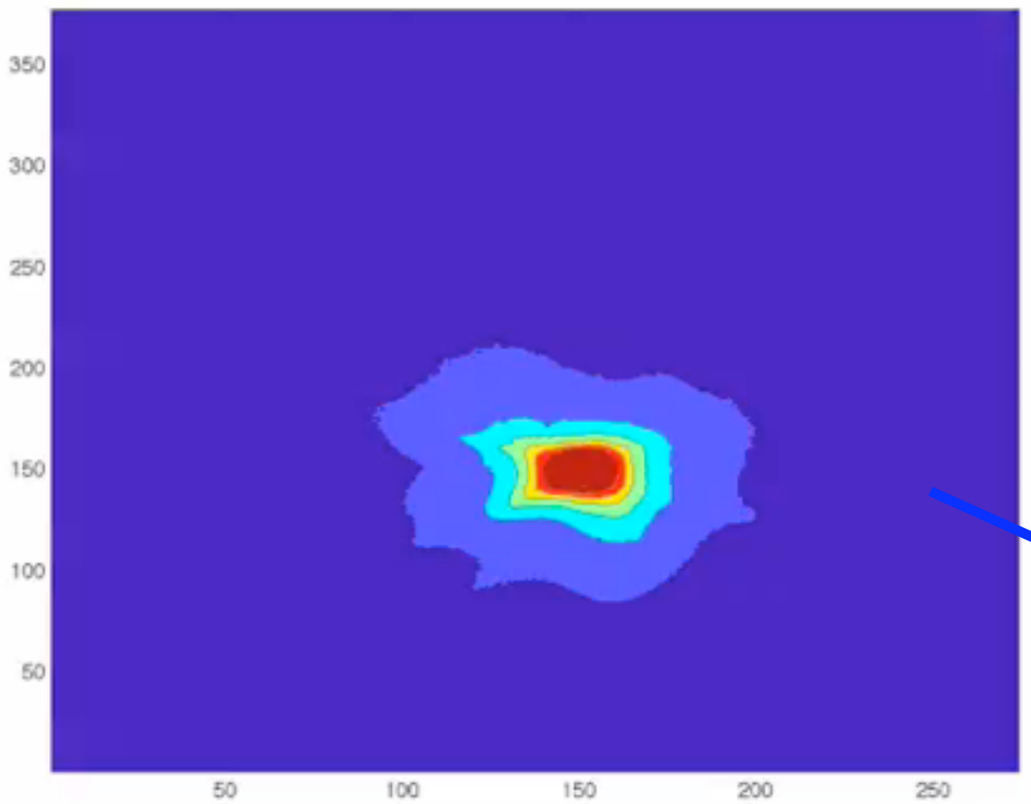
field on cathode is zero
(simulated field used as parmela input)





Measurements & Simulations

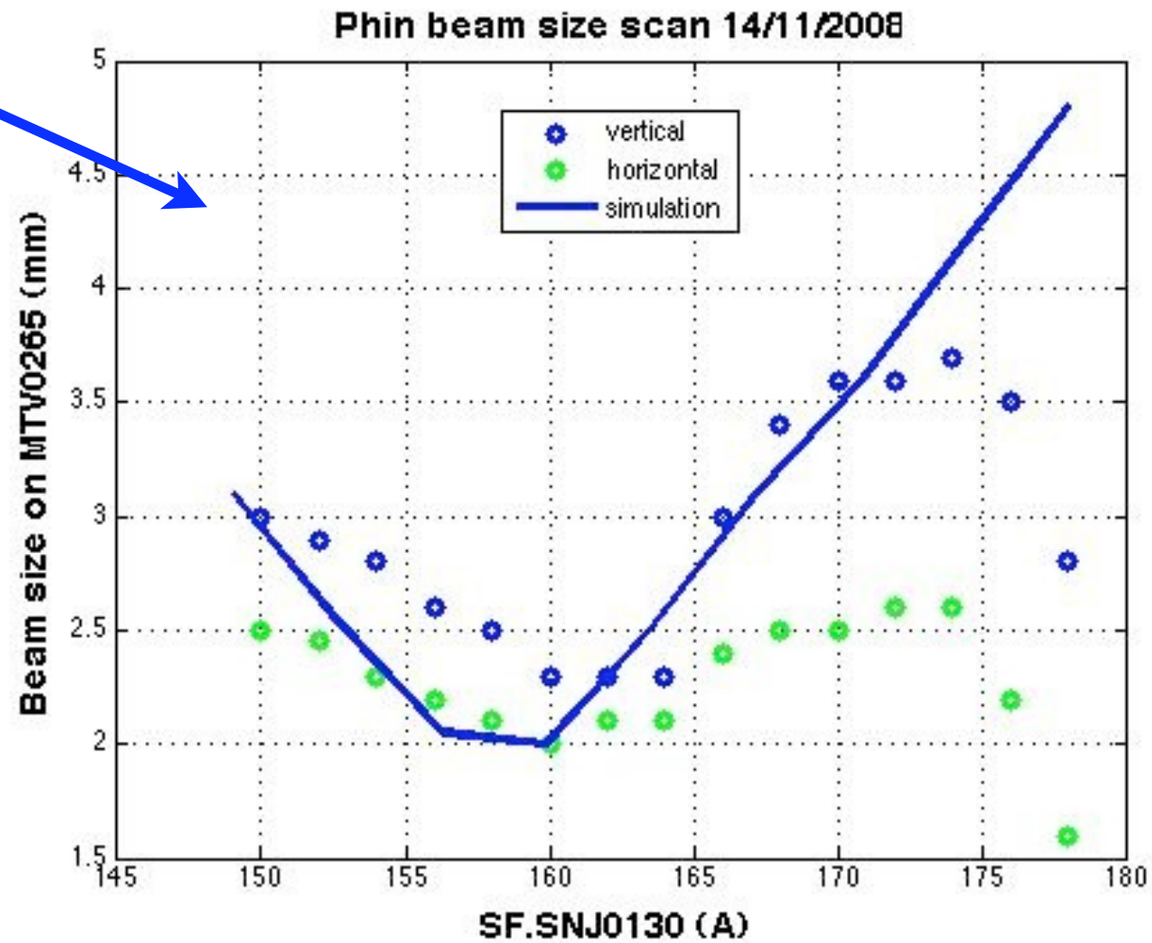
Solenoid Scan



Observation of the transverse beam sizes with respect to the systematic variation in focusing magnet current.

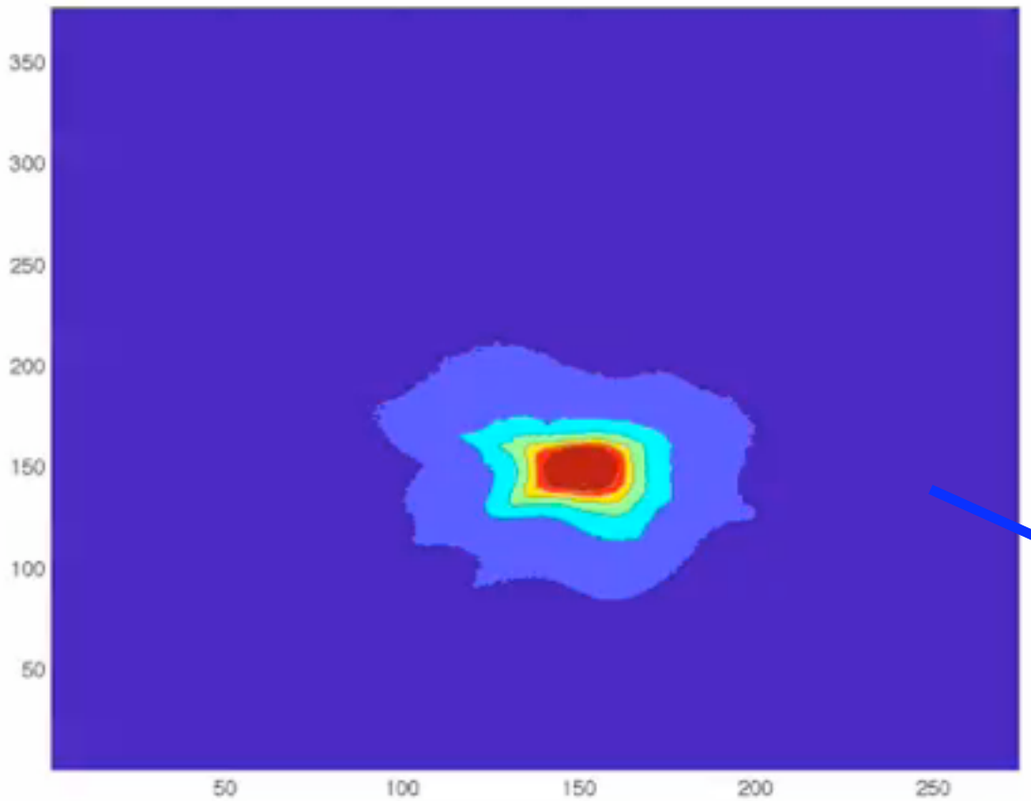
Bucking coil current has to be adjusted so that the field on the photo-cathode is zero.

SNH0110: 145A; SNJ0130: 150-178A,
290 deg at 5.06 MeV



Measurements & Simulations

Solenoid Scan



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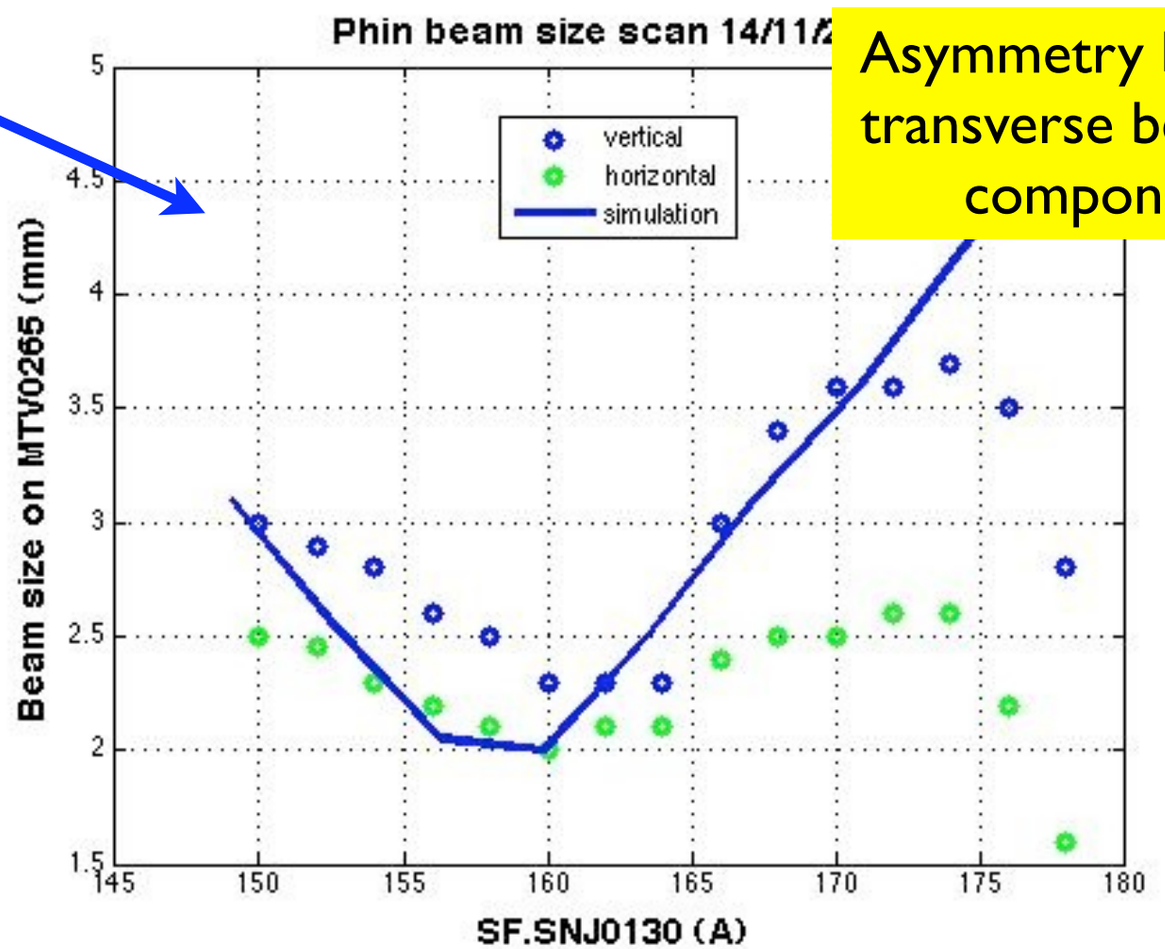
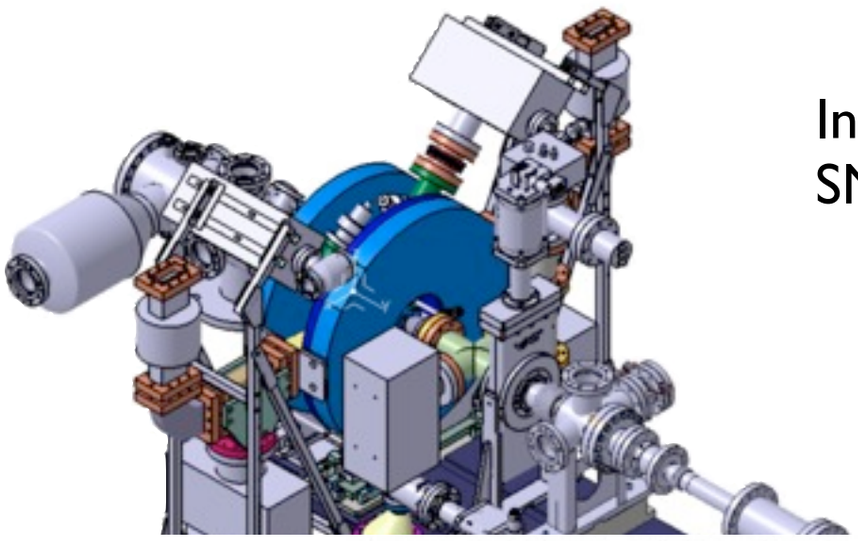


Asymmetry between transverse beam size components

Measurements & Simulations

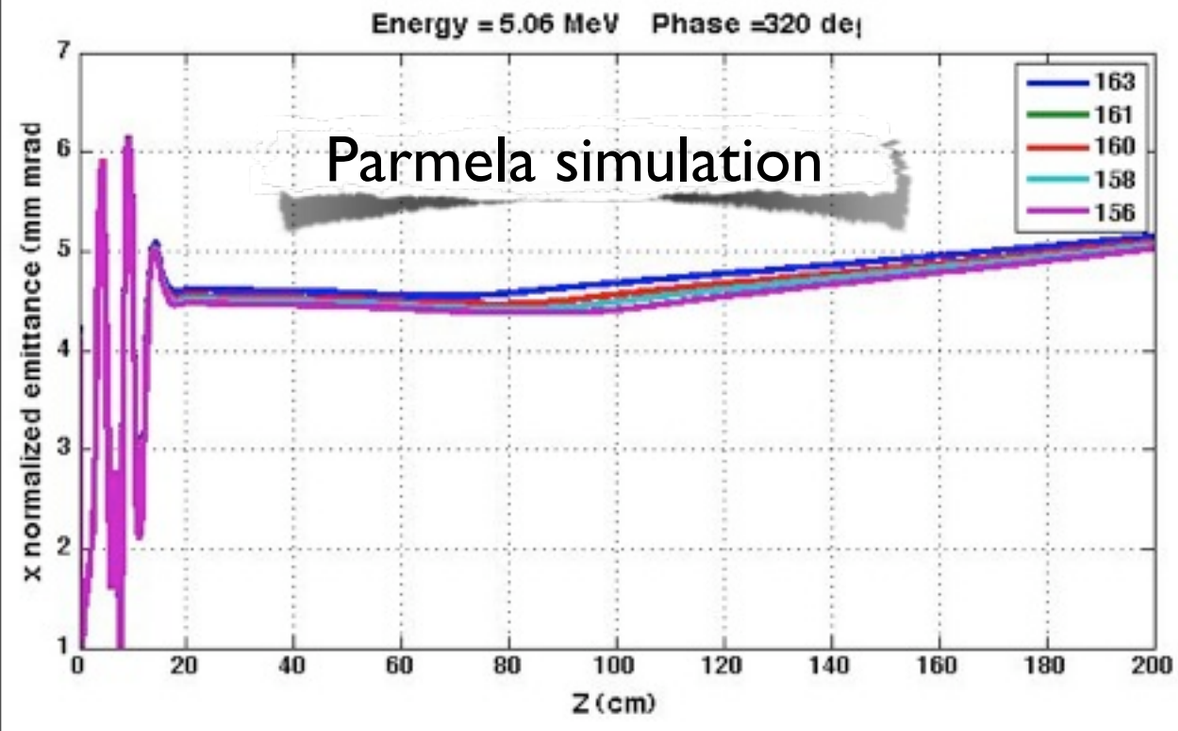
Solenoid Scan

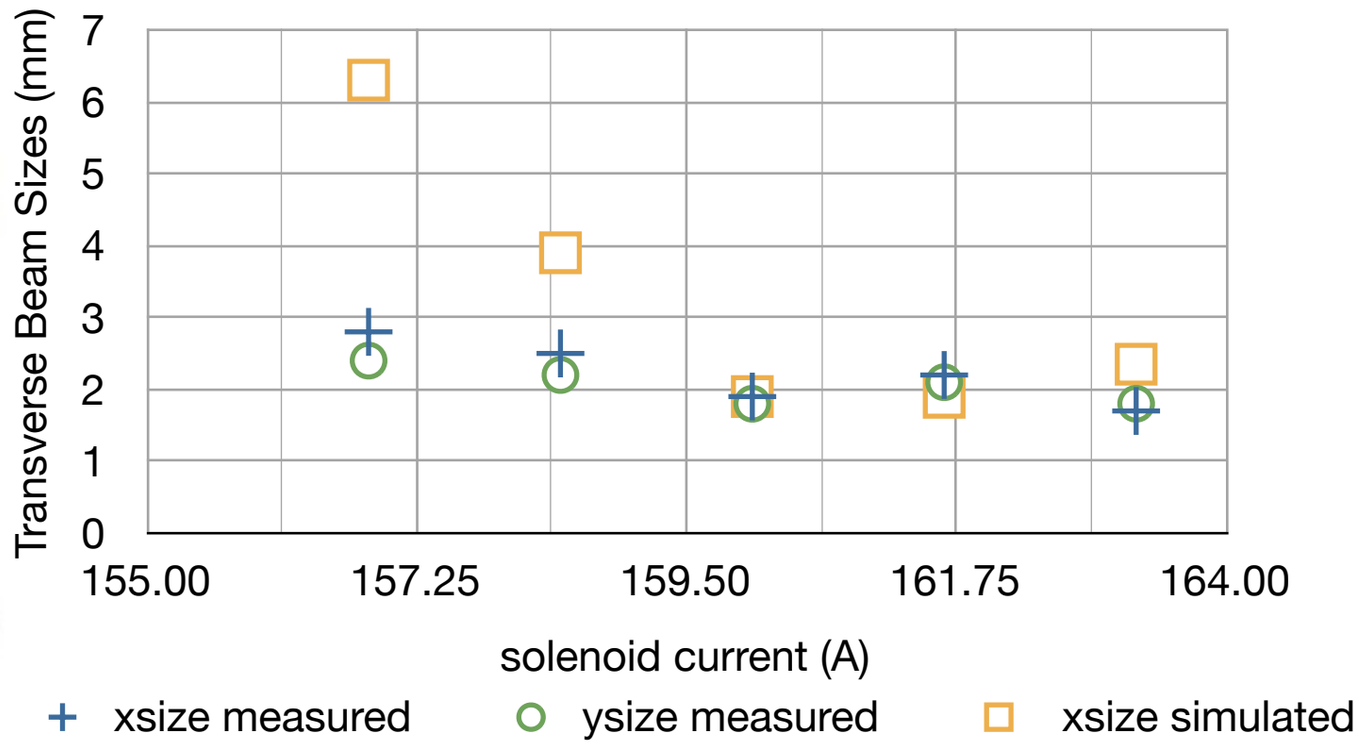
Change both of the solenoids with the same ratio



Initial magnet setting :
SNJ = 145 SNH = 165

coeff	SNH (A) acq.	SNJ (A) acq.
0.99	143.55	163.35
0.98	142.1	161.7
0.97	140.65	160.05
0.96	139.2	158.4
0.95	137.75	156.75



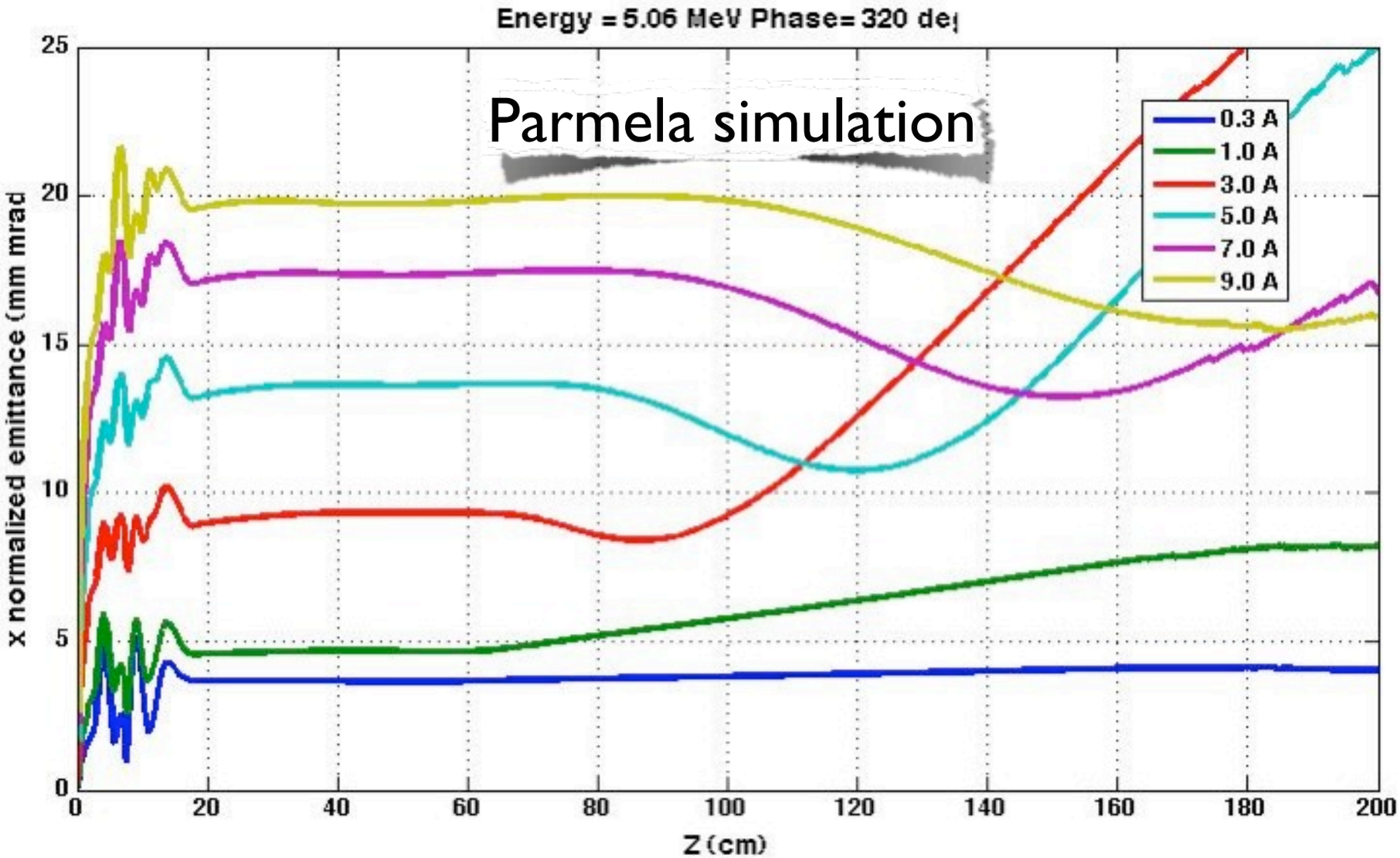


more data and higher charge operation is needed for compensation studies.

Measurements & Simulations

Solenoid Scan

Space Charge Effect and Compensation



increasing effect on emittance growth with the increasing beam current

Measurements & Simulations

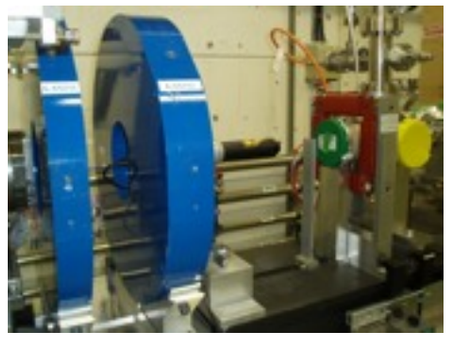
Solenoid Scan

how to compensate space charge induced emittance growth ?

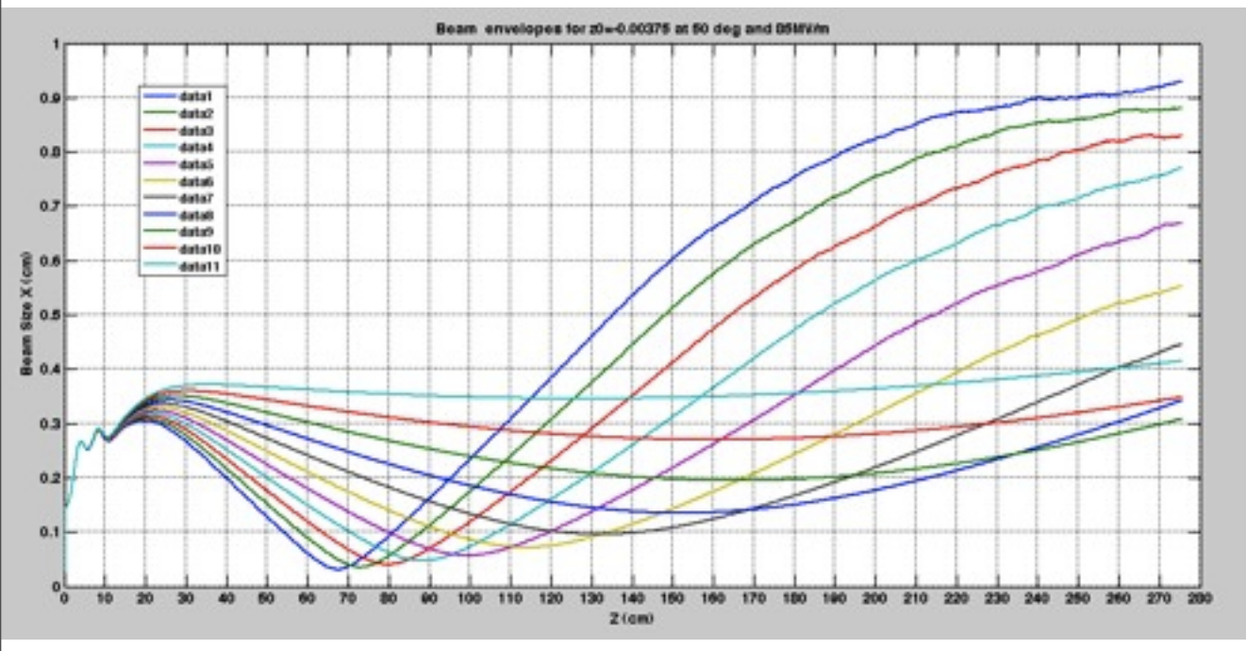
Measurements & Simulations

Solenoid Scan

how to compensate space charge induced emittance growth ?



adjust the position of the beam waist !



$$\epsilon_{x,y} = \frac{1}{2}\beta\gamma\sqrt{< \Lambda^2 >< \rho^2 > - < \Lambda\rho >^2}(2r_0(z_l + z_d) - \frac{z_d^2 r_0}{f})$$

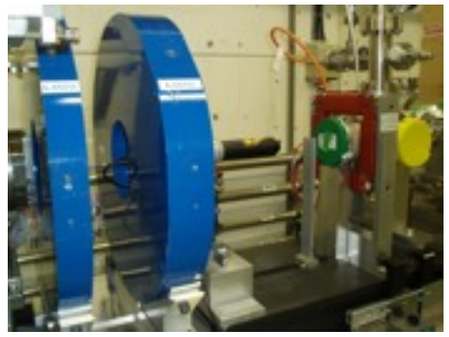
Parmela simulation

Michiko Minty and Frank Zimmerman
Measurement and Control of Charged Particle Beams (Springer 2004)

Measurements & Simulations

Solenoid Scan

how to compensate space charge induced emittance growth ?



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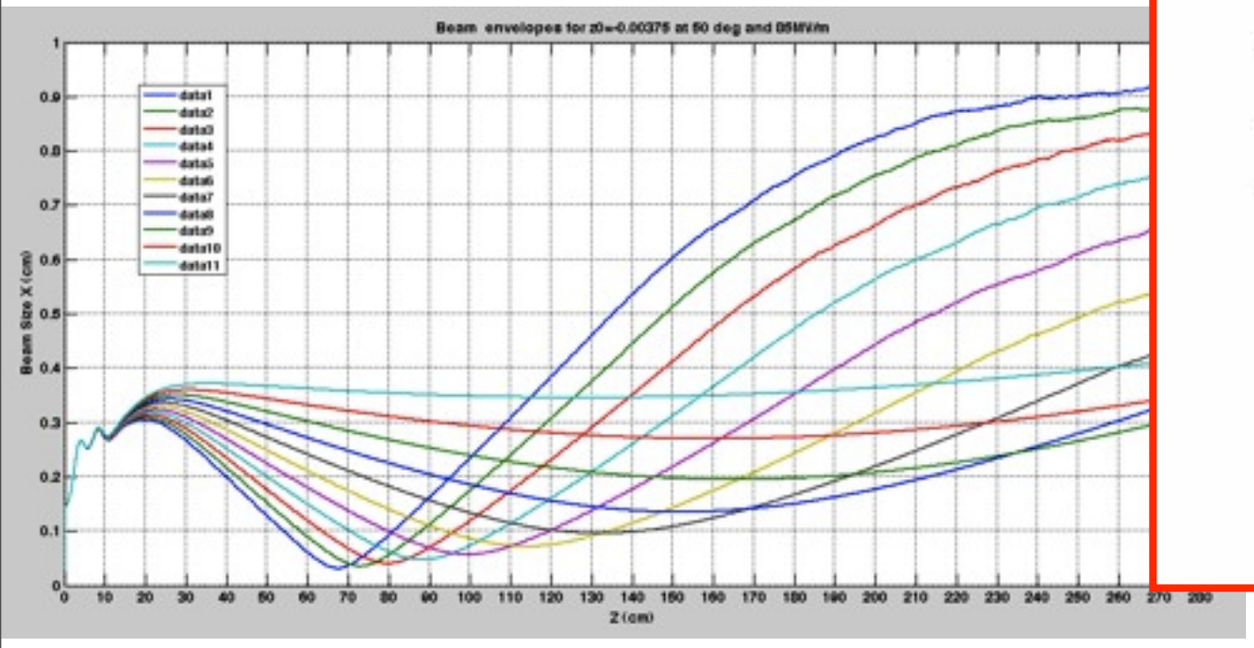

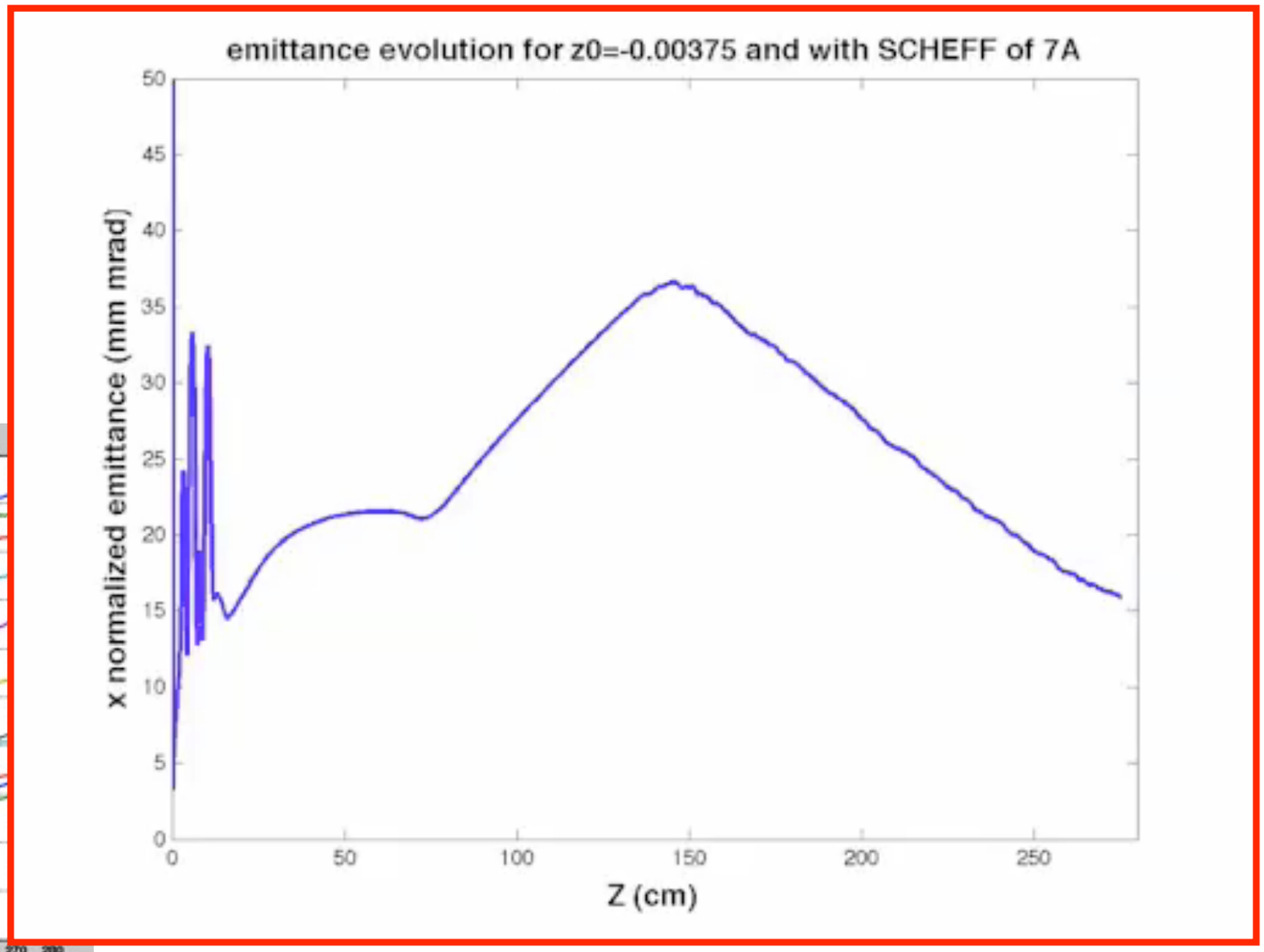

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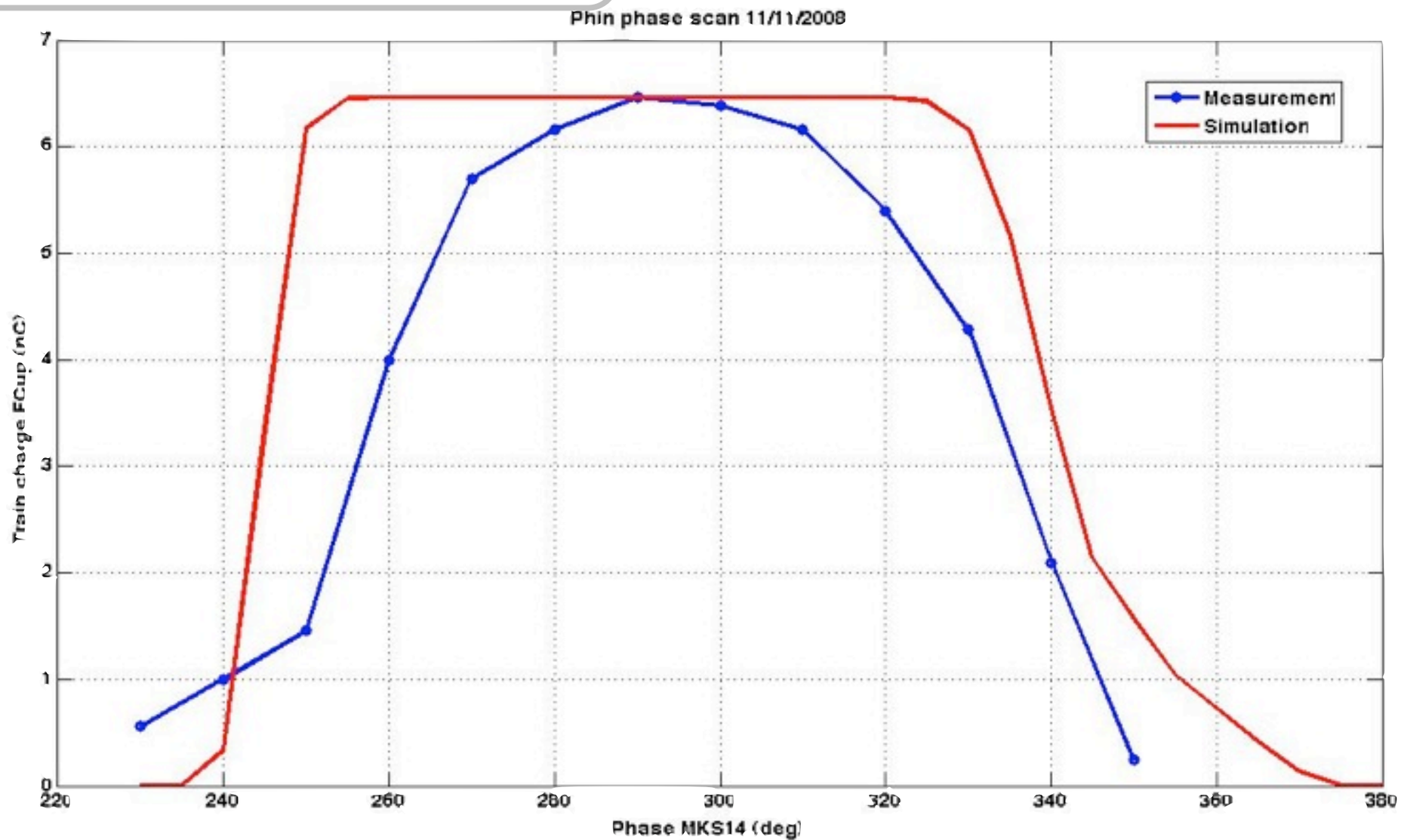
Parmela simulation

Measurements & Simulations

Phase Scan, Particle transport up to the FC

SNH0110:135A; SNJ0130:140A

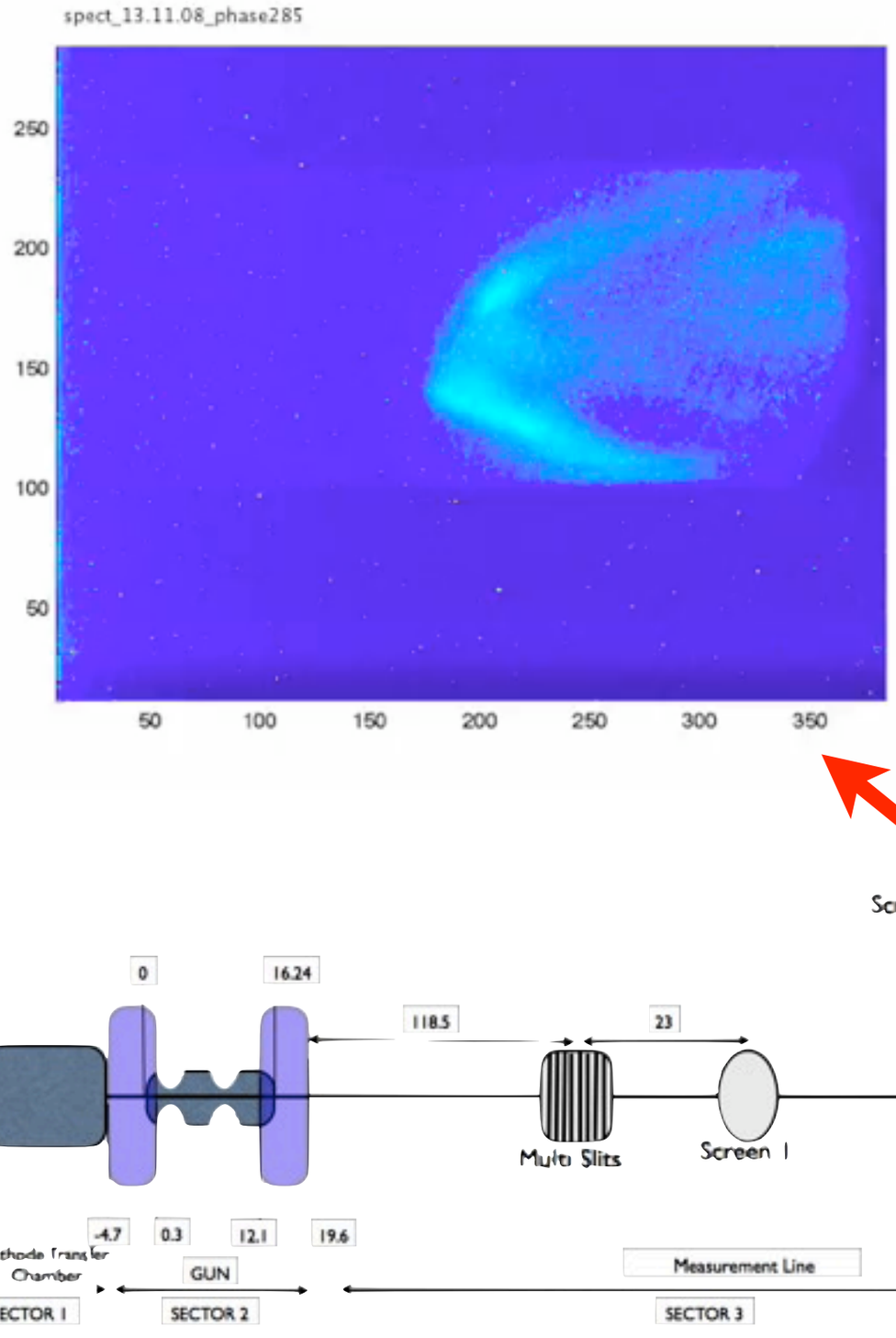
- Solenoid Scan
- **Phase Scan, rf phase wrt laser**
- Emittance



Measurements & Simulations

Phase Scan

SNH0110: 155A, SNJ0130: 168A, BHM0302: 10.10A



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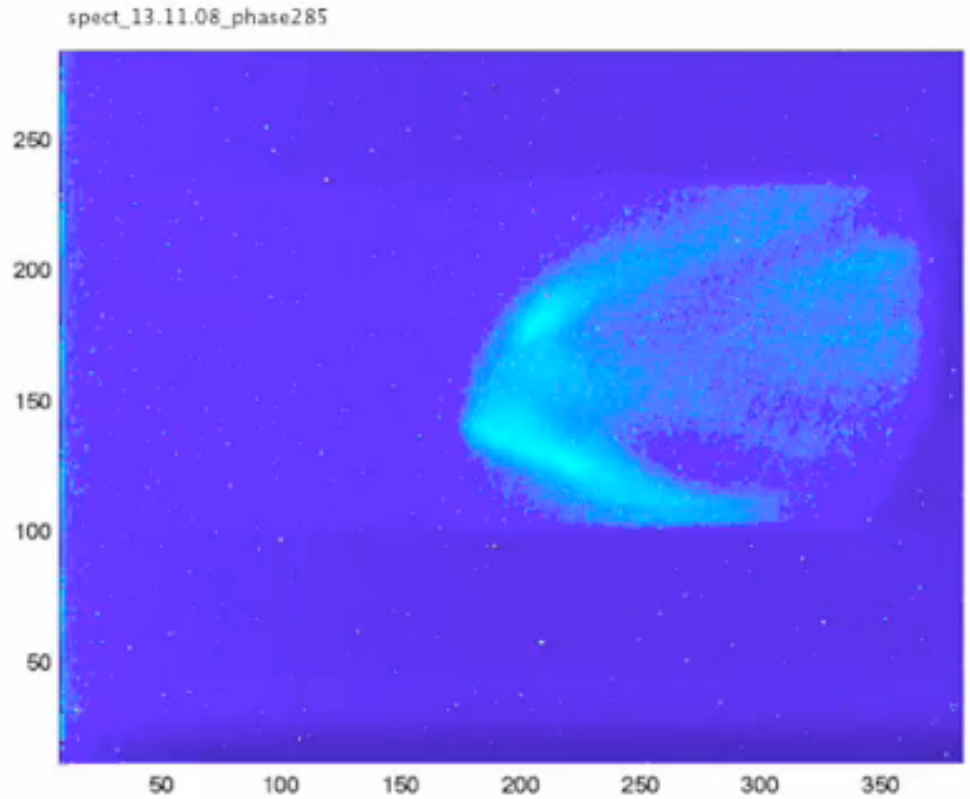

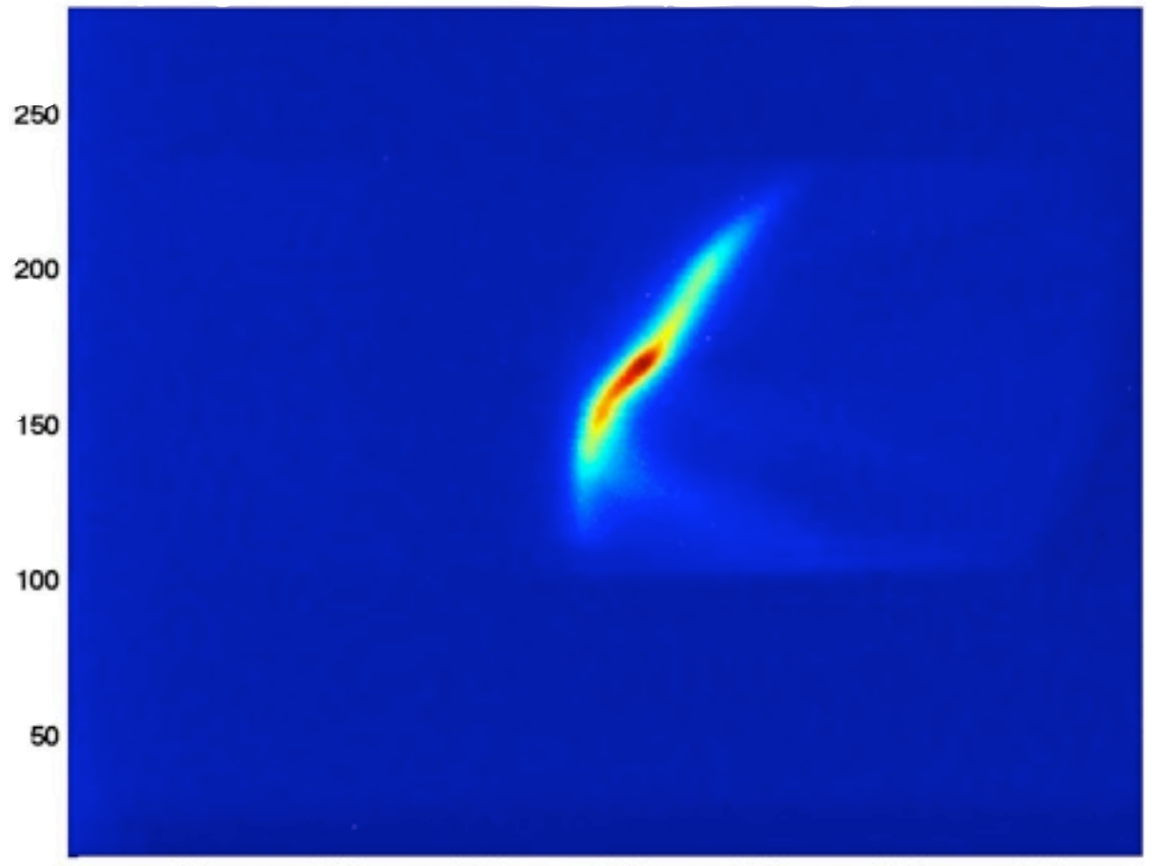

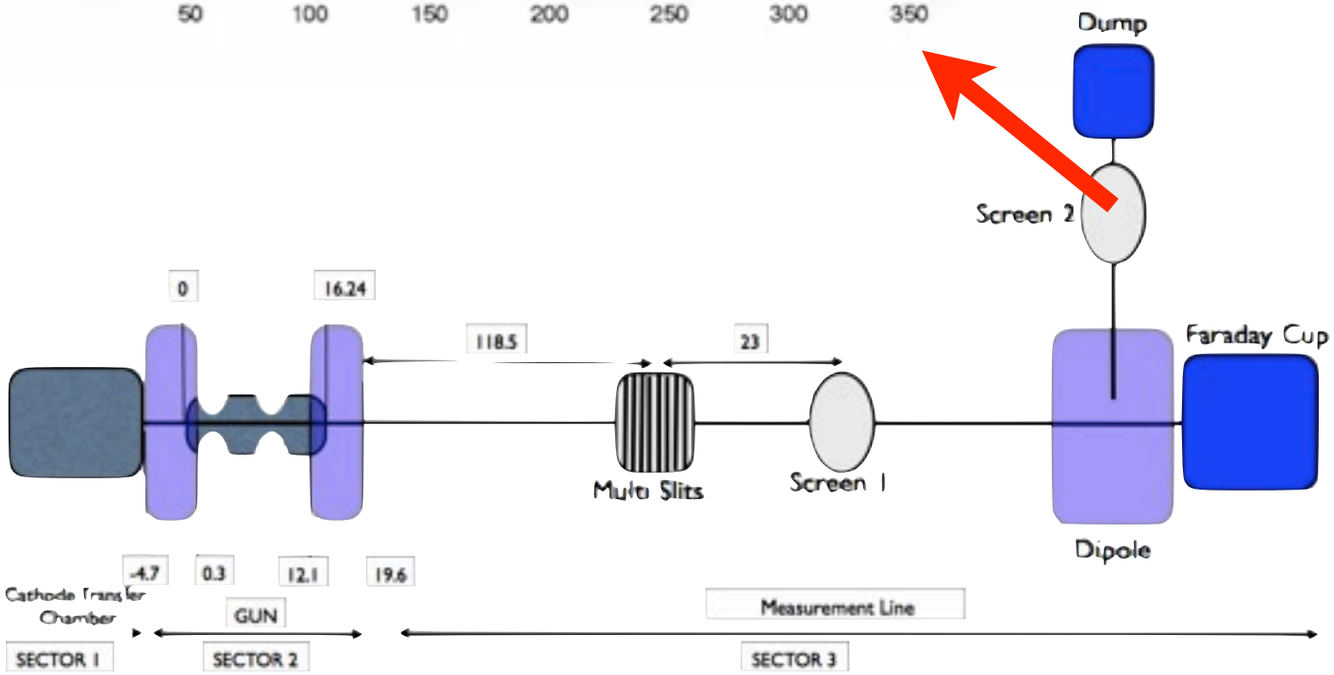

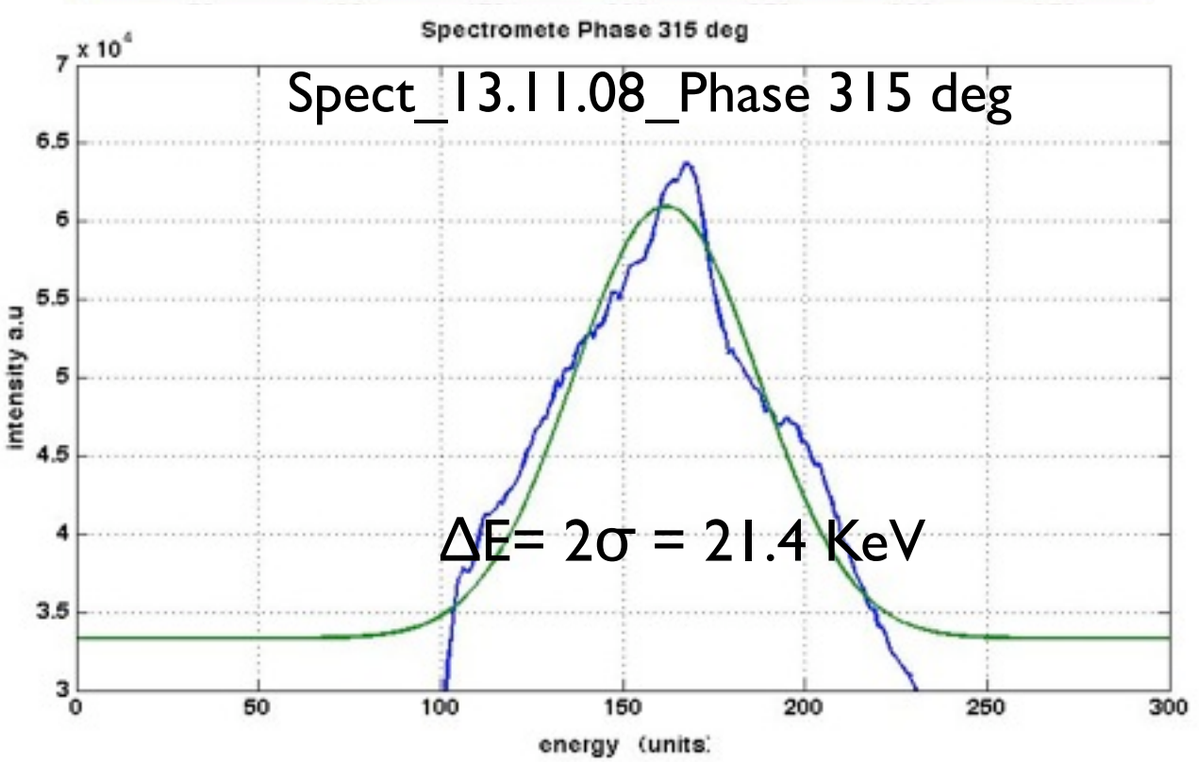

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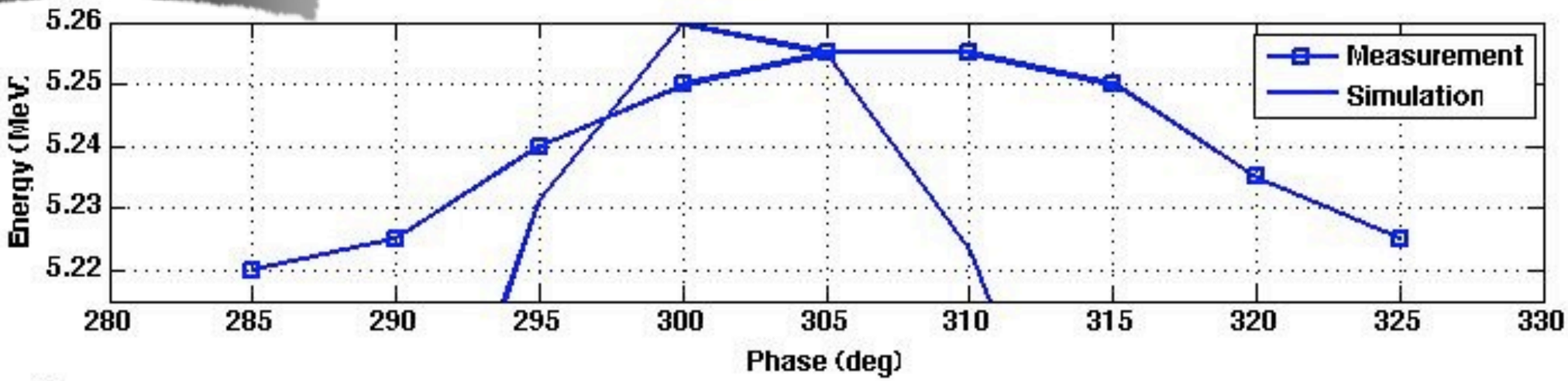
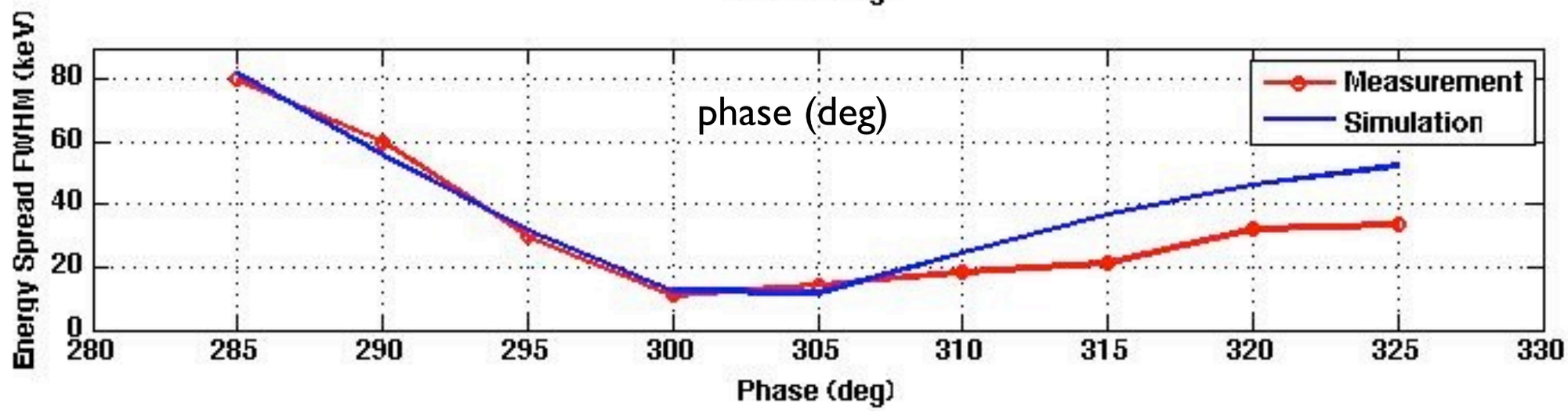
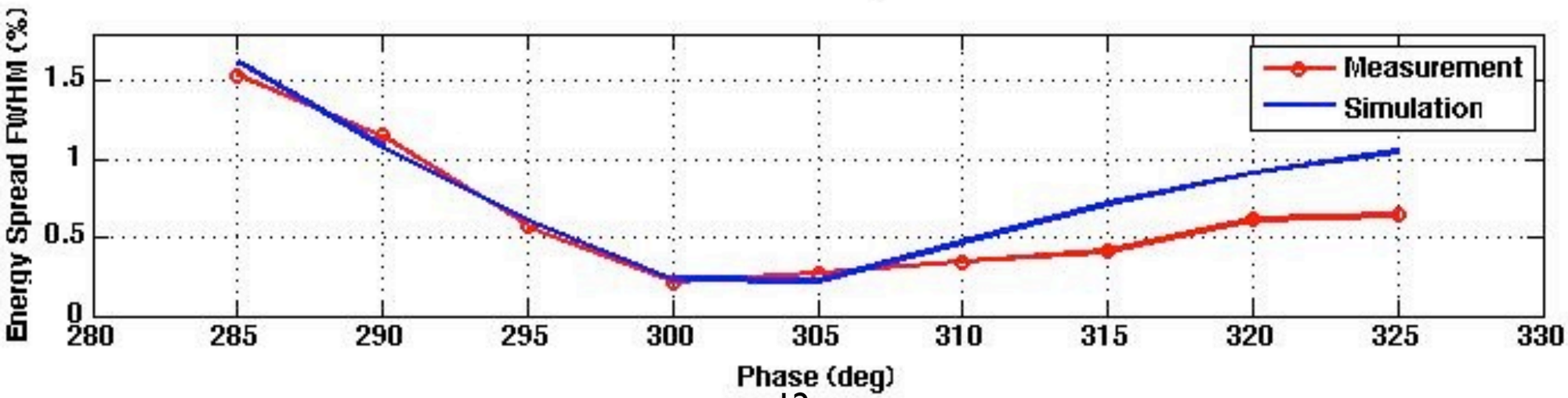




phase (deg)



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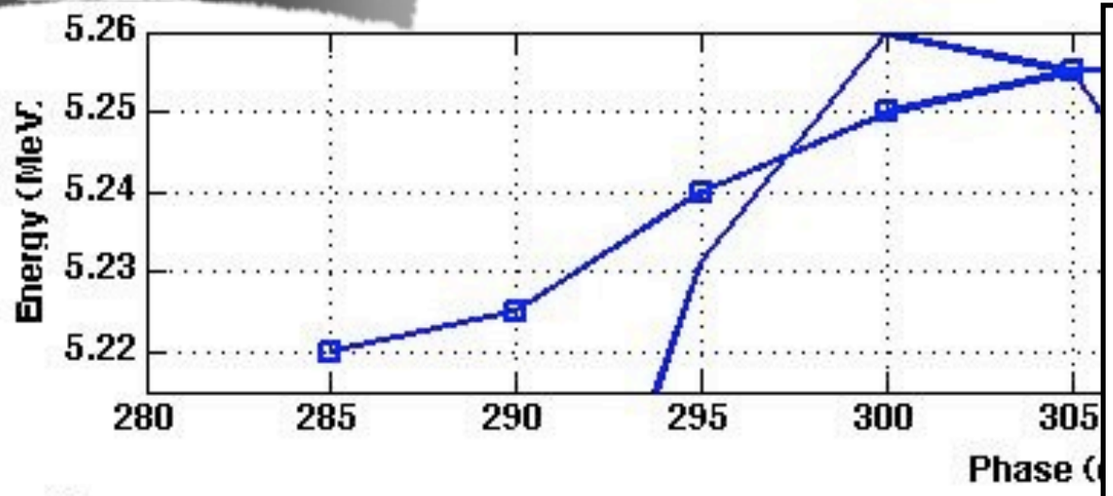
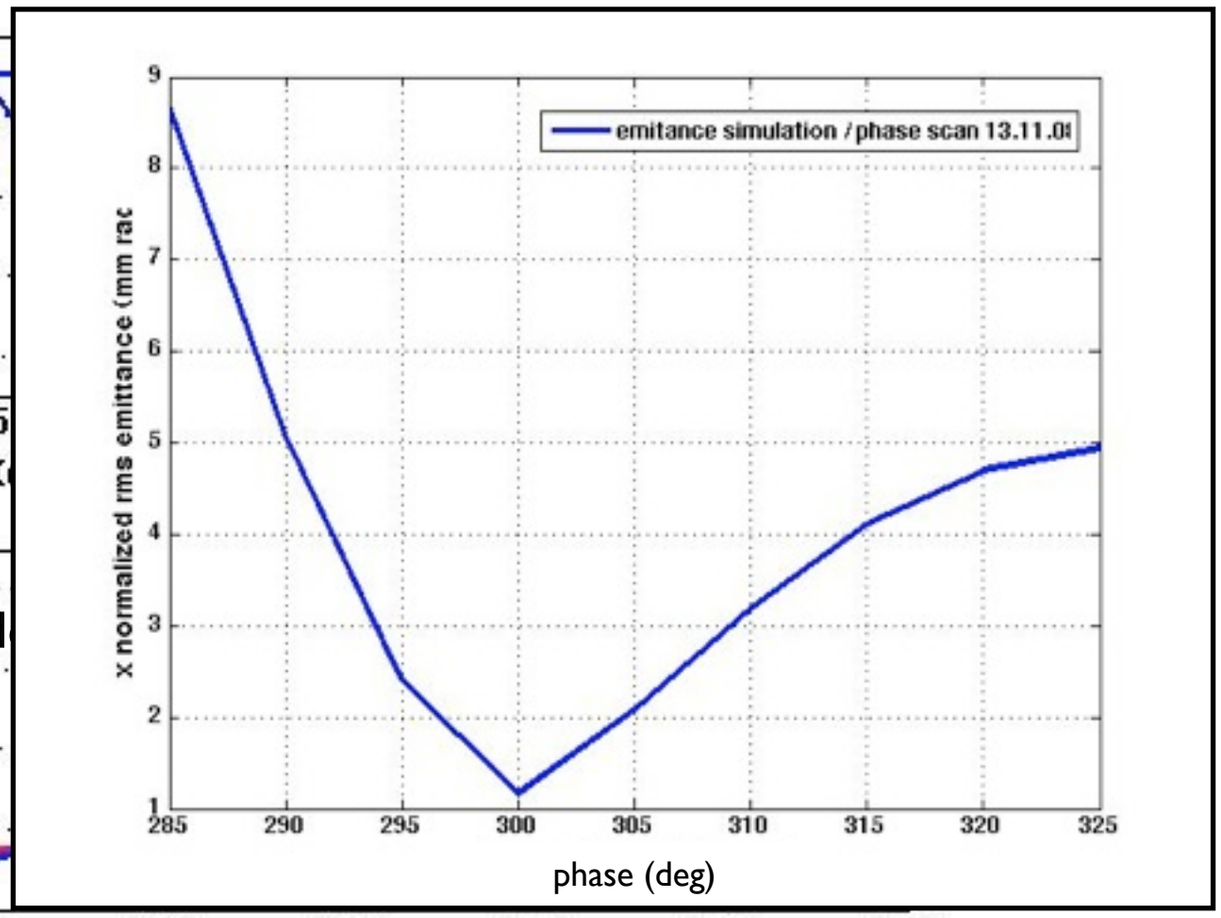
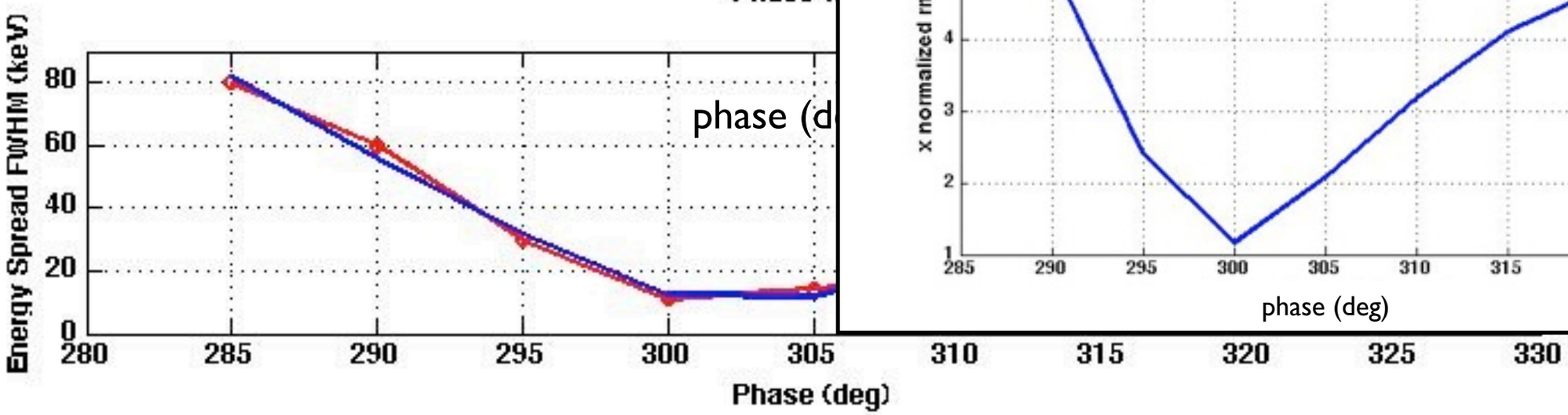
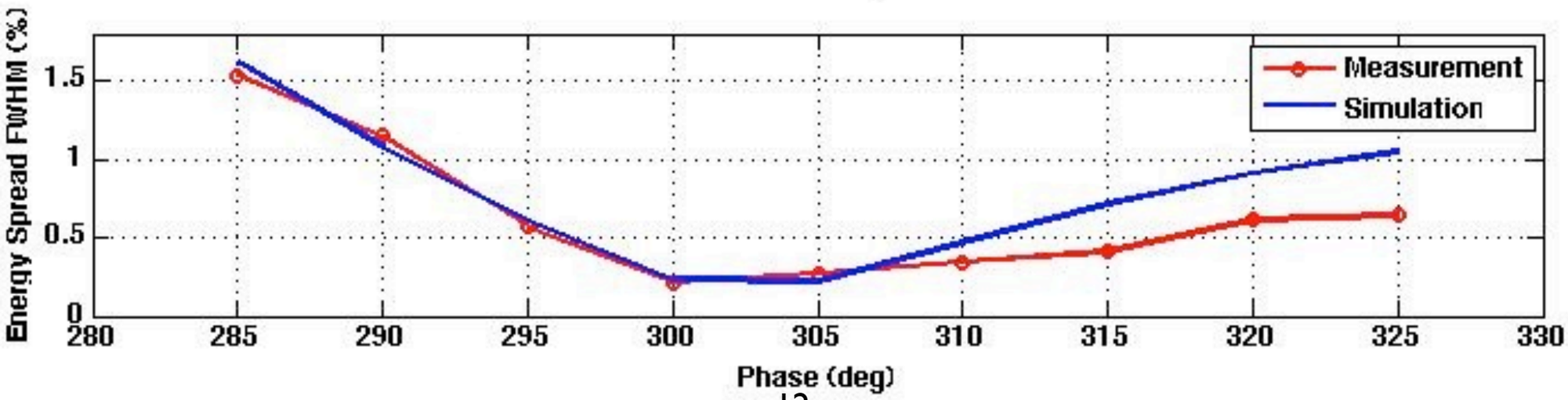






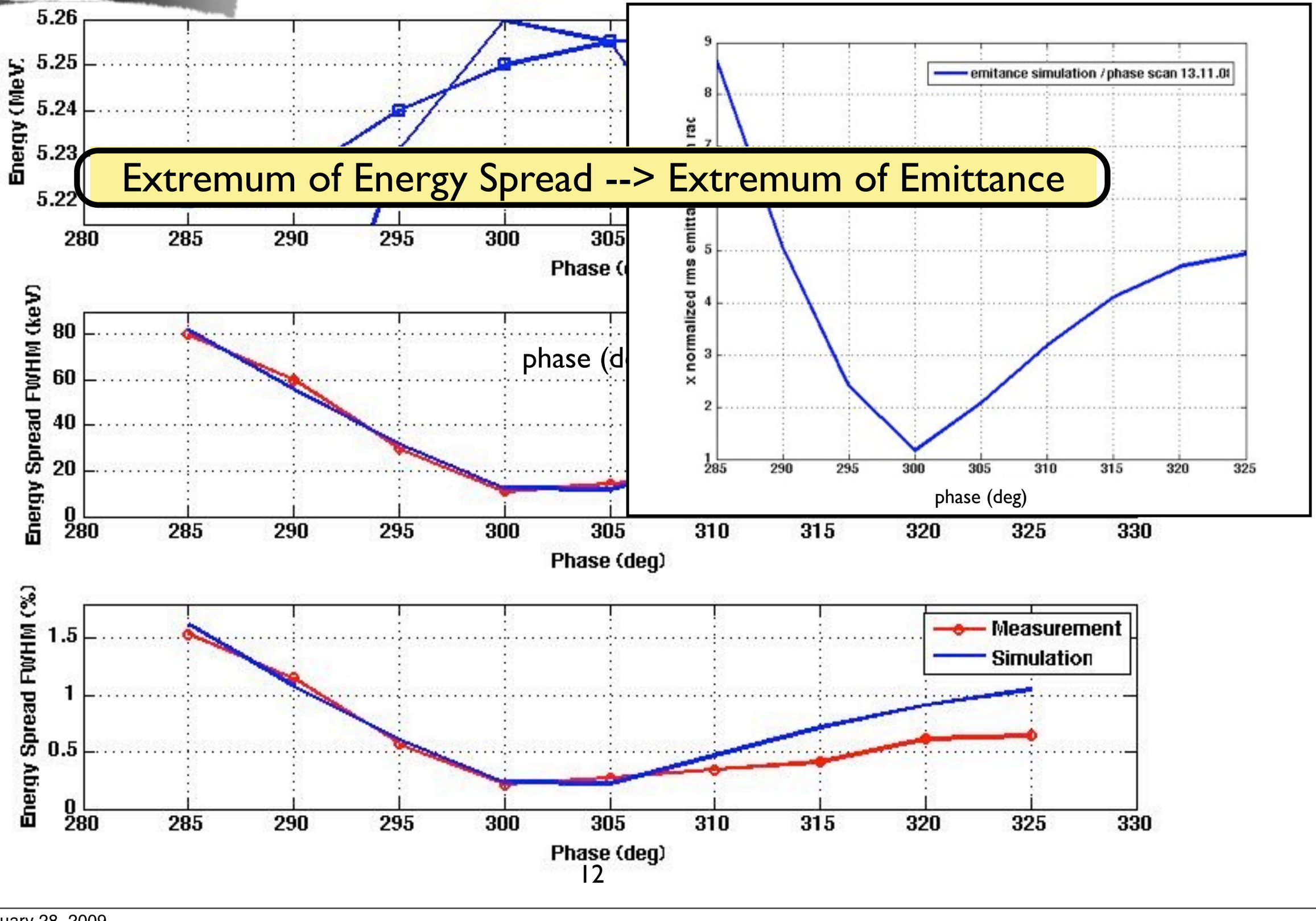


Measurements & Simulations

Phase Scan

SNH0110: 155A, SNJ0130: 168A, BHM0302: 10.10A

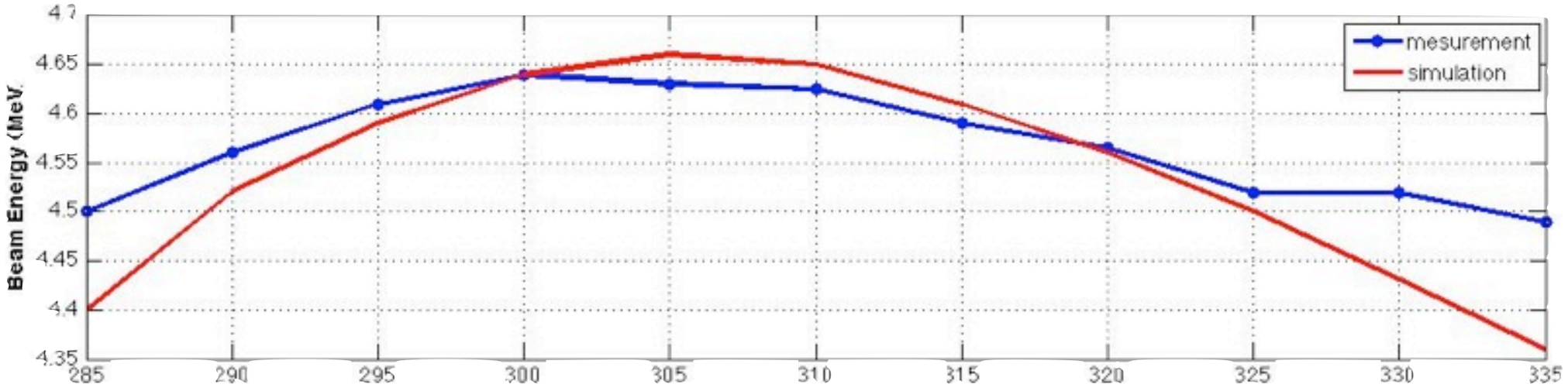
Extremum of Energy Spread --> Extremum of Emittance

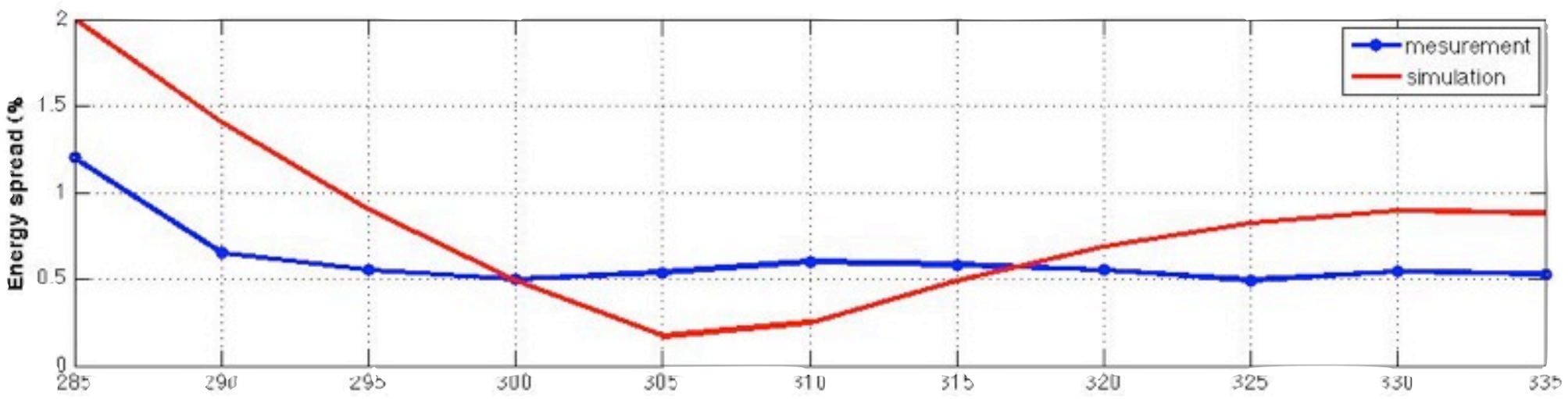


Measurements & Simulations

Phase Scan

SNH0110: 143A, SNJ0130: 145A, BHM0302: 8.8A

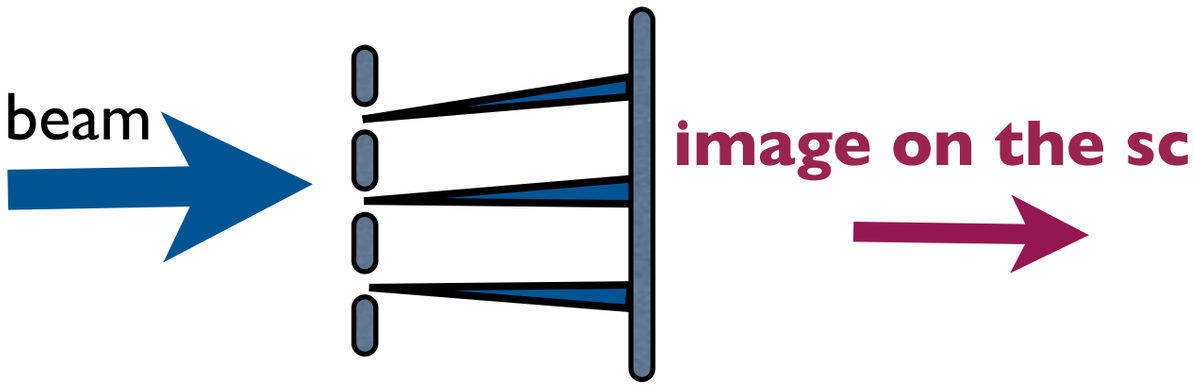


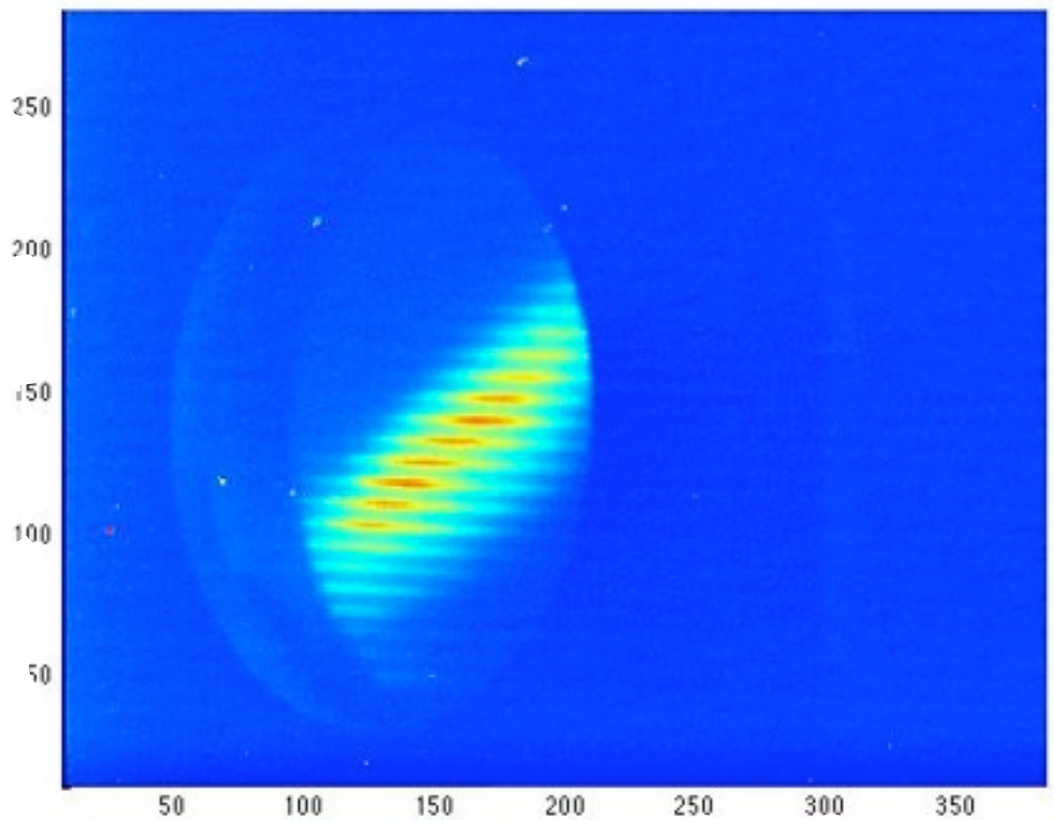


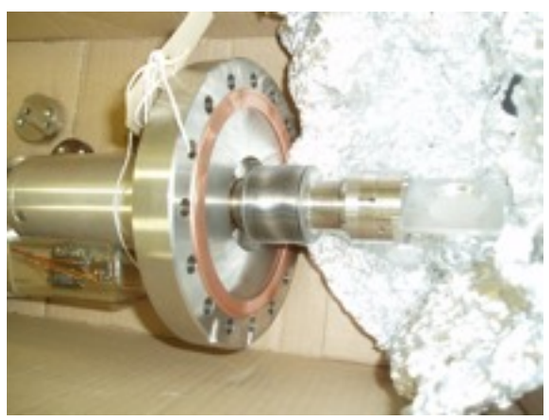
Measurements & Simulations

Emittance

Multi-slit based emittance measurement







for details of the method

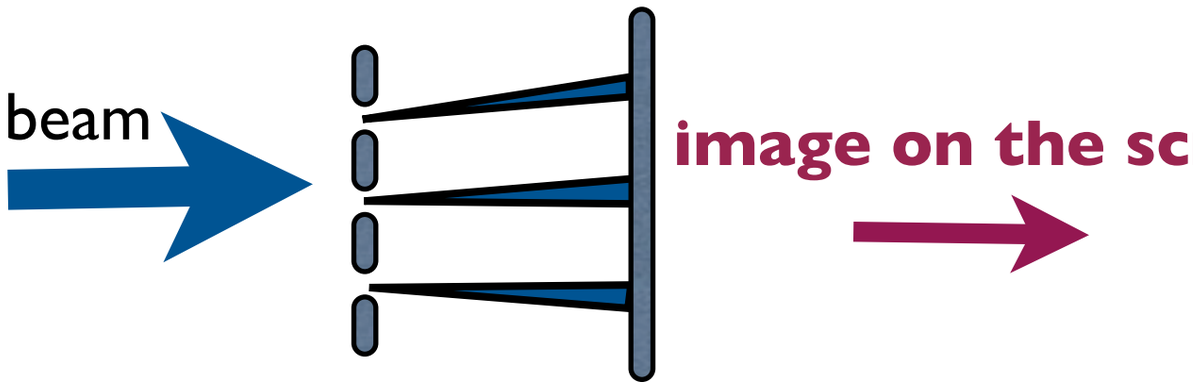
- S.G. Anderson et al., Phys. Rev. Vol 5, 014201 (2002)
- Min Zhang, Fermilab-TM-1988

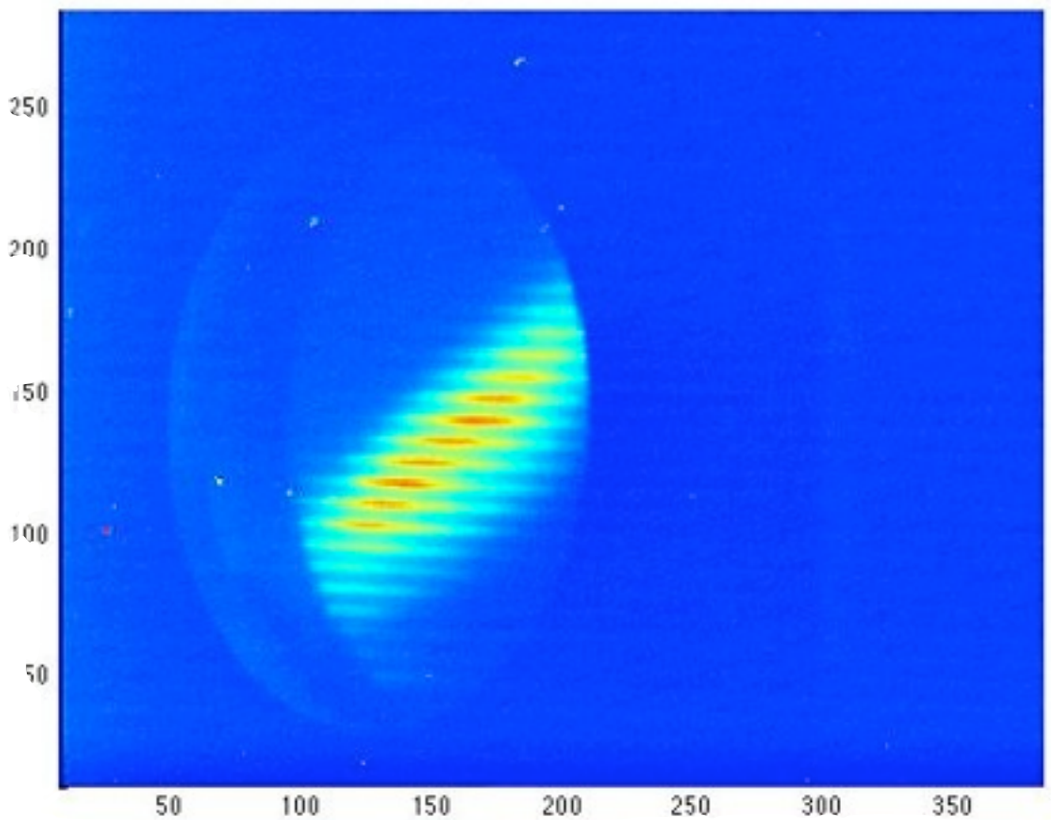
Measurements & Simulations

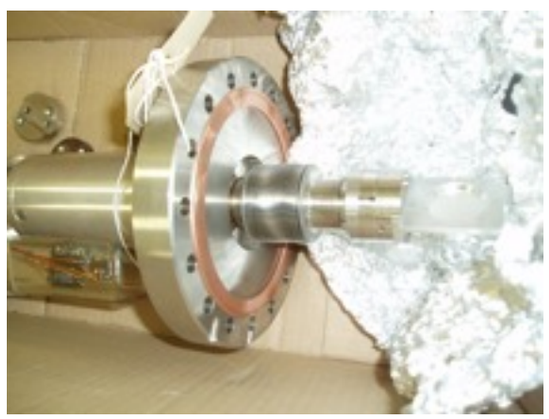
Emittance

Multi-slit based emittance measurement

☑ Slice up the beam into ‘beamlets’.







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Measurements & Simulations

Emittance

Multi-slit based emittance measurement

- ☑ Slice up the beam into ‘beamlets’.
- ☑ Let the beamlets drift.

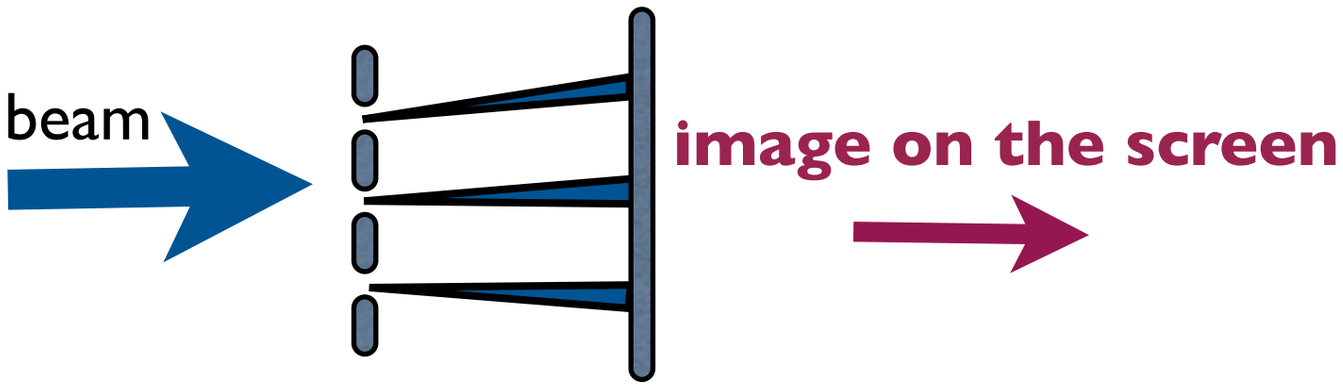
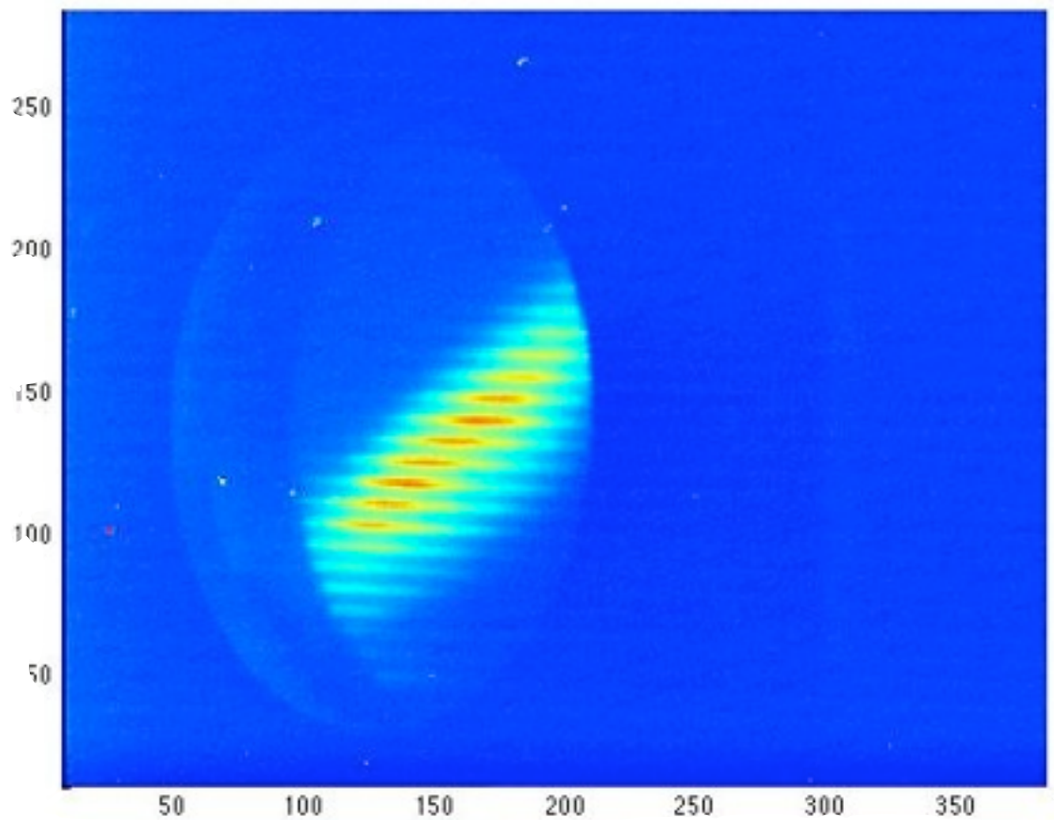
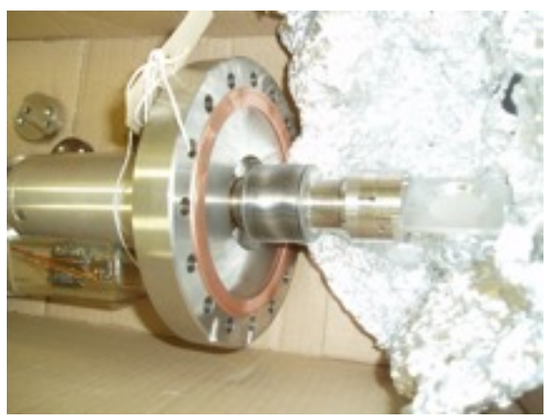


image on the screen





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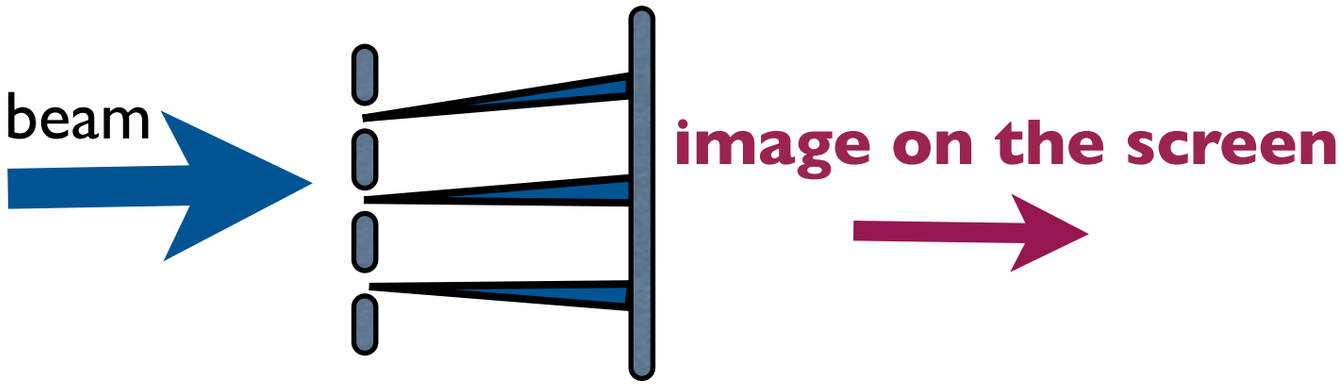
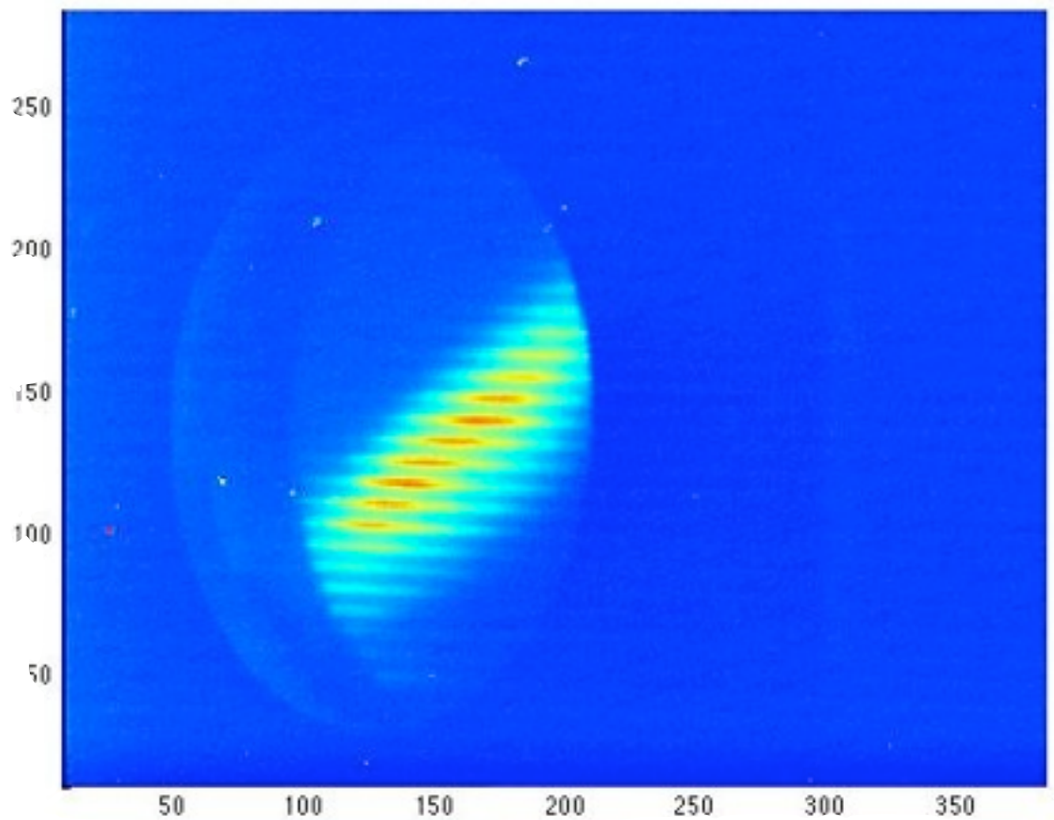
Measurements & Simulations

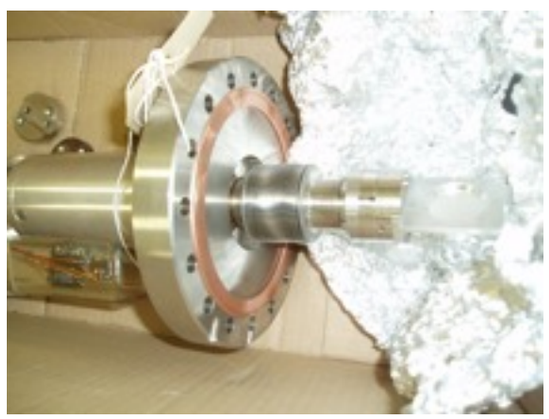
Emittance

Multi-slit based emittance measurement

- ☑ Slice up the beam into ‘beamlets’.
- ☑ Let the beamlets drift.
- ☑ Observe the momentum distribution with an OTR screen.







for details of the method

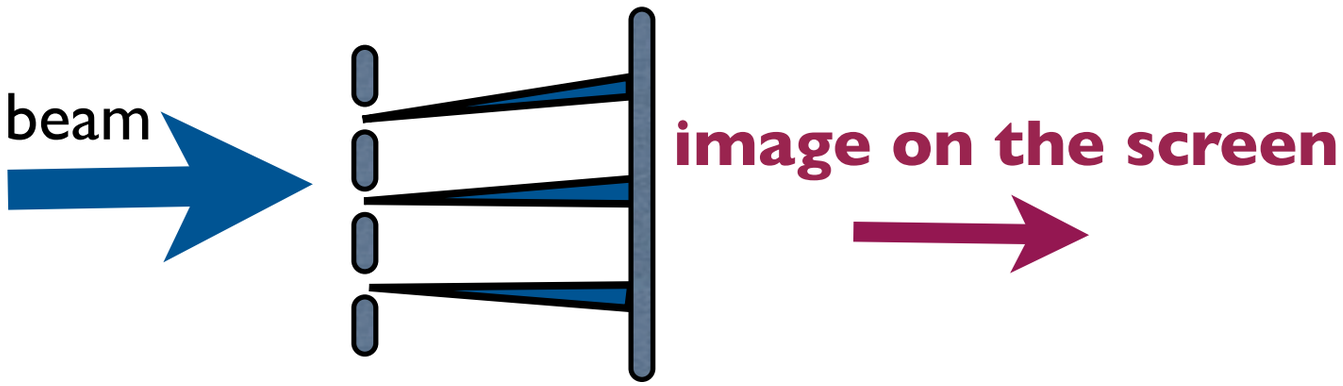
- S.G. Anderson et al., Phys. Rev. Vol 5, 014201 (2002)
- Min Zhang, Fermilab-TM-1988

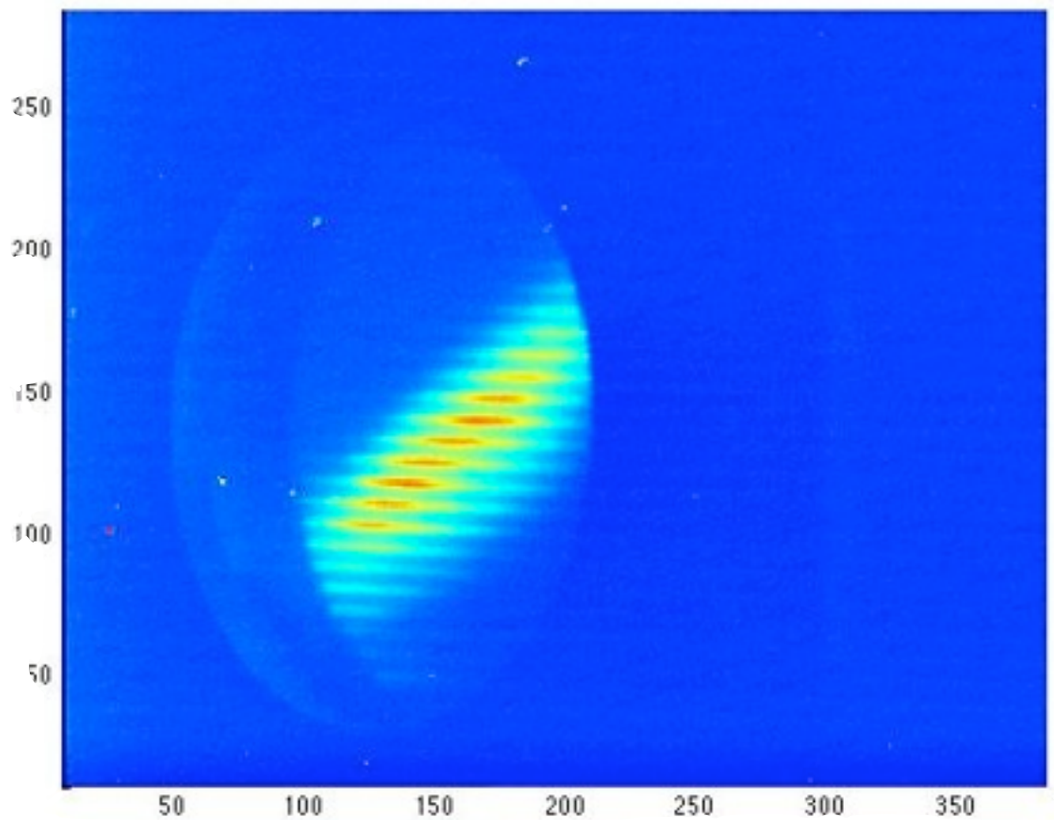
Measurements & Simulations

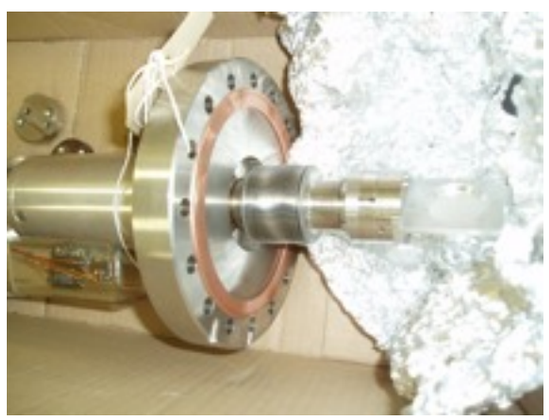
Emittance

Multi-slit based emittance measurement

- ☑ Slice up the beam into ‘beamlets’.
- ☑ Let the beamlets drift.
- ☑ Observe the momentum distribution with an OTR screen.
- ☑ Reconstruct the phase space out of these info.







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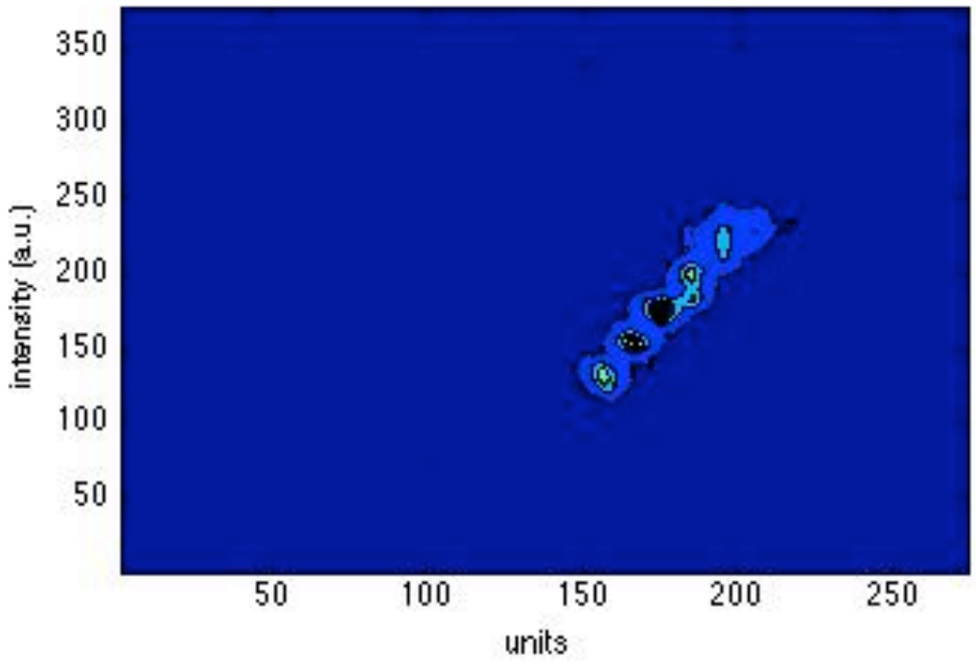
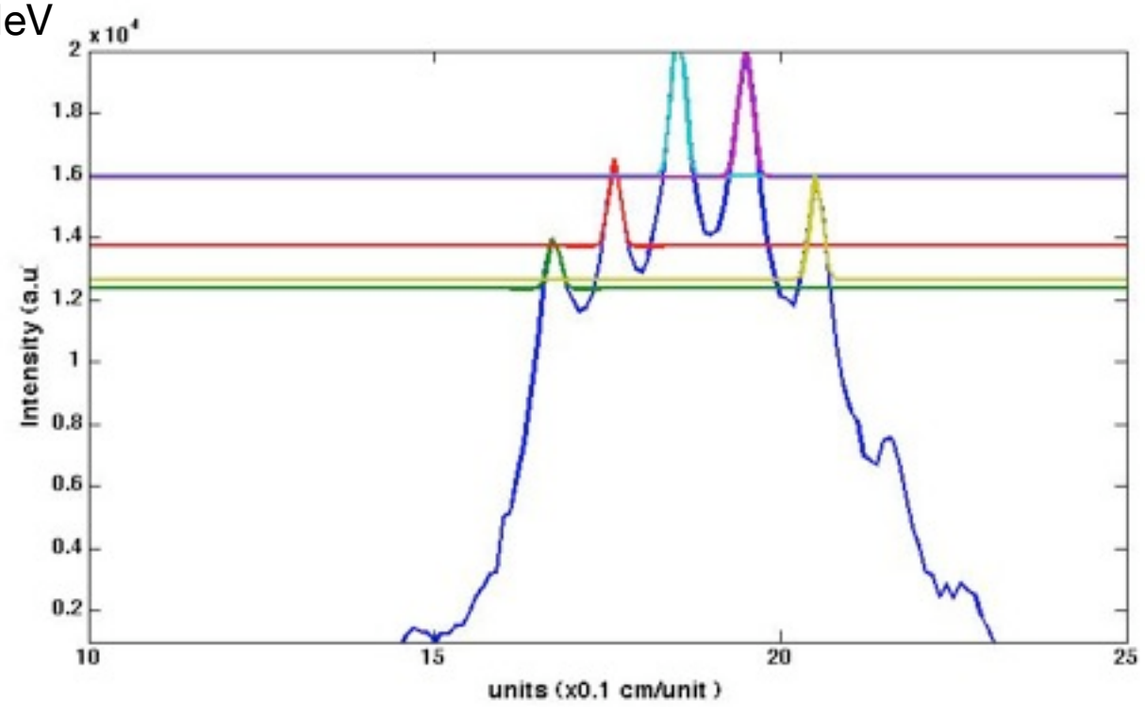
Measurements & Simulations

Emittance

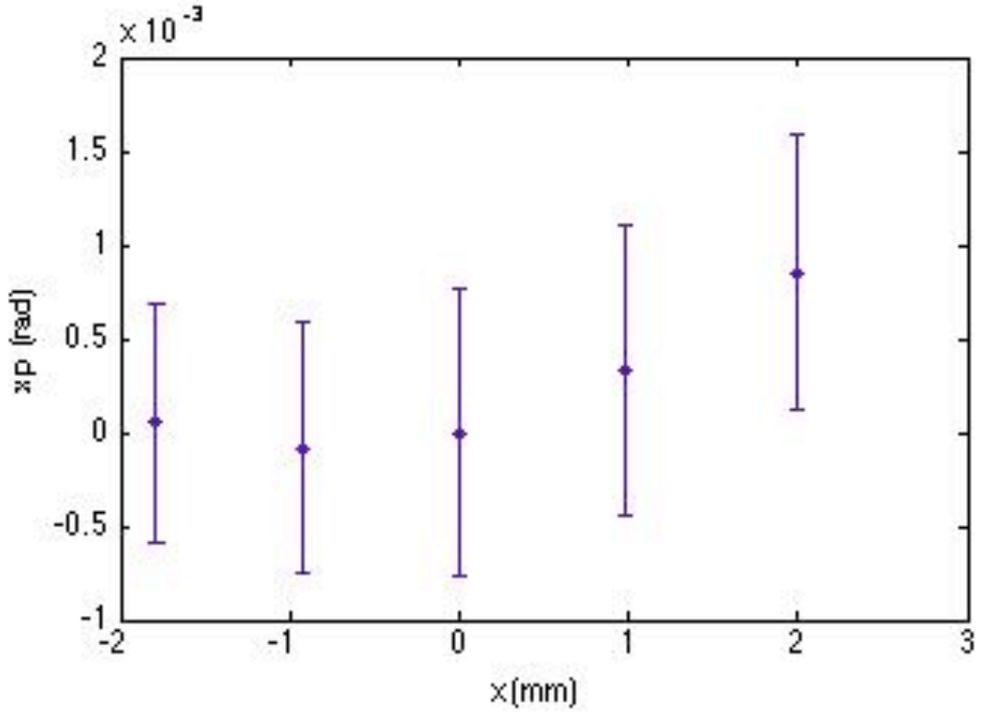
Data Analyses for Emittance Measurement

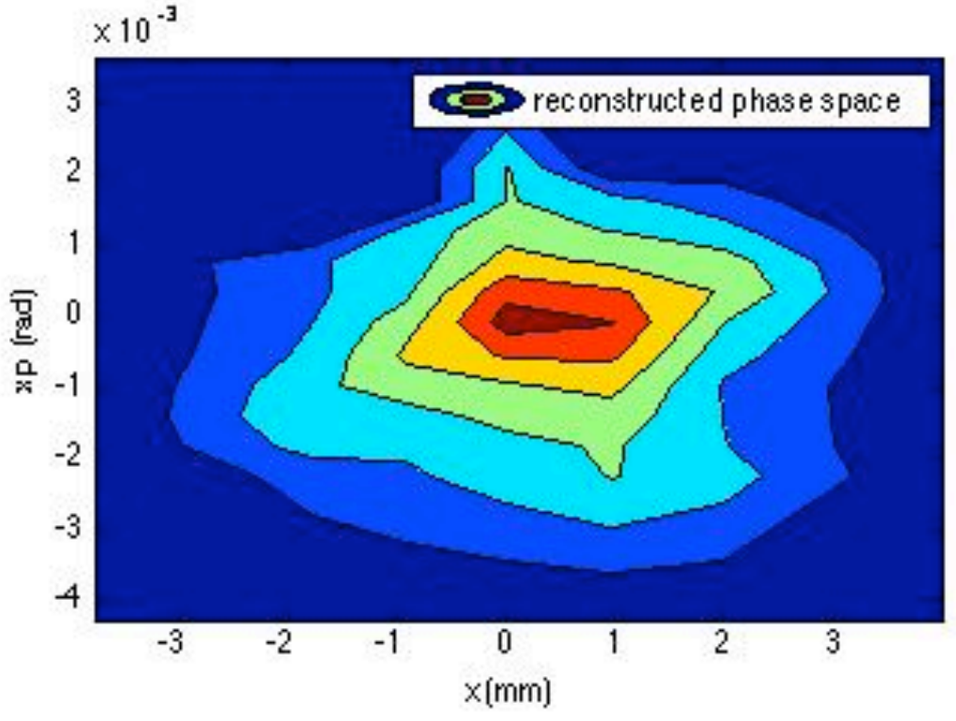
Phase = 320 deg SNH = 119 A SNJ = 160 A E = 5.06 MeV





Normalized rms emittance = 1.65 mm mrad





Measurements & Simulations

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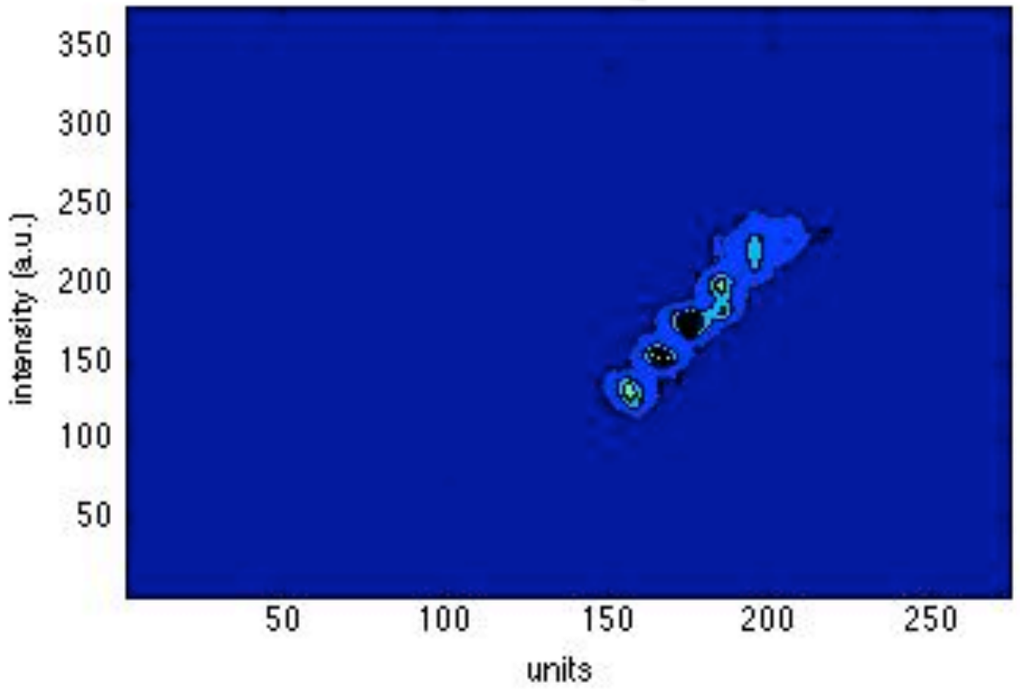
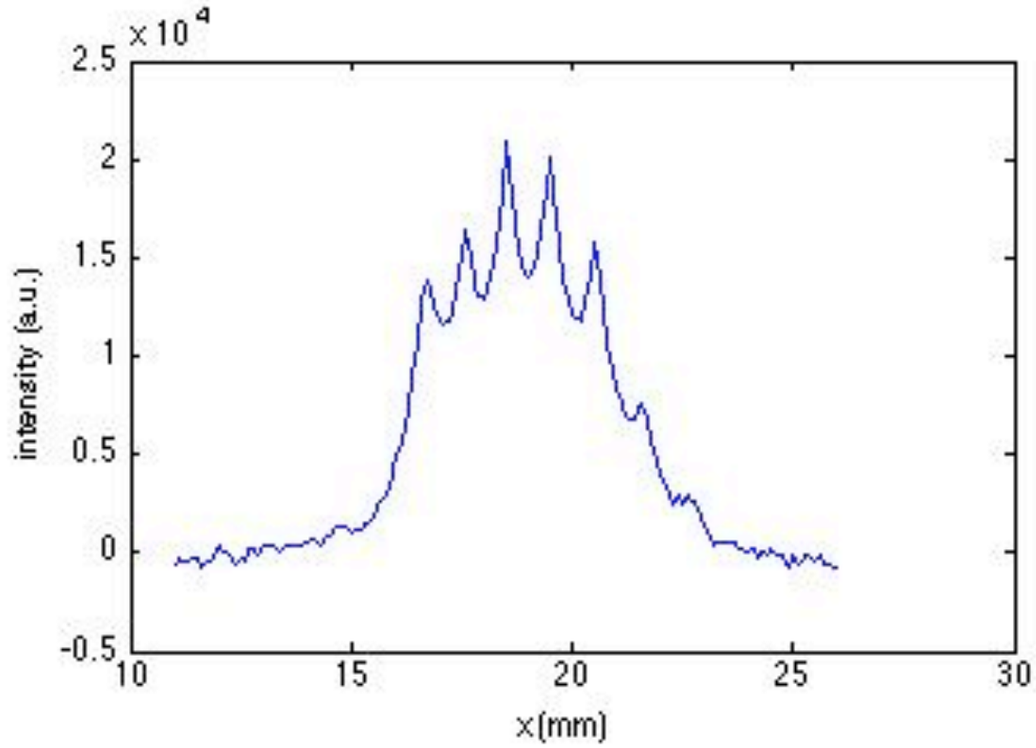
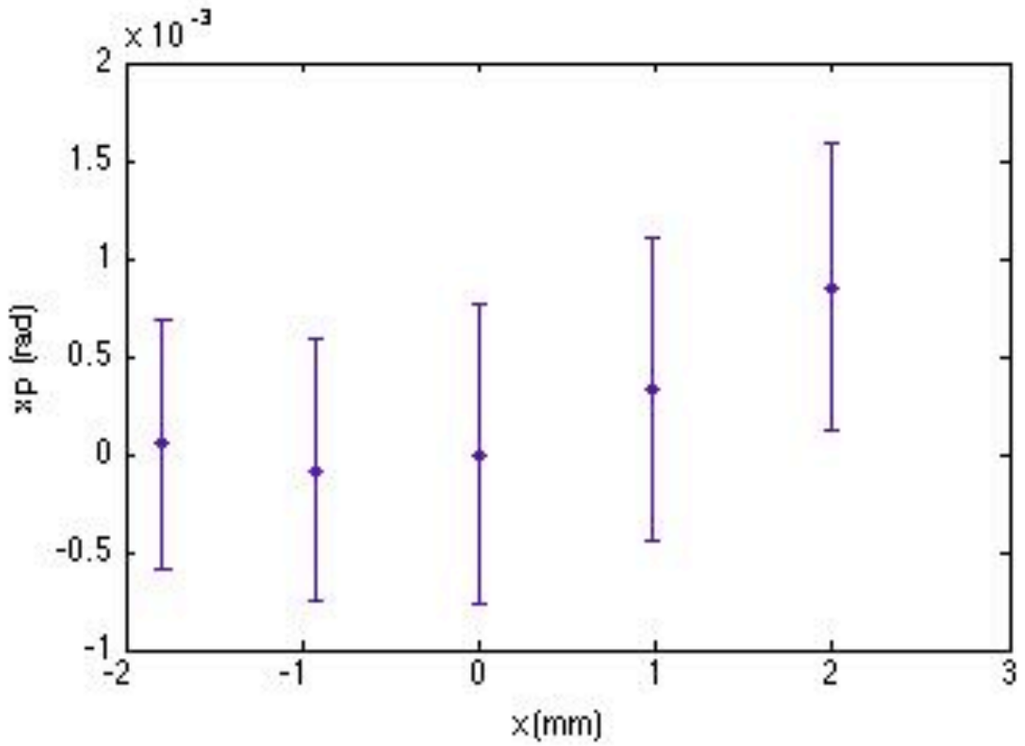
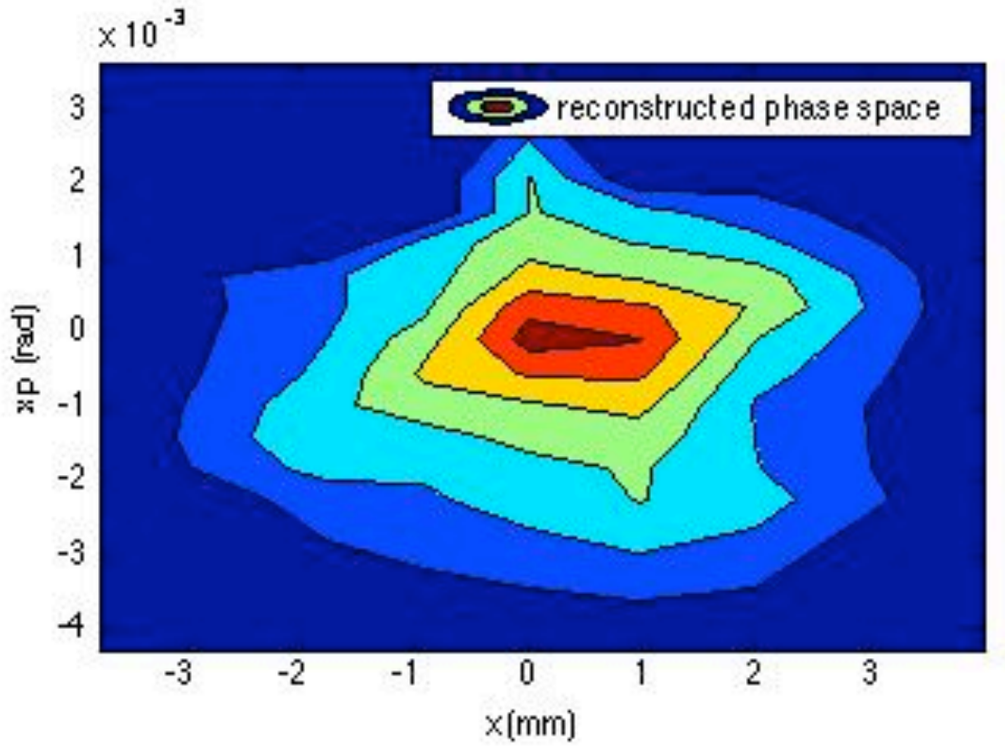




Normalized rms emittance = 8.9 mm mrad





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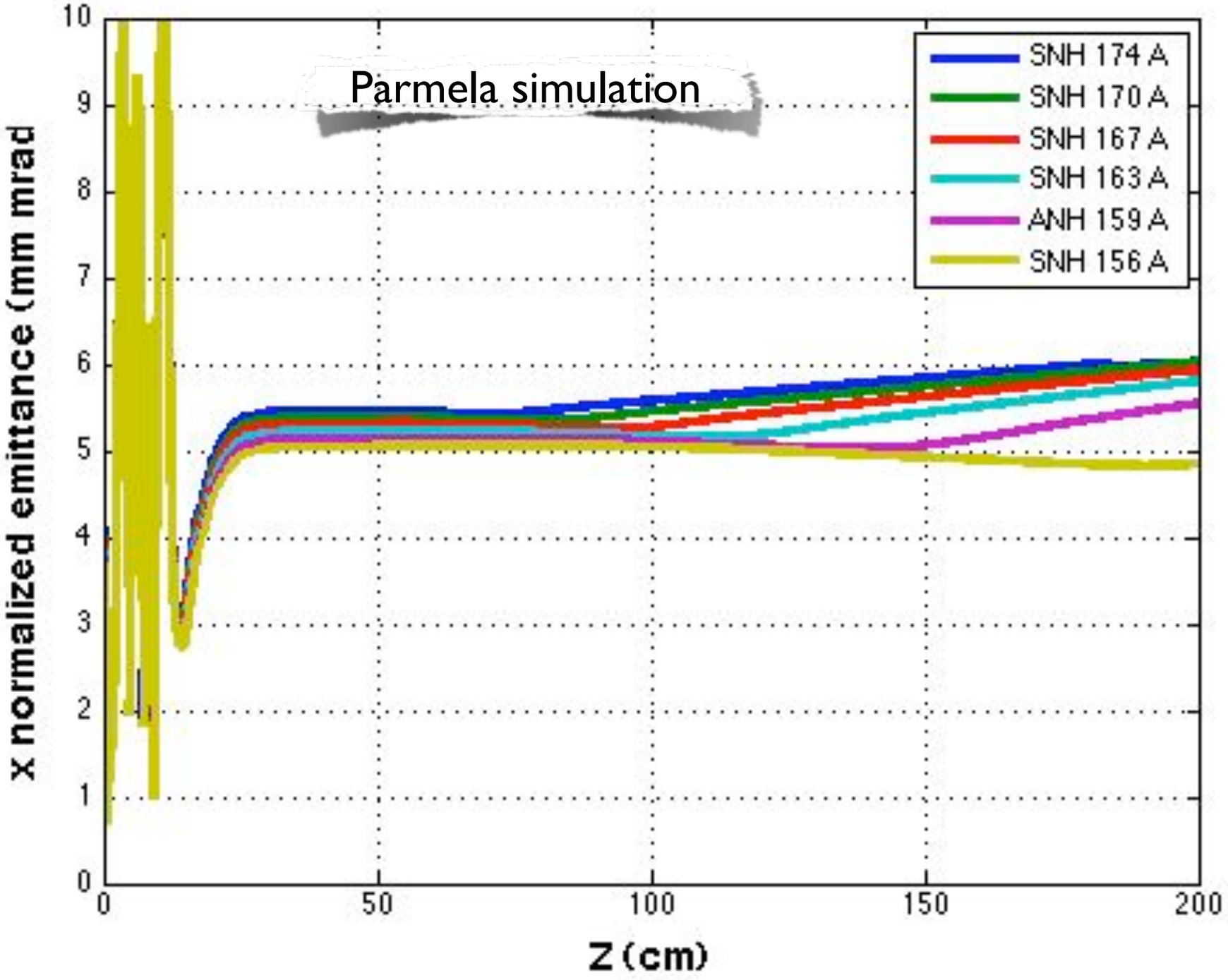

Conclusion and Outlook

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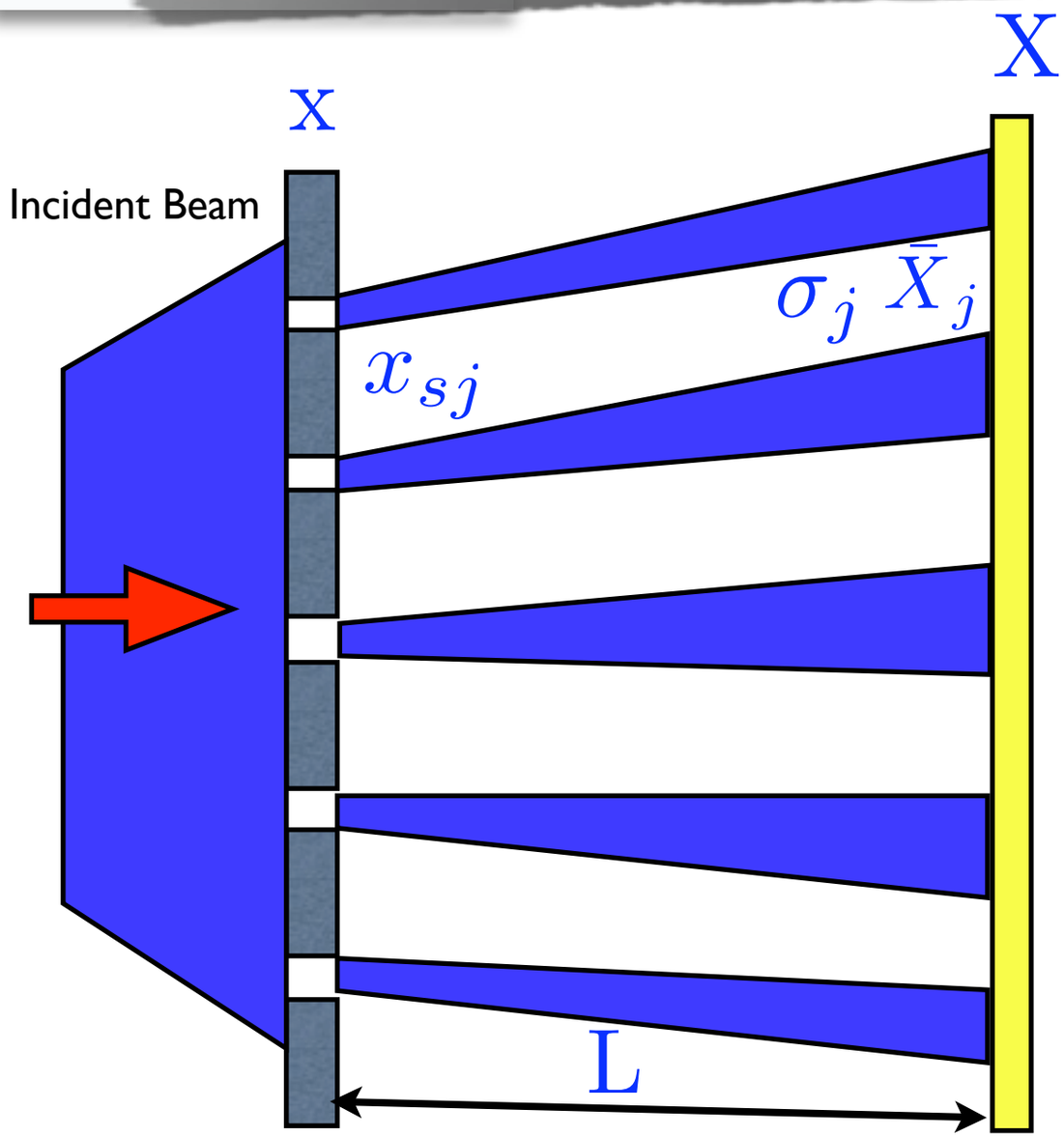
- In the end the run was fruitful to see where we are and what to do next.

Thanks to Steffen Doebert for his advices and all the people involved in the experiments...

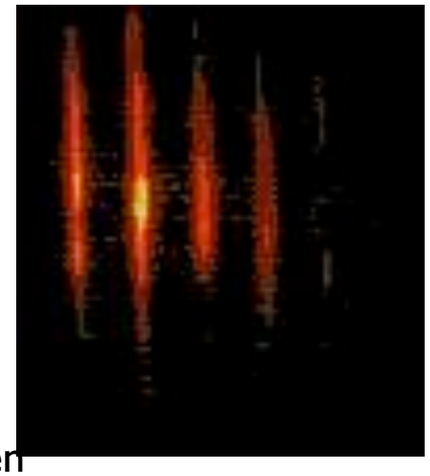
Thanks for your attention...

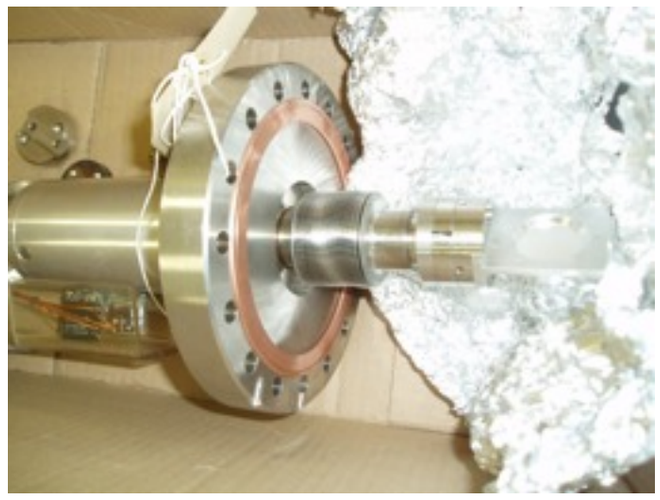
Back-up Slides

multi-slits method



$$x'_i = \frac{X_i - x_i}{L}$$





Slits Parameters :

x_{sj} jth slits' position

p total number of slits

Screen Parameters:

$\bar{X}_j$ mean position of the spots

σ_j rms size of spots

$\bar{x}$ mean position of all beamlets

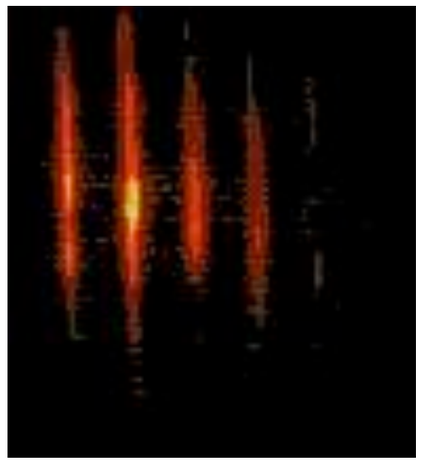
$\bar{x}'_j$ mean divergence of jth beamlet

$\sigma_{x'_j}$ rms divergence of jth beamlet

$\bar{x}'$ mean divergence of all beamlets

multi-slits method

$$\epsilon_x \equiv \sqrt{< x^2 >< x'^2 > - < xx' >^2}$$



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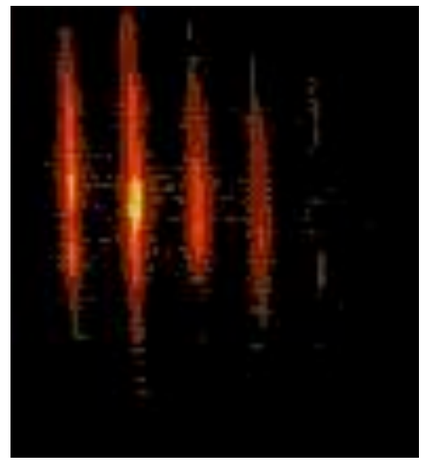

In terms of the parameters related with the image on the screen:

$$\epsilon_x^2 \approx \frac{1}{N^2}\{[\sum_{j=1}^{p} n_j(x_{sj}-\bar{x})^2][\sum_{j=1}^{p}[n_j\sigma_{x'_j}^2 + n_j(\bar{x}'_j-\bar{x}')^2]] - [\sum_{j=1}^{p} n_j x_{sj}\bar{x}'_j - N\bar{x}\bar{x}']^2\}$$

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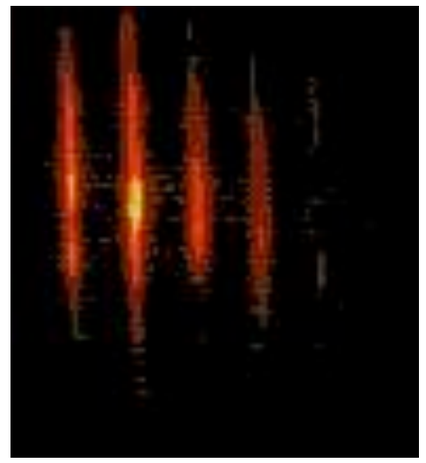

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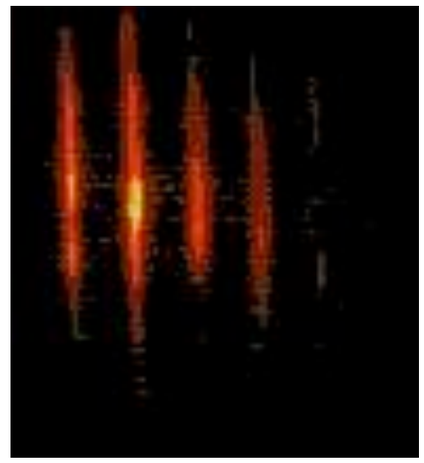
mean position of all beamlets

$$< x >= \frac{1}{N}\sum_{j=1}^{p} n_j x_{sj}$$

multi-slits method



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rms divergence of the jth beamlet

$$\sigma_{x'_j} = \frac{\sigma_j}{L}$$

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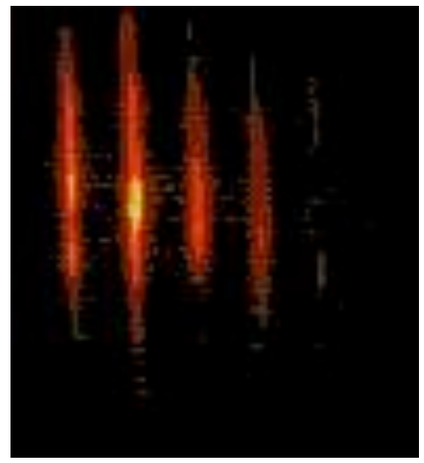

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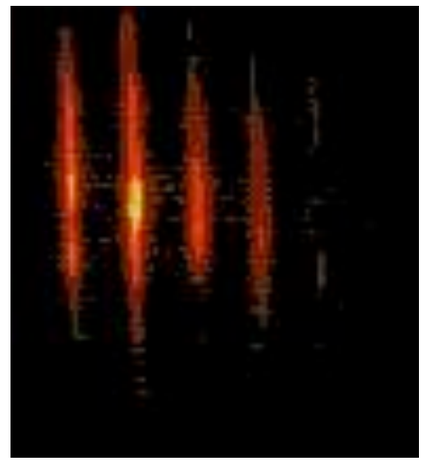

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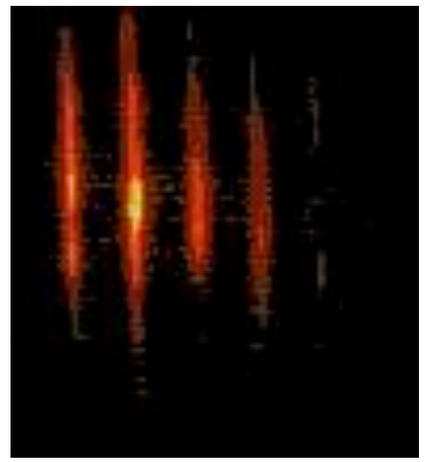

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rms divergence of the jth beamlet

from the measurement

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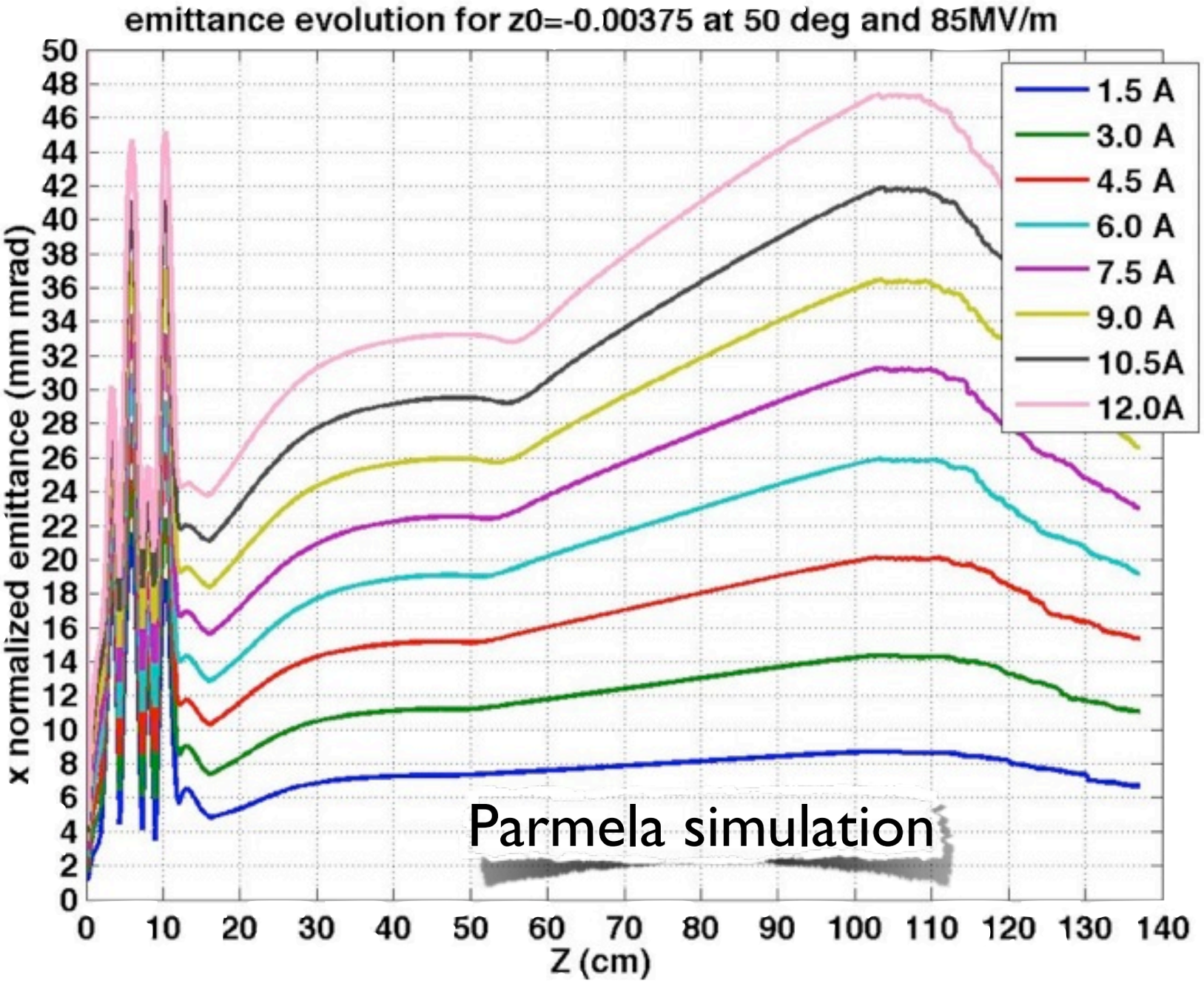
Measurements & Simulations

Solenoid Scan

Space Charge Effect



increasing effect on emittance growth with the increasing beam current