# Emittance Tuning Work Plan at ANL

*Louis Emery presenting slides from Vadim Sajaev and Bingxin Yang, March 6th 2007*

# Vertical Emittance Goal

- Goal is to realize low vertical emittance $\epsilon_y$ at APS running at a lower energy
  - Goals: Emittance ratio of 1/400 or vertical emittance of 2 pm or both
  - APS operations 7 GeV, $\epsilon_x$ =2.5 nm, 1% ratio, $\epsilon_y$ =25 pm, far to go.
  - ALS for special test had 0.1% emittance ratio and ~5 pm (PAC2003)
- Work coincides with maintaining an ideal reference lattice at APS for various performance measurements (i.e., not for operations)
  - Symmetric lattice with no (~ 1mm) user steering
  - No new equipment or GDE funding needed!
- Tuning methods (nothing new here)
- Expectations
- X-ray optical measurement method (B. Yang)

# APS vertical emittance control

- Consists of two parts:
  - Vertical dispersion control
  - x-y coupling control

# Present Vertical Dispersion Control

- Dispersion correction (alone) is easy to do
- Correction is done with skew quads using SVD to control level of correction and noise. (This is not LOCO, so coupling is not corrected here.)

$$\Delta \boldsymbol{\eta}_y = M \bar{\boldsymbol{k}}$$

where M is determined from model. All skew quads have high $\eta_x$.

- Normally dispersion is corrected to within few mm
- Estimation of natural emittance using synchrotron integrals for a model with $\eta_y$ of ±2 mm peak-to-peak gives 1.2 pm at 7 GeV. Assuming better $\eta_y$ correction and lower energy, it won't be a problem to achieve this.

# Present Coupling Control

- Coupling is corrected using 17th and 0th harmonic knobs† – skew quadrupoles are arranged into knobs that control those harmonics and generic control-room optimizer minimizes a vertical beam size measurement (or lifetime)
- Hardly affects vertical dispersion
- No local coupling control
- With recently installed 4-m x-ray pinhole camera, we get emittance ratio of 0.5%.
- With previous 9-m x-ray pinhole camera, we thought we obtained 0.25%, but the resolution was 2x worse and equal to the beam size. Thus the measurement may have been in error.

† $\nu_x$=36.14, $\nu_y$=19.2, $\nu_x$-$\nu_y$=17, $N_{cells}$=40

# *Possible Alternate Coupling Control*

- Response matrix fit gives a model with coupling included – it gives some values to our skew quad locations that represent measured "orbit cross-talk" and $\eta_y$, i.e. does both contributions of $\epsilon_y$
- We can try to use the model to perform coupling correction similar to $\beta$-function correction
- We tried only once and it didn't work for some reason. But we could try harder.

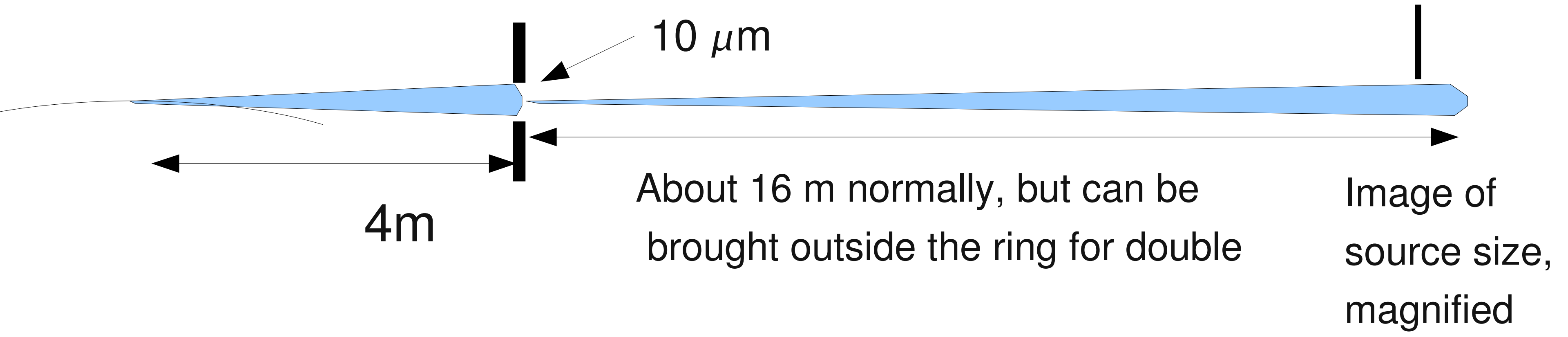
# *Number of Skew Quadrupoles*

- APS has 19 skew quadrupole magnets (one is missing) - one every two sectors, much less than number of quads, sextupoles and correctors
- We don't expect a coupling correction as high quality as orbit or beta functions
- However, we'll diminish the source of the coupling, which in our case is the vertical orbit in sextupoles (we think).
- Need to review/complete beam-based positioning of orbit, i.e. bpm-offset measurements using a) quad and orbit scan, b) sextupole scan
- Include analysis relative vertical misalignment of APS magnets (recorded every two years, three-week job)

# *Expected Beam Size in Optics Measurement at 2 pm-rad*

- Tiny
- Dipole source pinhole image: 7 $\mu$m (present nominal size 30 $\mu$m)
- ID source pinhole size: 2.5 $\mu$m (present size 9 $\mu$m)
- Significant challenges for optical measurement
- At 5 GeV x-ray photons decrease in energy and in numbers
  - Resolution worsens

# Scaling from 7 GeV: Dipole source 4-m pinhole camera

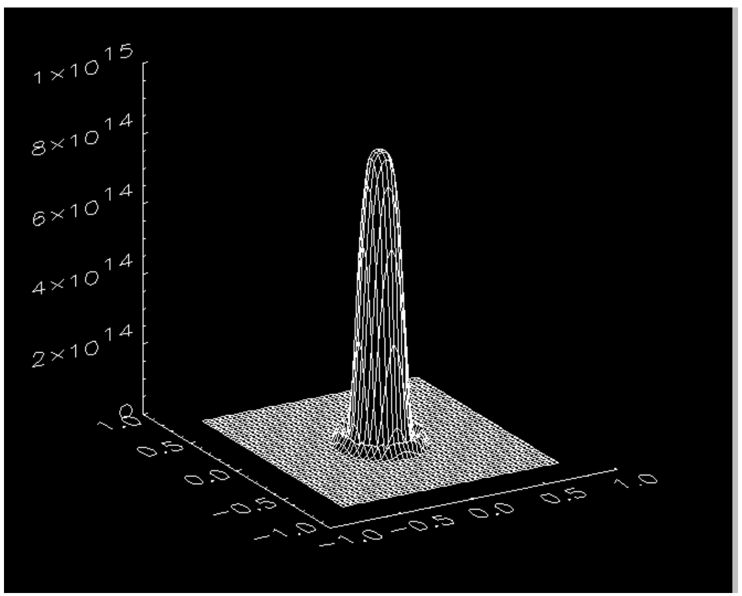


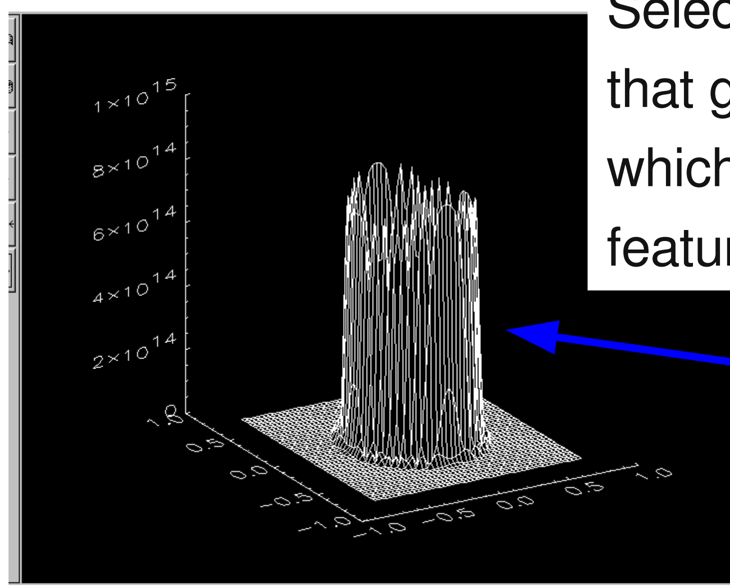

| | | |
|---|---|---|
| Electron energy | 7 GeV | 5 GeV |
| Critical x-ray energy | 20 keV | 7.2 keV |
| Pinhole Camera photon energy | 30 – 40 keV | 15 – 20 keV |
| Theoretical resolution (μm) | 6 - 7 μm | 8 - 10 μm |
| Emittance resolution ($\beta_y$ = 20 m) | 1.8 – 2.5 pm | 3 – 5 pm |

**(Better resolution with out-of-tunnel detectors)**

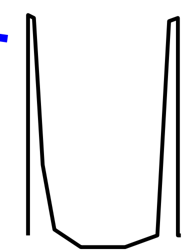
# *Scaling from 7 GeV: ID source pinhole camera*

| Electron energy | 7 GeV | 5 GeV |
|---|---|---|
| First harmonic x-ray energy | 24 keV | 12.93 keV |
| RMS cone angle at harmonic | 3.8 μrad | 5.2 μrad |
| Photon energy below harmonic | 23.5 keV | 12.70 keV |
| RMS cone "thickness" | ~ 0.7 μrad | ~ 1 μrad |
| Emittance resolution ($\beta_y$ = 3 m) | 1.5 pm | 2 – 3 pm |




Select energy that gives a cone, which has sharper features



## *Timeline*

- Setup of ideal lattice takes several shifts (4-6 h every week for 4 weeks)
  - Many BPMs to measure, even if automatically done
- Need to practise the ID radiation cone measurement, and its analysis.
- Correct optics and minimize vertical emittance at 7 GeV. Measure (one week).
- Setup ideal lattice at 5 GeV. Measure (one week)

# *Conclusion*

- Need to do in order
  - Beam orbit preparation (to minimize coupling sources), beam optics correction, coupling correction
  - Set-up x-ray optics for lower energy measurement and outside the ring in experimental hutch, practise optics measurement of “cone”
  - Measure beam size