Vertical emittance growth due to non-linearity in the ATF extraction line

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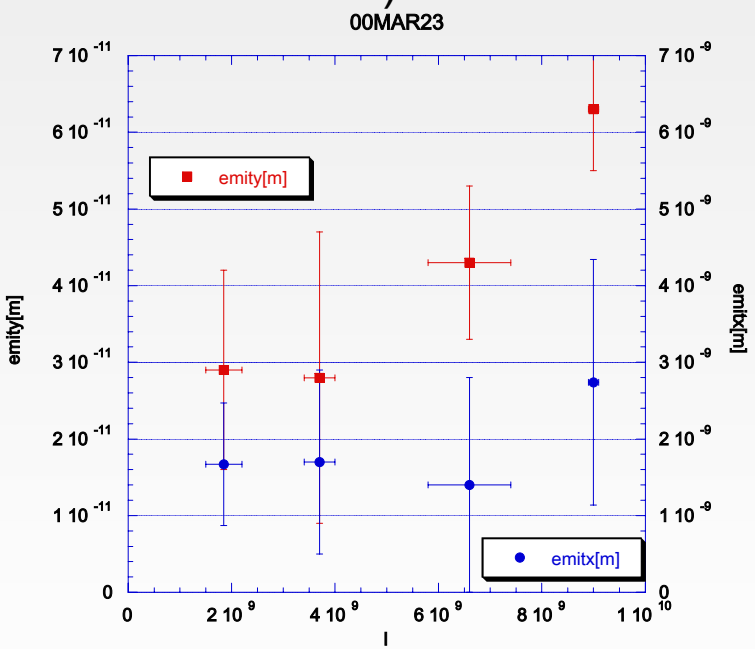
A. Faus-Golfe (IFIC), F. Zimmermann (CERN)

Vertical emittance growth in ATF Extraction Line

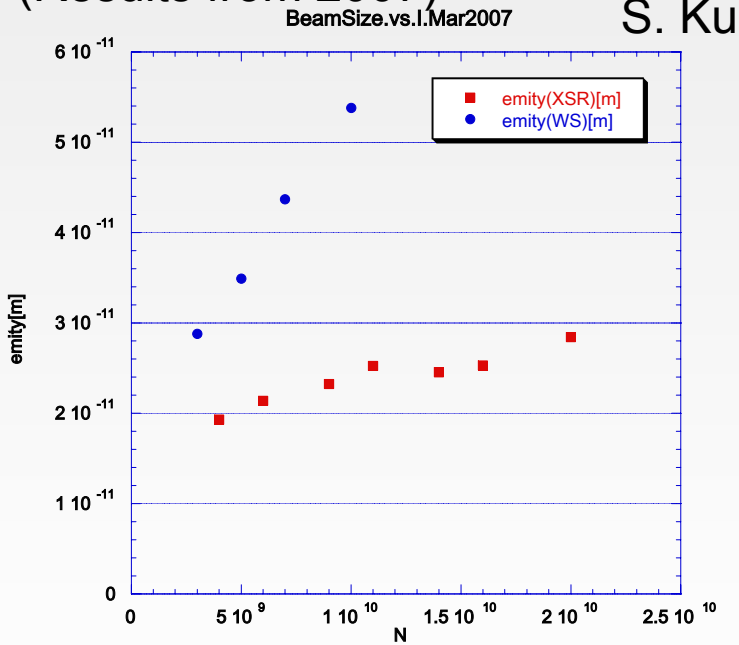
Measured vertical emittances are higher than expected, and there is a dependence with the beam current.

(Results from 2000)



(Results from 2007)

S. Kuroda et al.



Hypotheses

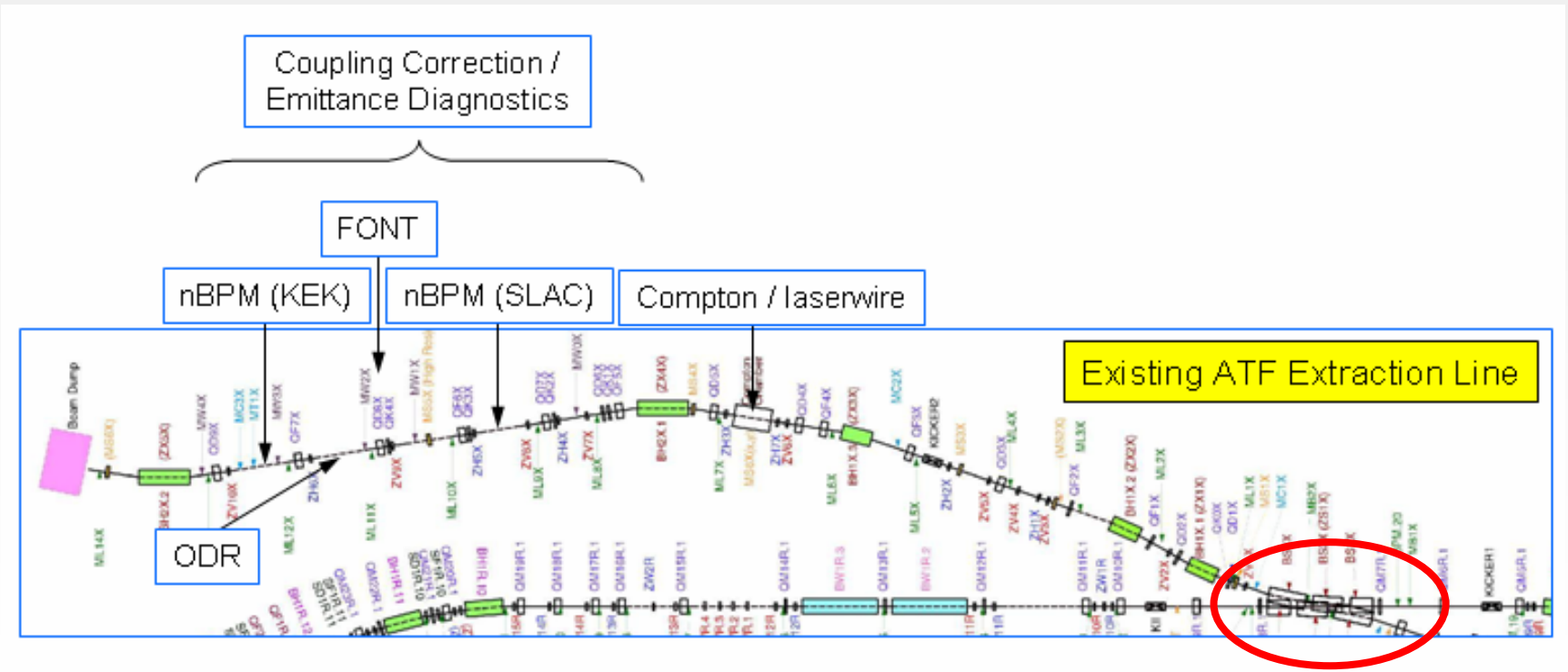
-Non-linearity (coupling)

-Emittance measurement accuracy

-Intensity dependence: wakefields, orbit (BPM) ?

ATF Extraction Line (EXT)

Study the effect of the non-linearities of the magnets shared with the DR on the vertical emittance

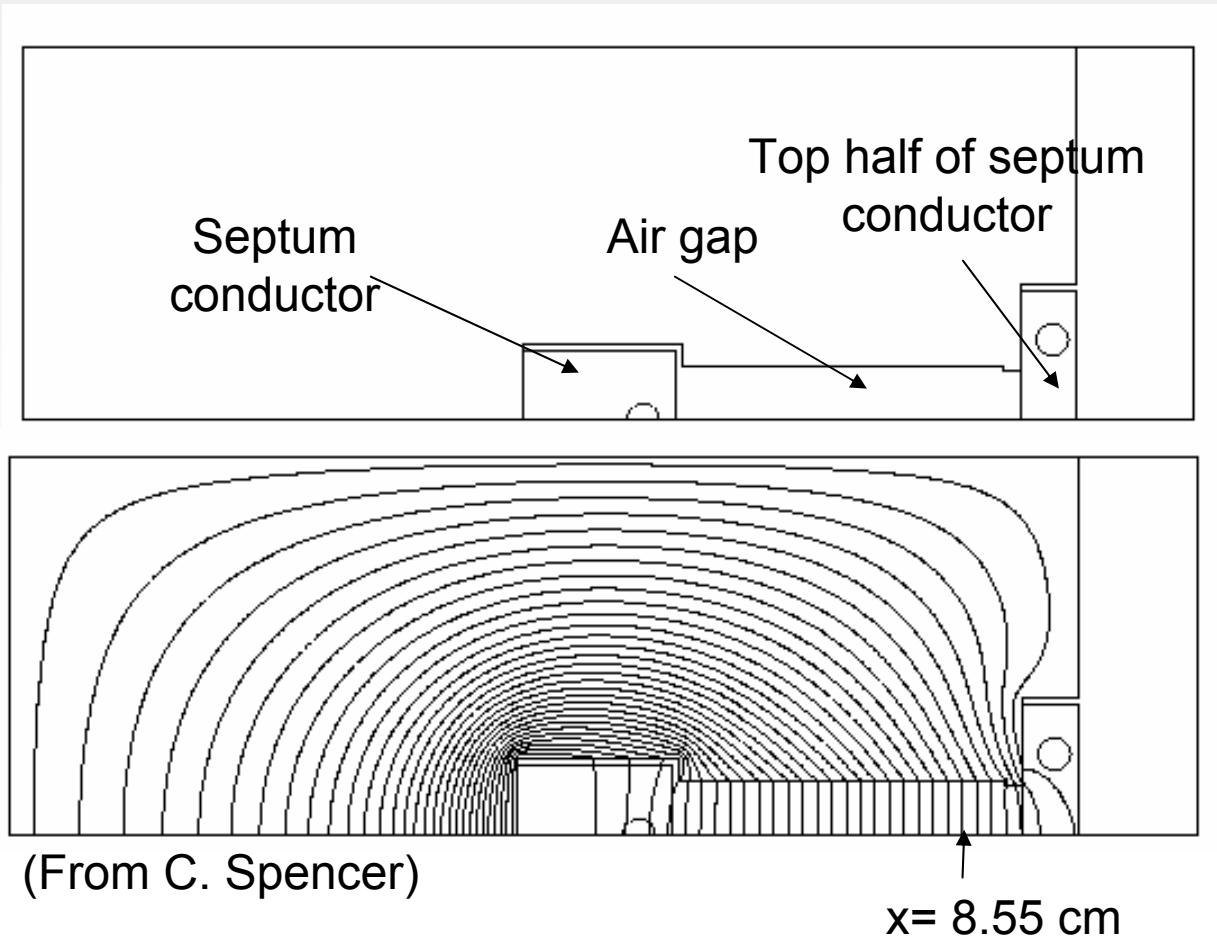


Septum magnets + Q7 and Q6 quadrupoles

Shared magnets

The beam passes off-axis through

- QM6X, QM7X quadrupoles
- BS1X, BS2X and BS3X extraction septum magnets



(From C. Spencer)

The beam passes off-axis through the septum (BS1X)

Simulation work

Tracking studies in the ATF Extraction Line:

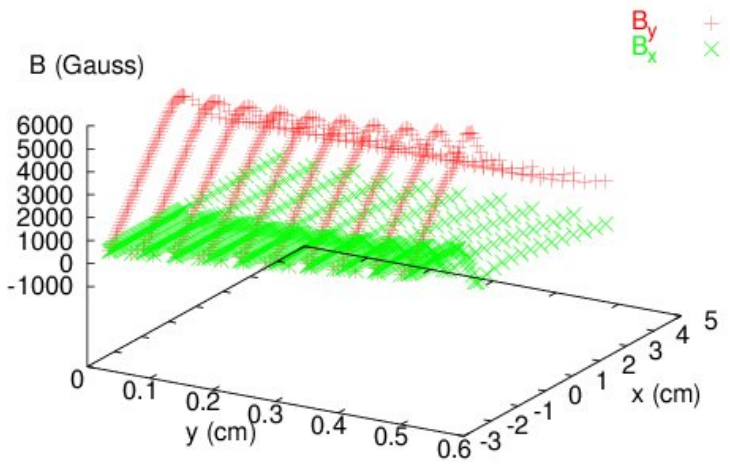
- Introducing multipole components for the septum magnets and the QM7 quadrupole (from C. Spencer)

-For different beam offsets

to estimate the impact on the emittance of the beam.

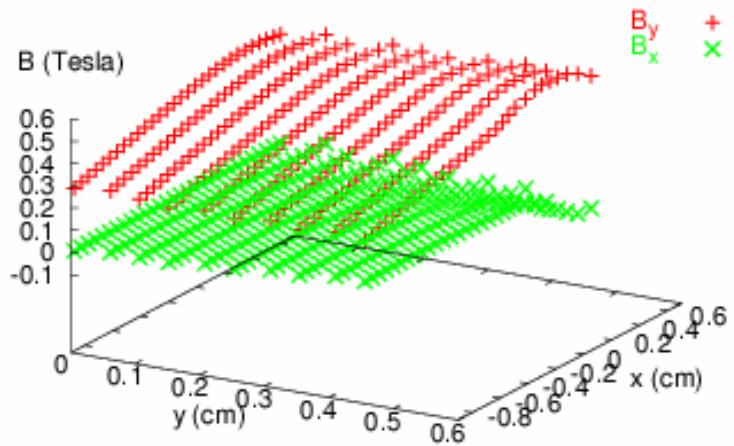
Field maps for QM7 quad. and BSX1 septum

QM7 quadrupole field map (from C. Spencer)

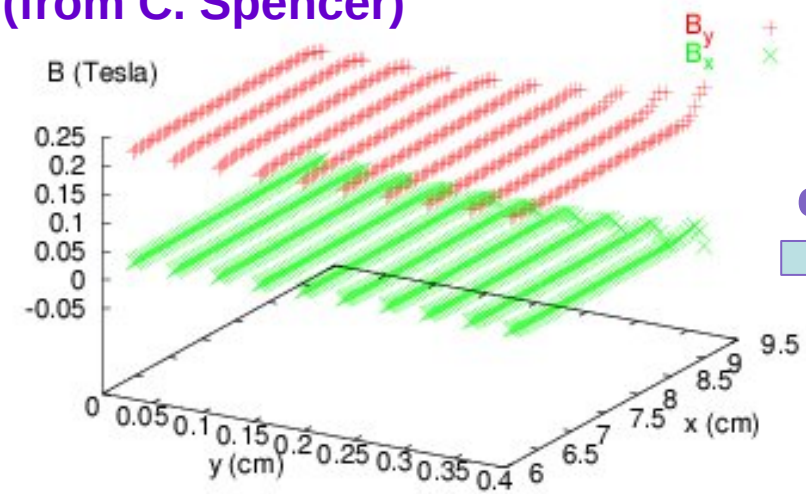


cut x

x_0=-2.2 cm

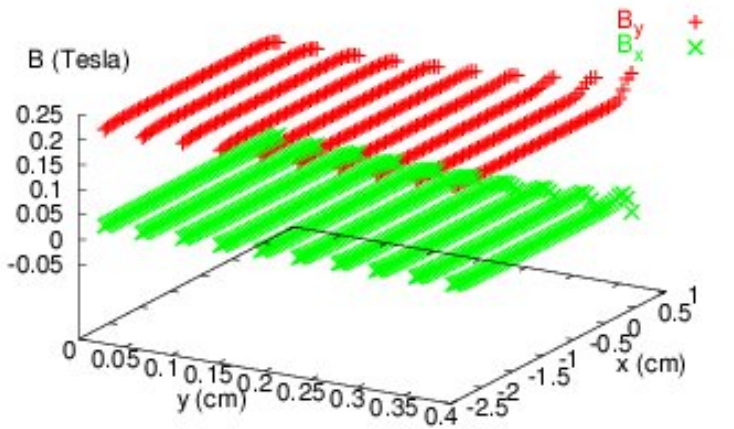


BSX1 septum field map (from C. Spencer)



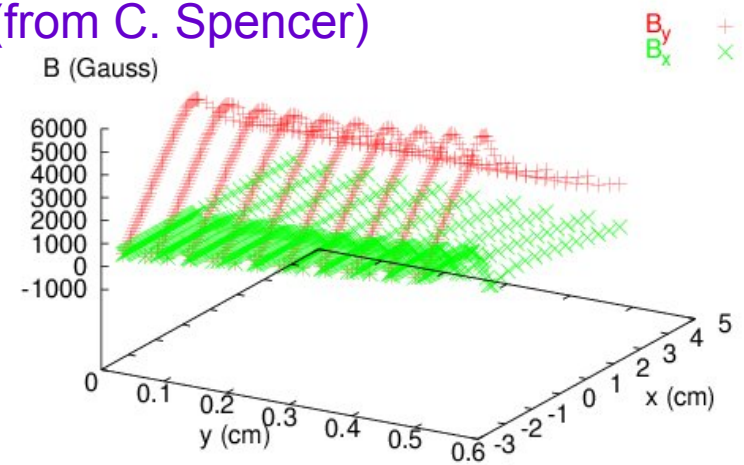
cut x

x_0=-8.55 cm

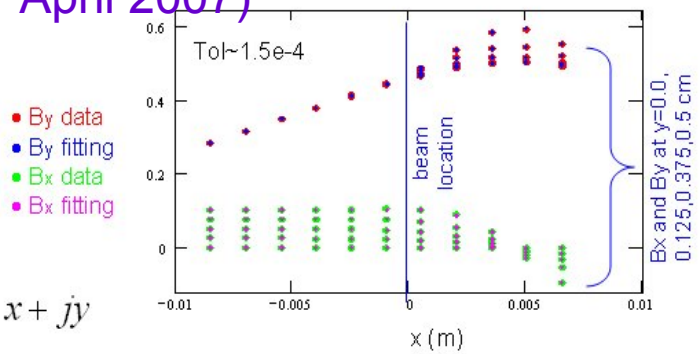


Quadrupole QM7 (multipole decomposition)

Field map of a Q7-like quadrupole (from C. Spencer)



2D fit presented by F. Zhou and S. Seletskiy (25th April 2007)



$$z = x + jy$$

$$B_y + jB_x = 0.461 + 17.557z - 959.345z^2 - 1.426\cdot10^5 z^3 - 9.898\cdot10^6 z^4$$
$$+ 4.93\cdot10^8 z^5 + 1.551\cdot10^{11} z^6 + 6.512\cdot10^{12} z^7 - 9.81\cdot10^{14} z^8$$
$$- 9.424\cdot10^{16} z^9 + 2.051\cdot10^{18} z^{10} + 4.082\cdot10^{20} z^{11} - 6.191\cdot10^{21} z^{12} - 1.281\cdot10^{24} z^{13}$$

QM7 Multipoles:

N	KN	MAD notation
1	0.008393025	K0L
2	0.319194707	K1L
3	-26.54876593	K2L
4	-11839.7016	K3L
5	-3287021.959	K4L
6	818592369.1	K5L
7	1.5452E+12	K6L
8	4.54134E+14	K7L
9	-5.47305E+17	K8L

⟷ ~20% weaker than on-axis

High order aberrations (in particular coupling)

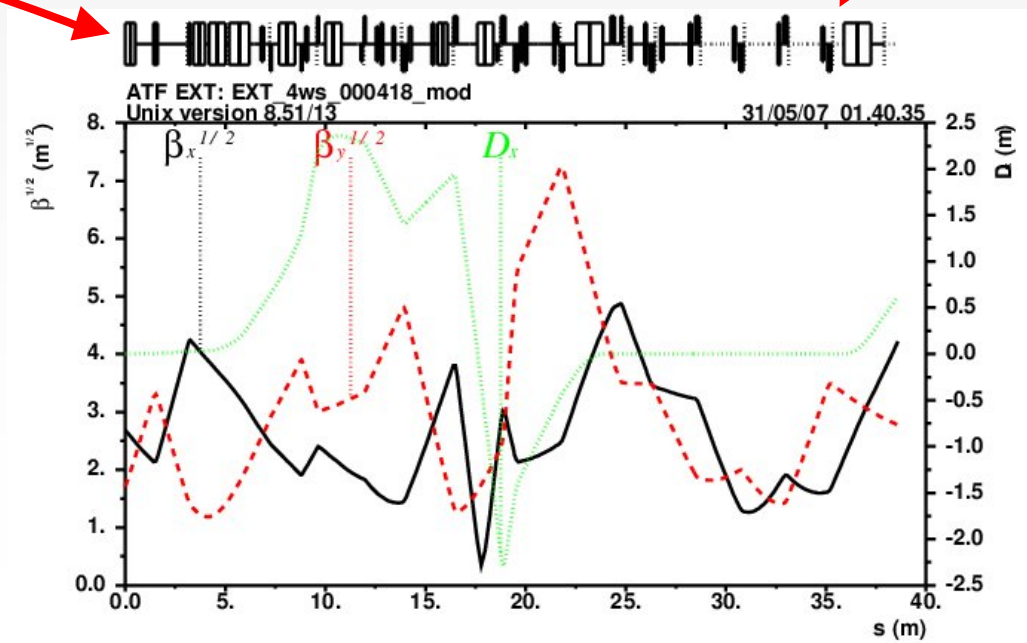
uncertainties in 2D fit procedure being checked

Tracking simulations

- Create distribution of particles with PLACET (50000 particles) at the entrance of EXT (KE1X) with different x & y beam offsets

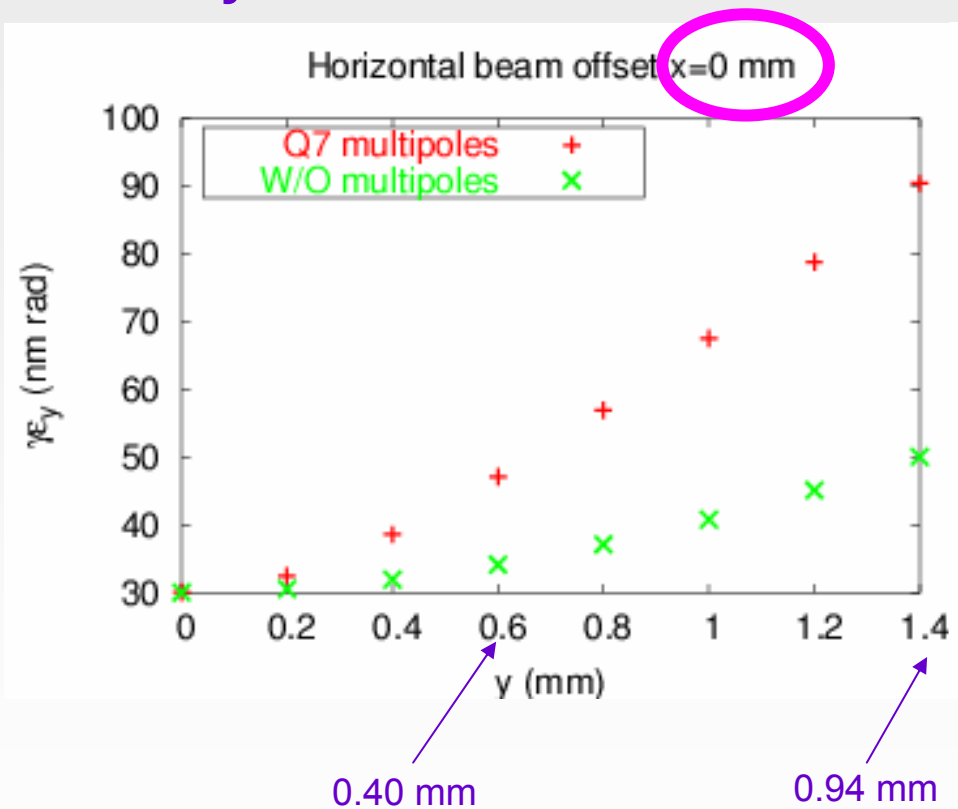
-Tracking with MAD8, including QM7 multipoles

-Compute emittance at last wire scanner (MW4X):



Tracking studies with multipole field for QM7

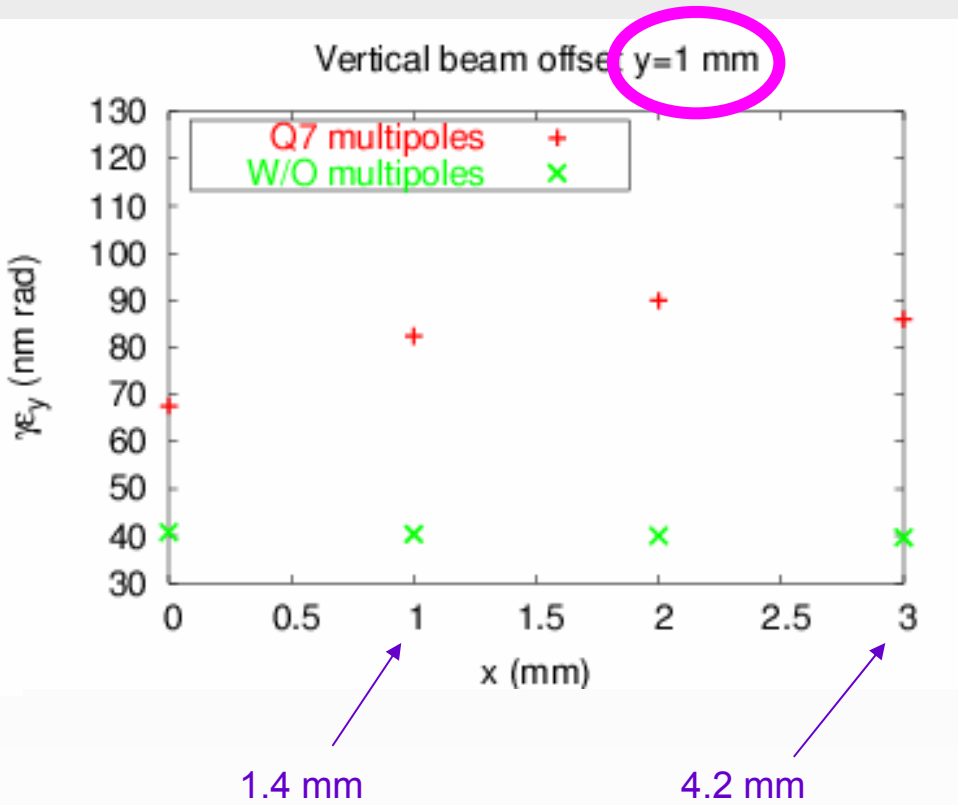
ε_y vs *y* beam offsets



0.40 mm

0.94 mm

ε_y vs *x* beam offsets



1.4 mm

4.2 mm

Beam position in QM7

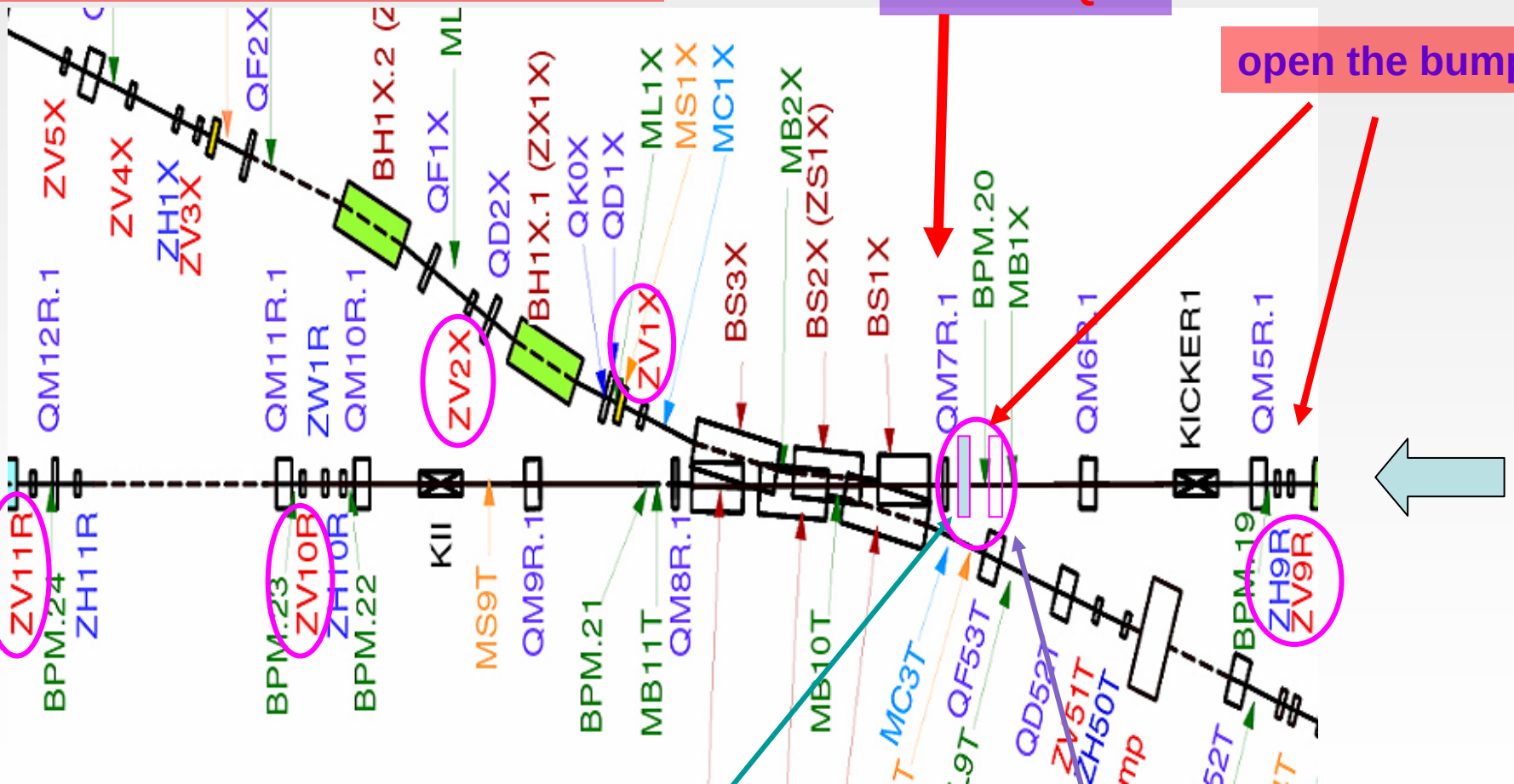
Vertical emittance affected by vertical offsets mainly

Creating bumps in QM7

close the bump in EXT and DR

offset in QM7

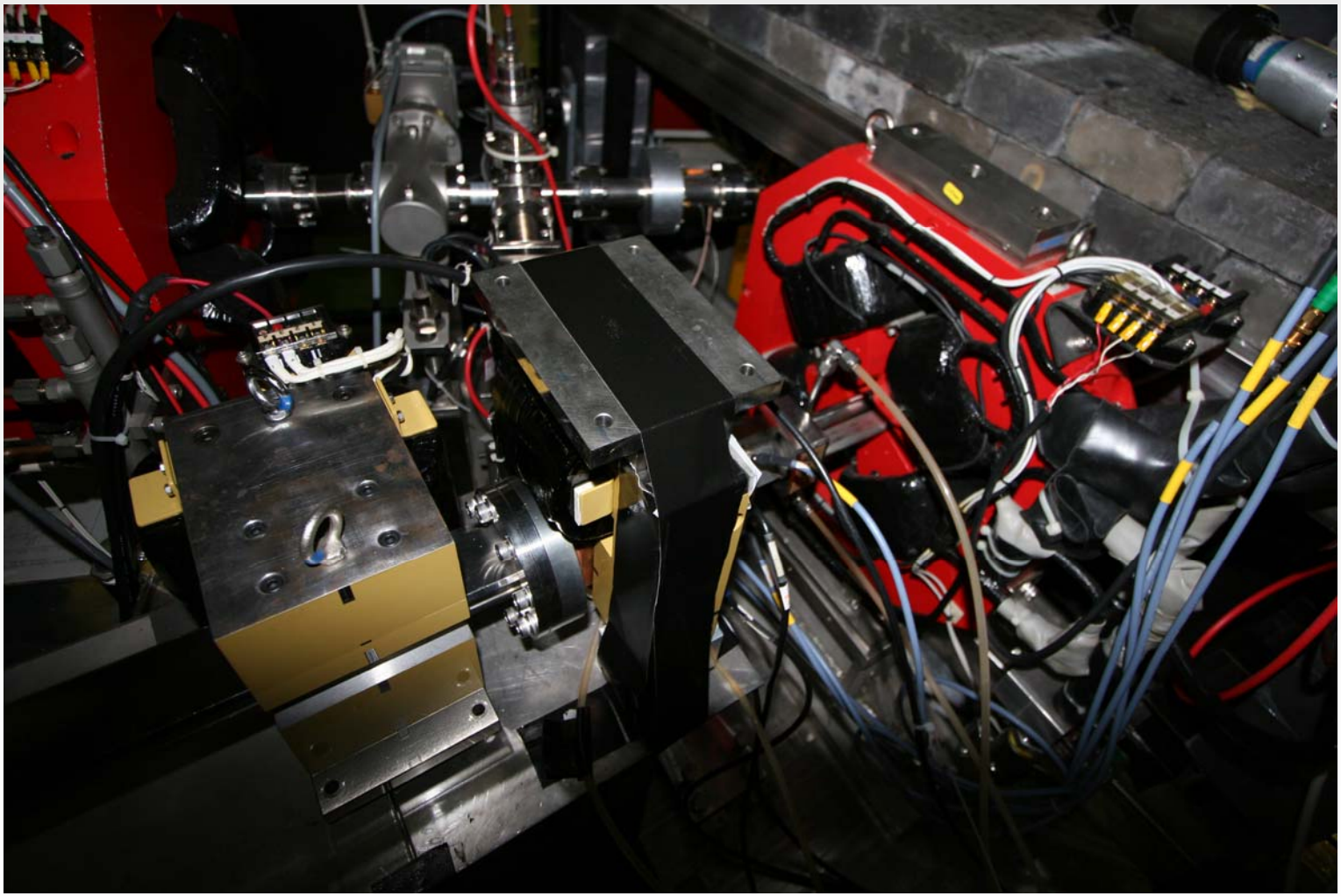
open the bump



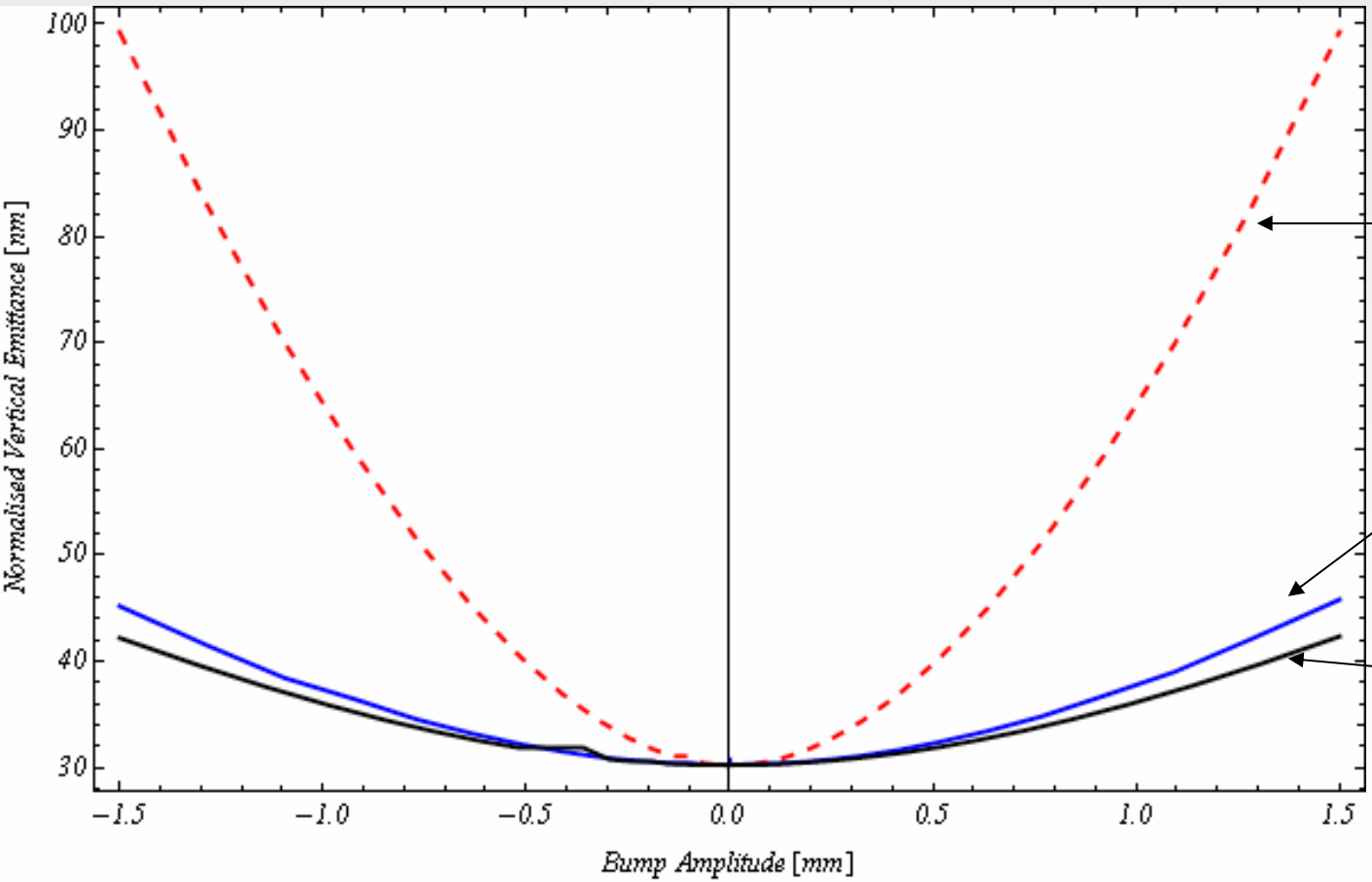
V corrector, installed recently

H corrector, installed by Naito group by Summer 2007

ZV100R corrector installed recently



Simulations for variable bump in QM7 with linear coupling correction



With QM7 multipoles

With QM7 multipoles + coupling correction (remaining is residual non-linear fields)

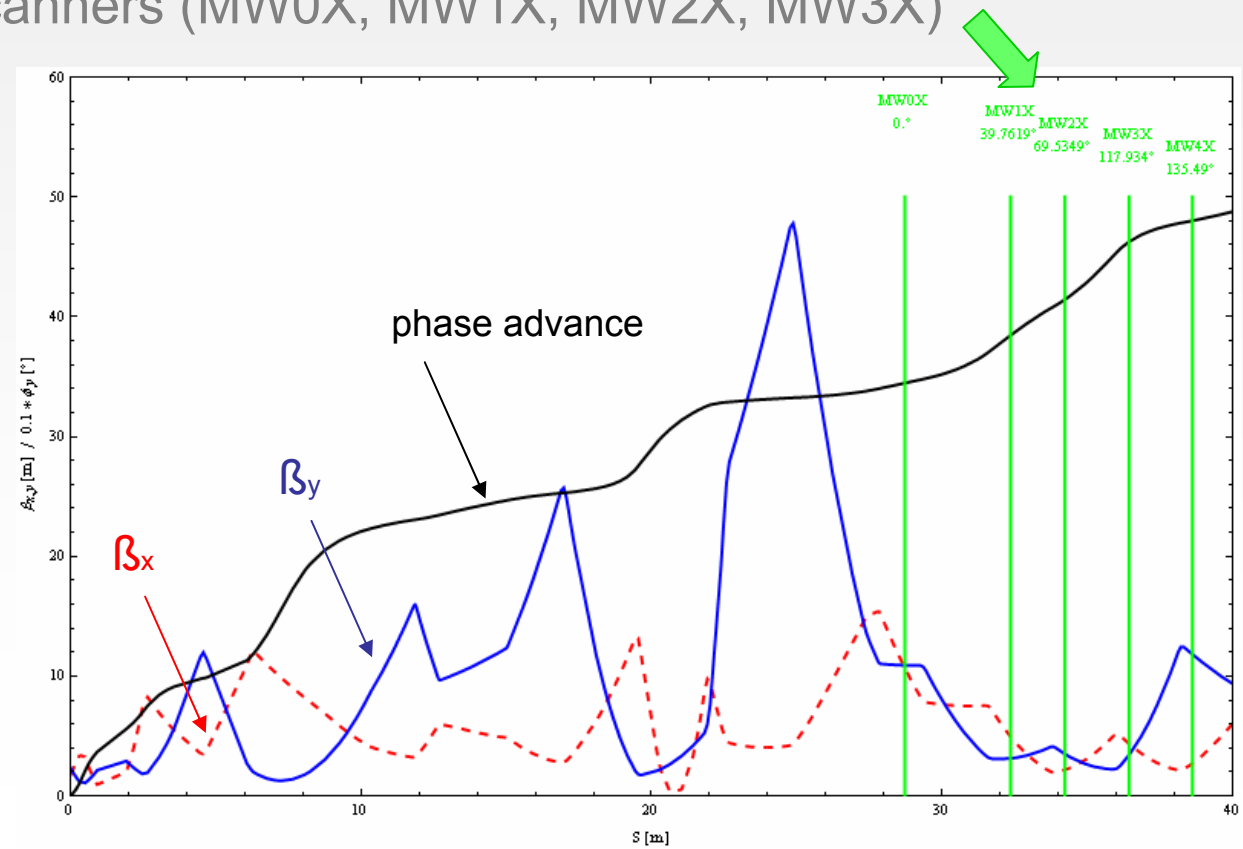
No multipoles (from energy spread)

Linear coupling induced by QM7 multipoles corrected by adjusting four skew quadrupoles in diagnostic section.

Experimental proposal

Creating bumps in QM7 to probe effects on the vertical emittance

Measure emittance in the diagnostic section with the wire scanners (MW0X, MW1X, MW2X, MW3X)



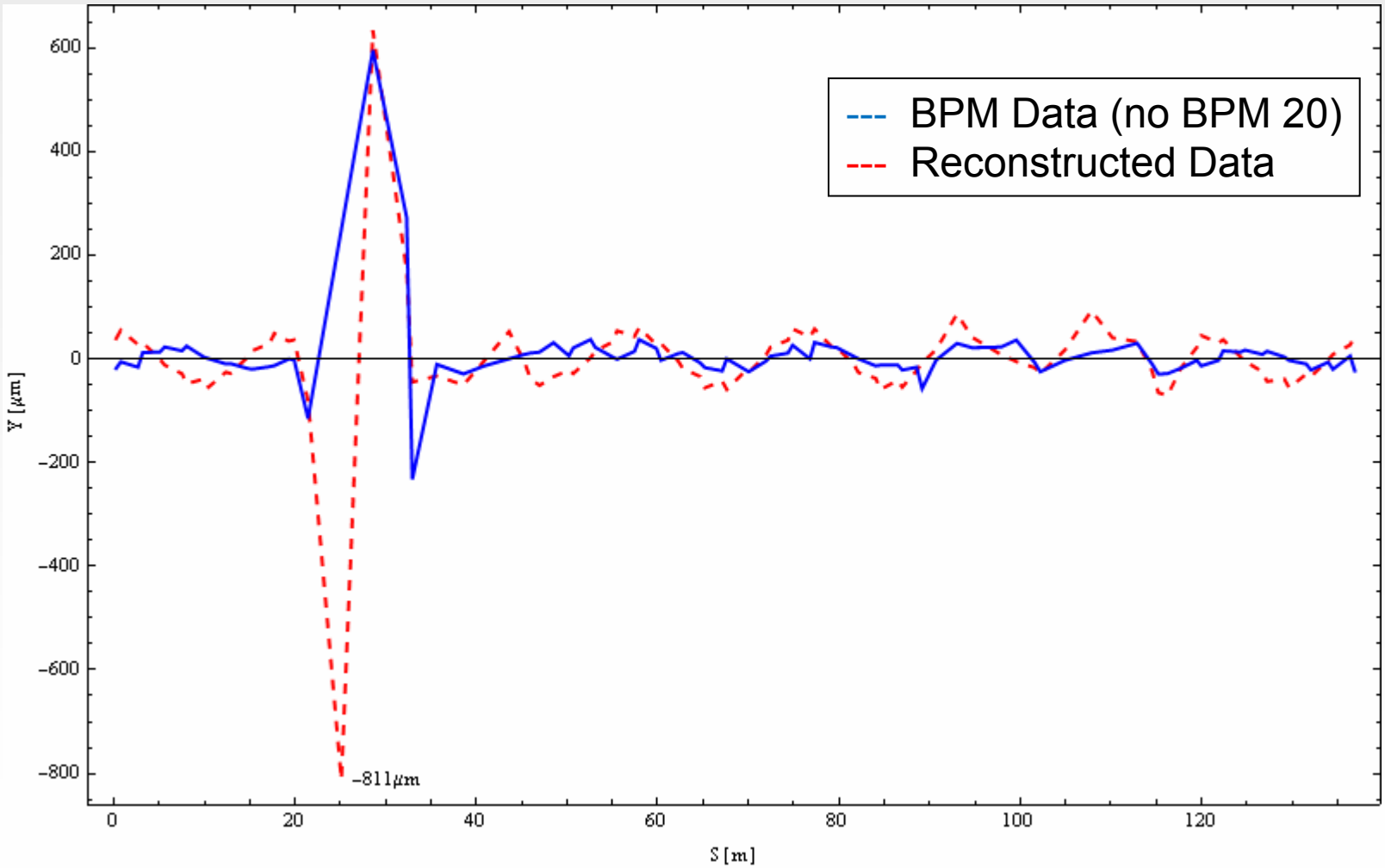
Shift time (Dec. 2007) (1)

- Several hours spent to tune the beam in the Damping Ring and the Extraction Line
  - Needed to correct orbit, dispersion and coupling
  - Needed long shifts to correct dispersion for each bump configuration
- Several problems found → required in future :
  - modify optics to get the right phase advance between the WS for the emittance reconstruction
  - ZV9R corrector saturated when attempting to create positive bumps: need to make this corrector weaker when correcting the orbit
  - study the errors on the emittance reconstruction

Shift time (Dec. 2007) (2)

- Tuned damping ring (orbit, dispersion and coupling correction)
  - XSR vertical size 11μm
  - Subsequent Beta measurement 2.6m
  - DR vertical emittance 47pm
- Tuning Extraction line (orbit and dispersion)
  - Emittance measurement
- Applied 3 magnet bump with ZV9R, ZV100R and ZV10R of computed magnitude y=-0.9 mm
  - Reconstructed magnitude -0.81 mm
  - Emittance measurement
- Would need positive bumps or more points to determine the orbit corresponding to the minimum emittance

Reconstructed orbit in QM7



Emittance reconstruction

- Emittance measurement with wire scanners in the extraction line
- The emittance reconstruction needs the dispersion measurement

$$\sigma_y = \sqrt{\varepsilon_y \beta_y + \delta^2 \eta_y^2}$$

- Dispersion errors are very big → this may explain the big errors in the emittance reconstruction procedure implemented in SAD:
  - Emittance without bump → (52 < 52 < 84) pm
  - Emittance with vertical bump → (9 < 47 < 59) pm

Emittance reconstruction

No bump

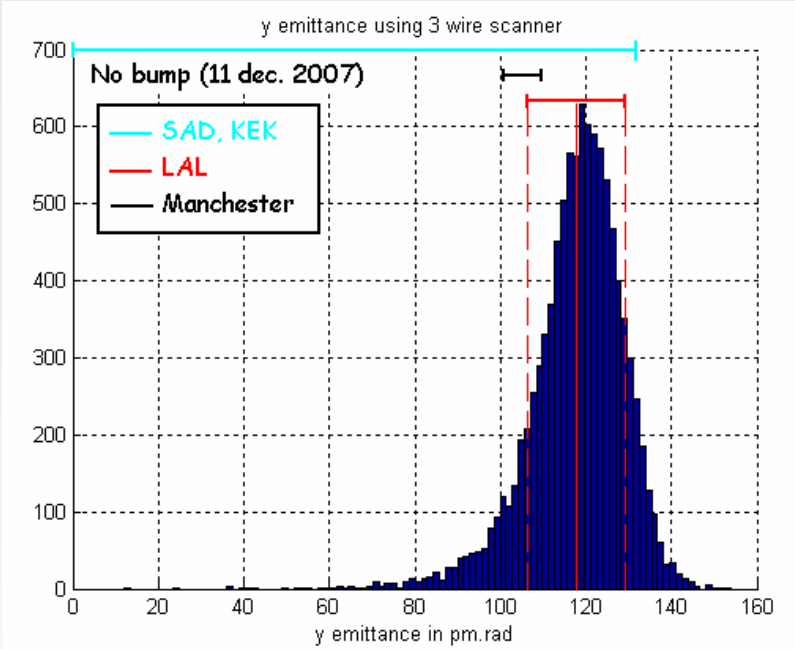
Vertical emittance =

118 +/- 11 pm.rad (J. Brossard, LAL)*

108 +/- 7 pm.rad (A. Scarfe, Manchester)

(52 +84 -52) pm.rad (SAD result)

*Results based on 10 000 test within the error bar.
(rejection level of 0.02 %)



With bump

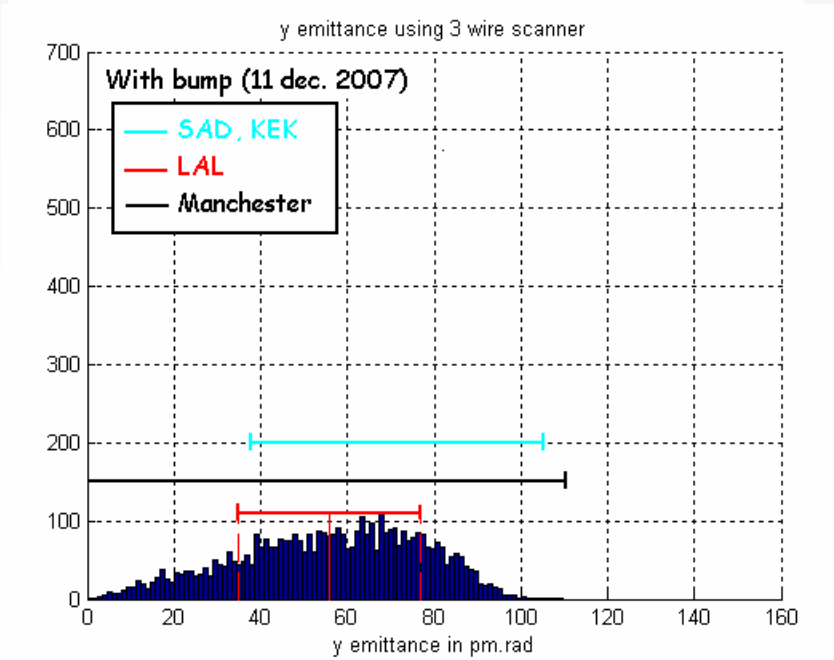
Vertical emittance =

56 +/- 21 pm.rad (J. Brossard, LAL)**

40 +/- 70 pm.rad (A. Scarfe, Manchester)

(47 +58 -9) pm.rad (SAD result)

**Results based on 10 000 test within the error bar.
(rejection level of 54.42 %)



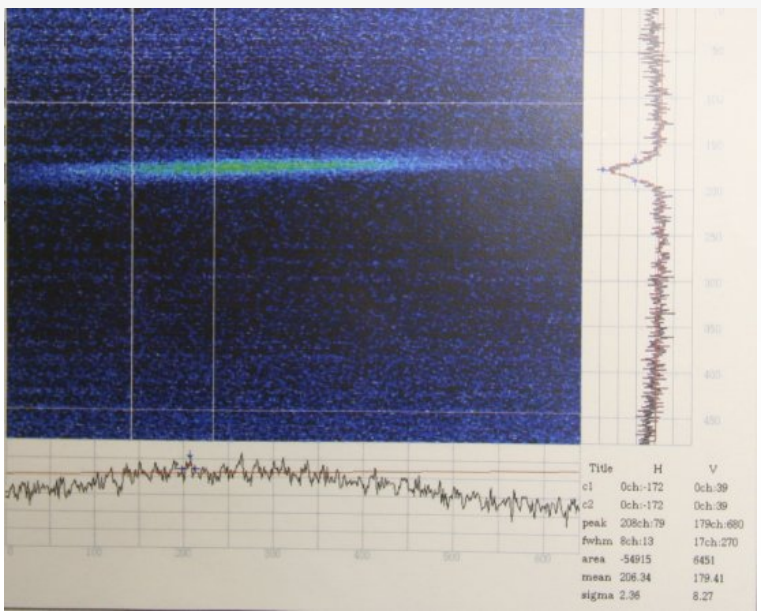
OTR monitor after the Septum (1)

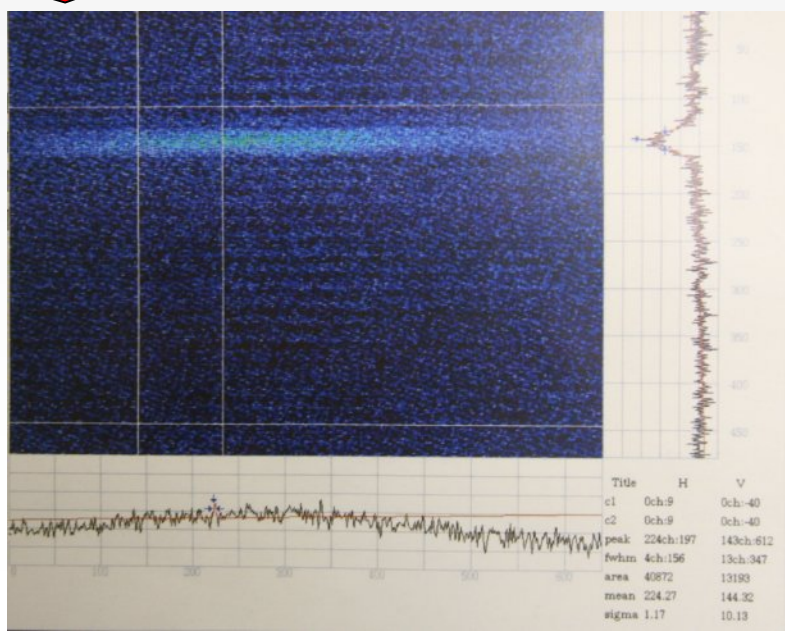
- OTR monitor installed recently after the Septum magnet by the SLAC group
- It allows a fast beam size growth diagnostic with bumps
- Data taken by S. Kuroda et al. on17th Dec:

Without bump

σ_y increase ~ 19%

With bump
y=-0.4 mm (in M20)





OTR monitor after the Septum (2)

More systematic measurements have been taken (last night) with a vertical bump from 0 to -0.8 mm

(and will hopefully be taken also for positive bump values)

More complete analysis soon

Conclusions and prospects

- Bump experiments this December:
  - Not enough quality data taken to conclude yet
  - Learned to work in control room and identified lots of problems to solve for future shift periods
  - Longer shifts seem important to achieve stable conditions and a good-enough tuning in the ring and extraction line
  - First look with new OTR diagnostic → promising
- Simulations predict that vertical offsets in the shared magnets of the EXT with the DR can cause vertical emittance growth at levels compatible to what is seen experimentally for $N=5\times10^{9}$ e^{-}/bunch
- The intensity dependence of the emittance growth is however not yet explained
- More work on assessing non-linearity in EXT magnets (3D for QM7, uncertainties in current 2D multipole fit procedure…)
- Work on more automatic procedures important for efficient use of beam time →preparations off-line

→ Progress on this topic important to prepare commissioning of ATF2

Many thanks to the ATF2 collaboration for all the support and help!