Rhic Beam Experiments Workshop 2003

Beta Star related experiments

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Outline

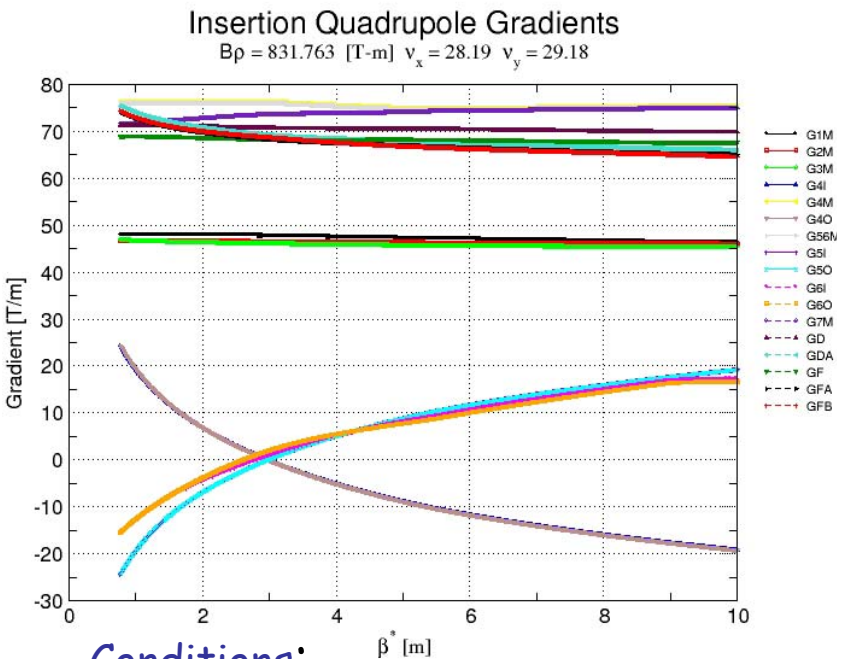
- Status of optics $\beta^*<1m$ — Tepikian
- Squeeze & fit with online model — Van Zeijts
- β^* knobs (results MADX study) — Wittmer
- IR correction

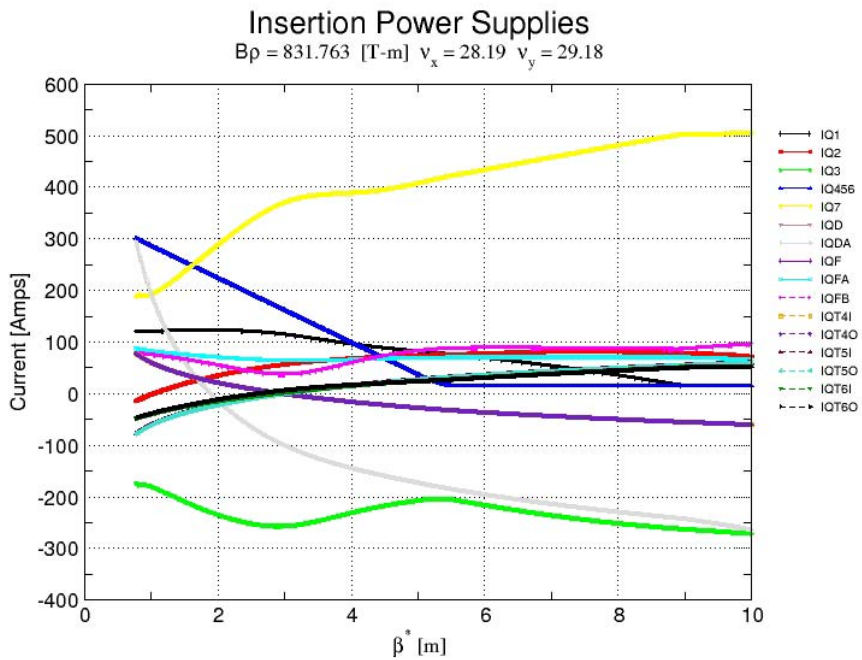
  model results, dynamic aperture, IR filter operations and beam experiments plan
- **List of β^* squeeze related experiments**

β*~0.8m with existing power supplies

β*=**0.77m** optics matched solution found for Au-Au (S.Tepikian) with existing power supplies

β*=1m→0.8m 25% potential luminosity increase





Conditions:

Good tuning of beta*=1m optics

- ❑**Optics measurements**
- ❑**Improved online model (Coupling, dispersion,…)**
- ❑**Beta* online matching → see later in the talk**
- ❑**IR correction**

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Optics β* =0.4m - intro

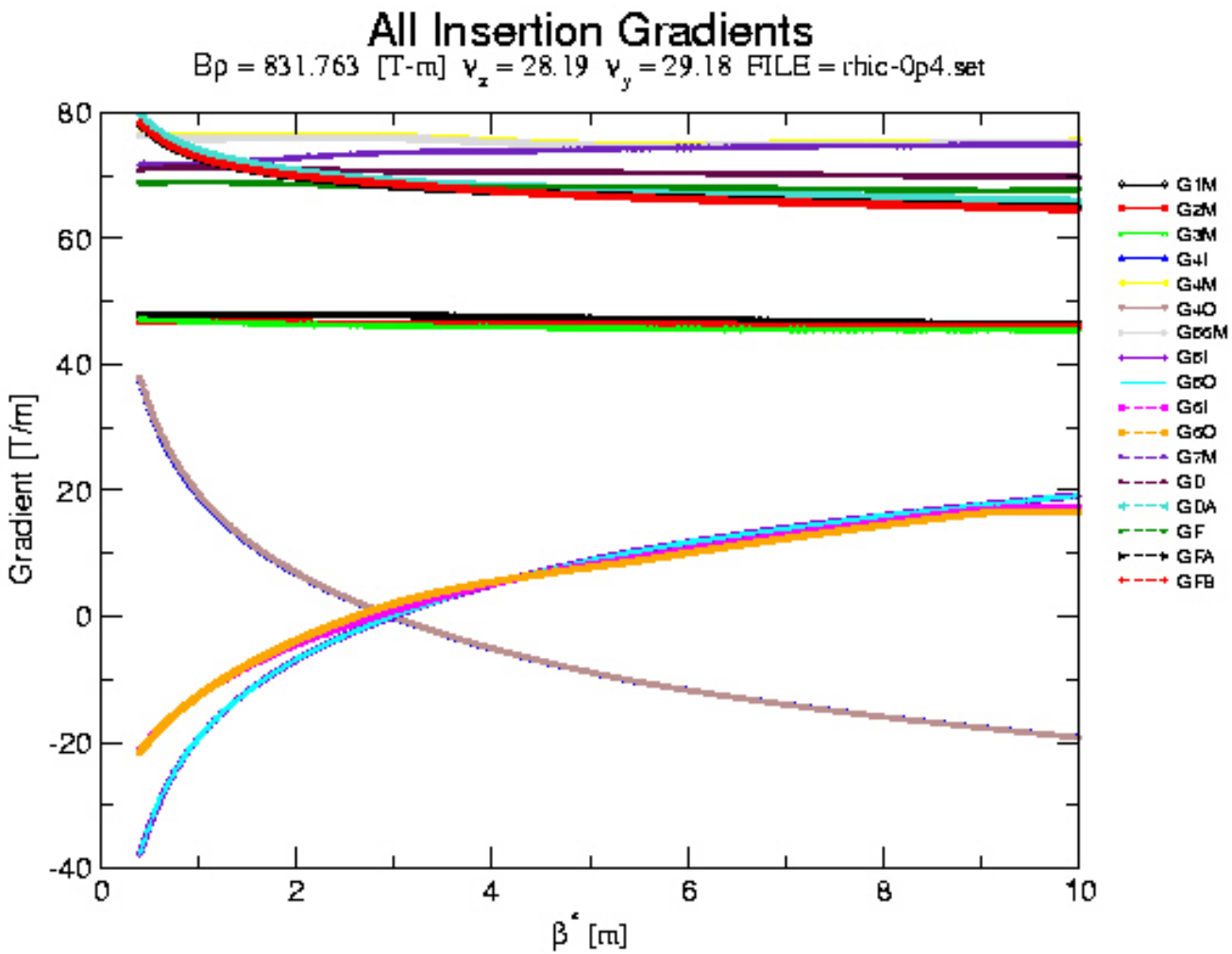
A solution for β*=0.4 m optics exists (for **100 GeV/u Au** And **250 GeV pp**) – that only needs

- **upgrade of the q89** IR power supplies (presently 300A bipolar)
- Measurements of TQ's quads TF beyond 100A (1 set of measurements is DONE – A.Jain)

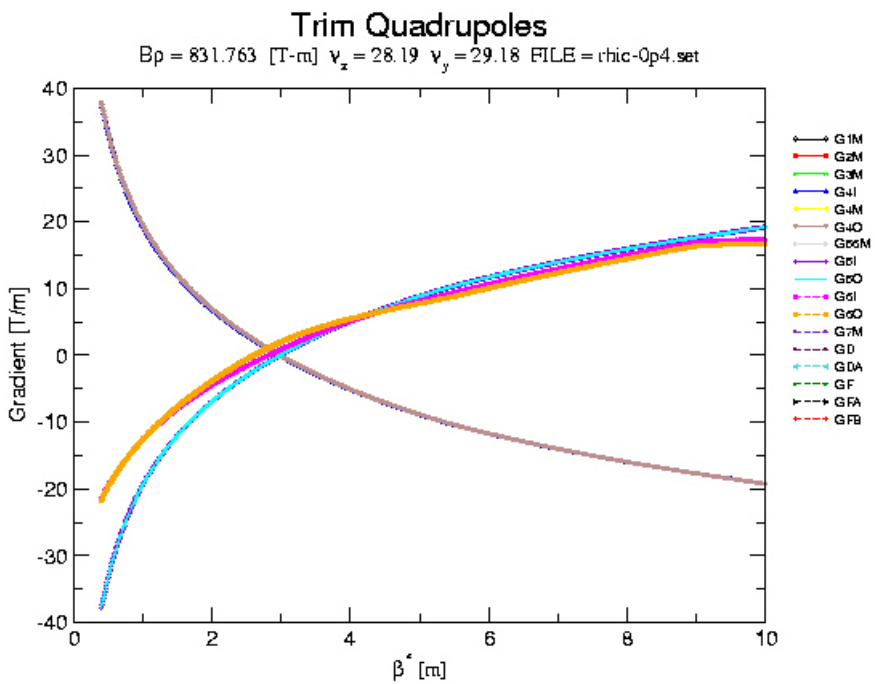
Solution can be tested with **pp at 100 GeV**.
Did not get done as planned during beam experiments (prioritization of existing, limited, beam time during pp run)
Should be tried out in the 100 GeV pp run in 2004,assuming good experience with the 1m optics and the β* beam experiments during the 2004 Au-Au run.

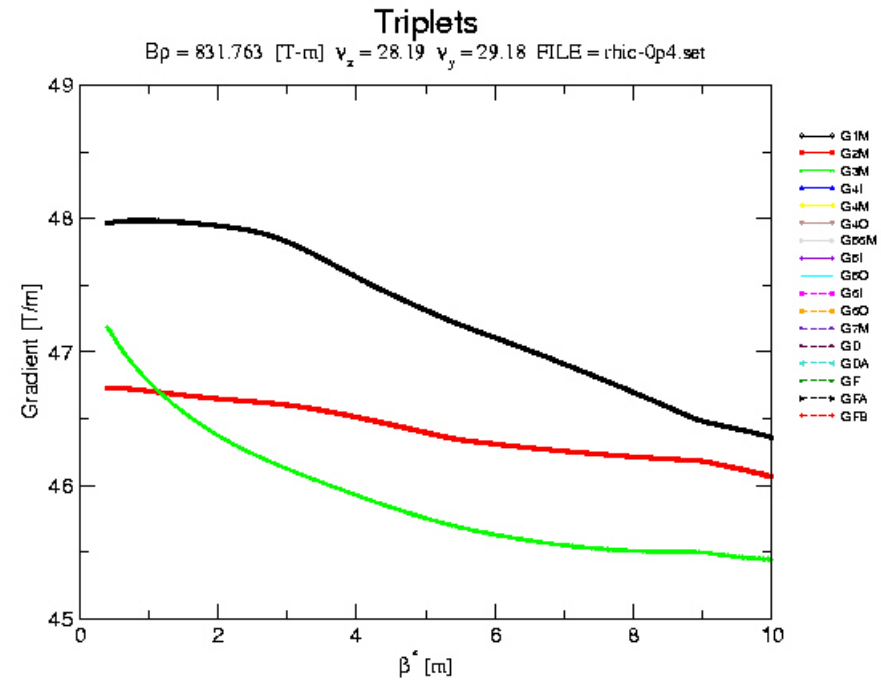
- luminosity increase potential
- Upgrade path

Optics β* =0.4m gradients

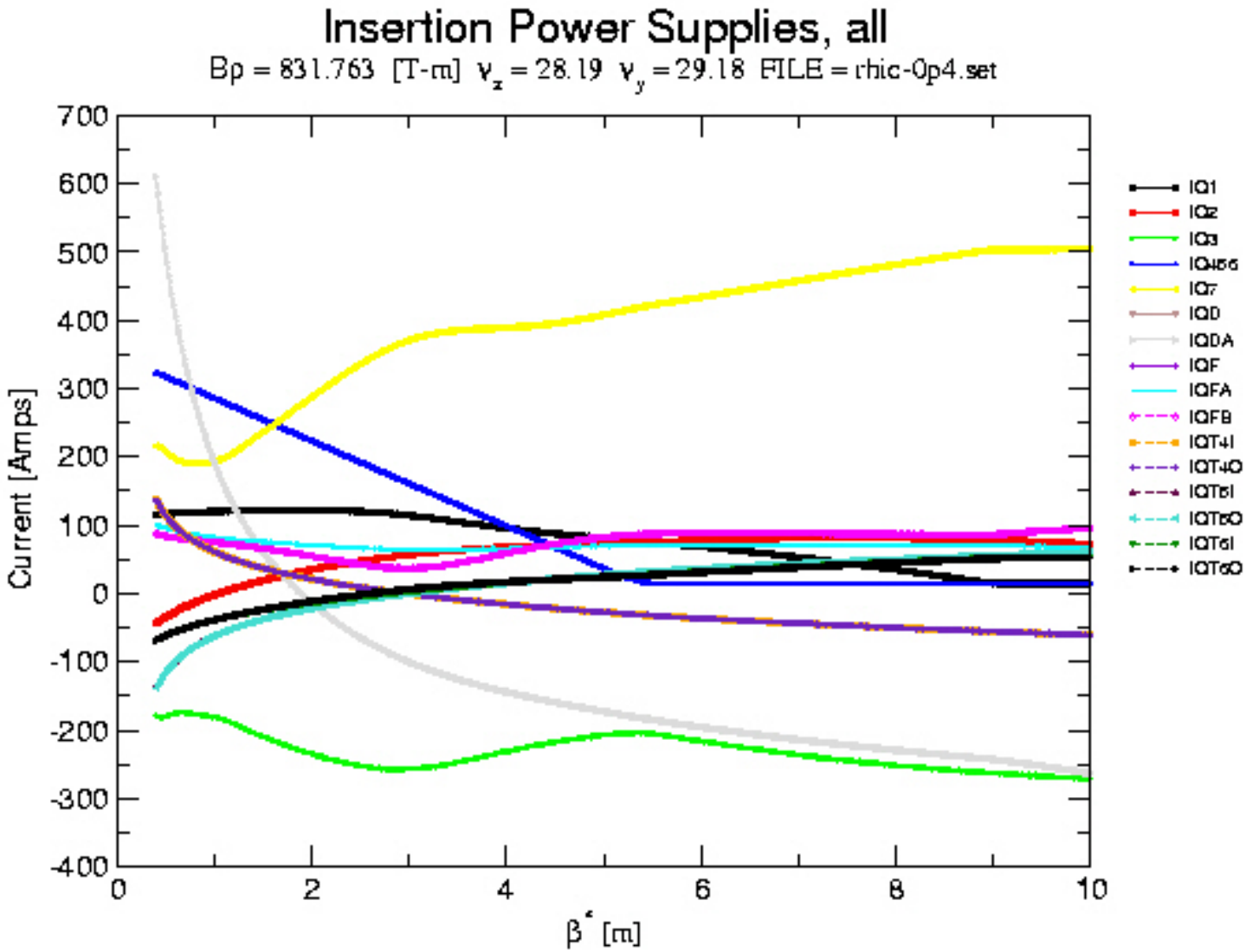


Optics β* =0.4m gradients trims, triplets

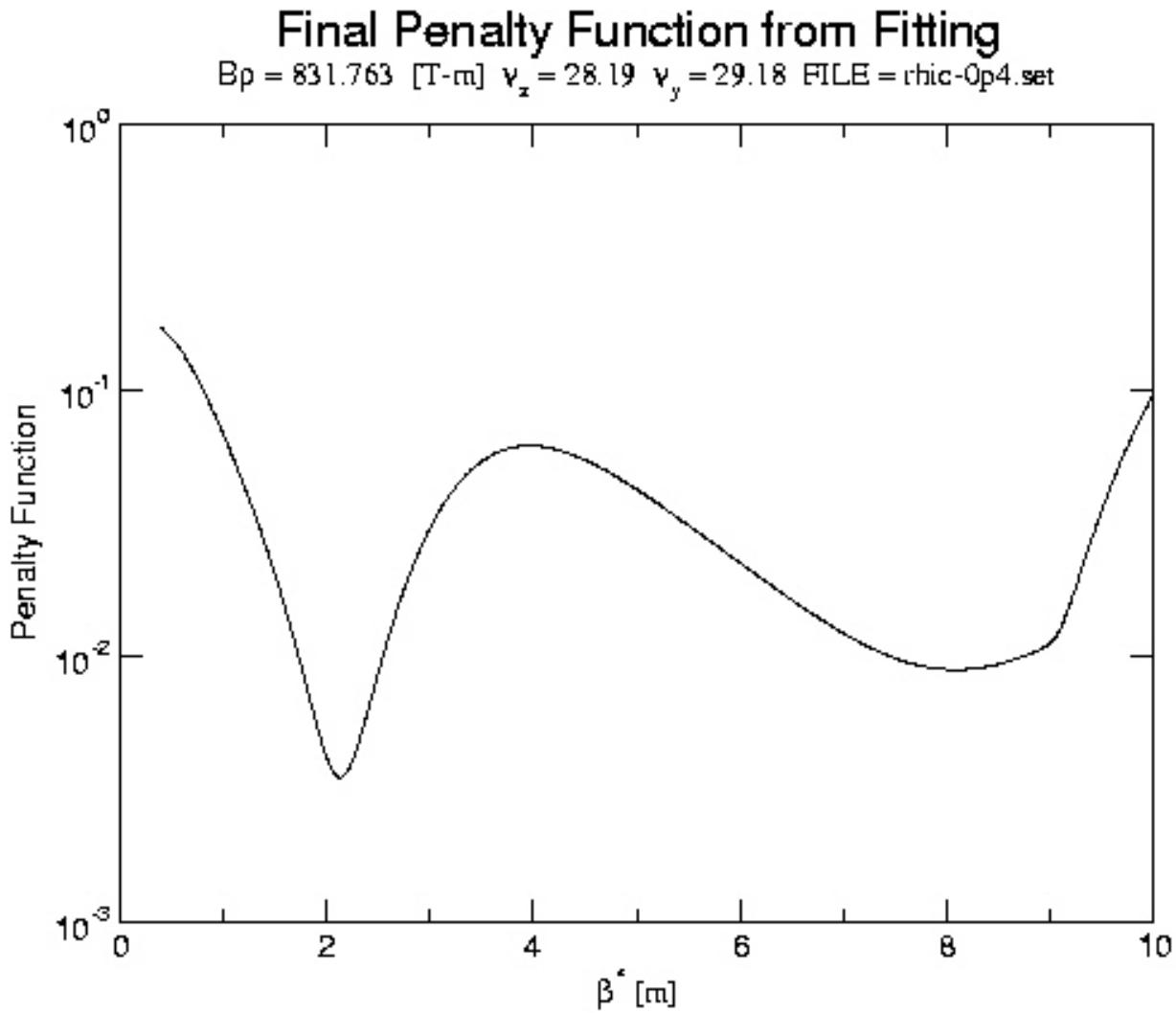




Optics β* =0.4m power supplies



Optics β* =0.4m penalty function



Fitting with Online Model

What is it good for?

- Squeeze more
  - To do: extrapolate TQ Transfer Functions
    - 1 was measured to higher currents
- Correct 'measured' lattice errors
  - Fix Horizontal/Vertical Dispersion
  - Beta waves

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Logical Steps for lower β squeezing

- Understand Linear Optics
  - We do not want a 0.8m squeeze to do (0.6m,1.4m)
- Refit Design Store Stone to new specs
  - Obey PS limits
  - Perhaps add dispersion reduction term
- Update ramp with new store stone and □ *(time)
  - Correct tunes in Design Model
- Commission: Ramp, retune last couple of stones

Squeeze Error Function

(Modified from Tepikian's MAD function)

- Function to minimize
  - At IP: β, α=0, η= 0
  - Across IP match maximum: $\beta_x^{left} = \beta_y^{right}$
  - Arc FODO match: (β_x,$\beta_y$$\alpha_x$,$\alpha_y$,$\eta_x$,$\eta_x$') at start - end
  - Tunes

Squeeze Parameters

- Parameters to change
  - Quad Bus
  - IP quads (anti-symmetric strength across IP)
  - TQ quads (hook up in families)
- Interface is through StepStone
  - Optionally set specified ps currents to fixed value

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(Possibly?) Coupled Model Fitting

- Add to Minimize:
  - Effects of Solenoids at STAR and PHENIX
  - Measured Vertical Dispersion
- Add Parameters to change:
  - Skew Quads
- ? 'maintain' □Qmin

Live Demo

- This is where a demo would go….

typical johannes…☺

β* tuning "knobs"

For β*< **2m** we would benefit from β* tuning "knobs"
Tuning knobs = (quasi) **orthogonal** quadrupole vectors able to produce **matched** changes in β* in a range of about **+/-20%**

Necessary:

- Find the appropriate orthogonal knobs
- Verify **orthogonality** and **matching** (offline)

- Implementation in RE (**online matching** capability helpful)
- **Optics measurements** with 5-10% resolution

Existing work for LHC ("Correcting the LHC β* at collision"
Wittmer Verdier, Zimmermann, PAC2003)

- Calculation & matching
- Tested orthogonality
- Tested performance in simulation (with errors)

β* knobs study (W. Wittmer, CERN)

MADX study with the β*=1m RHIC lattice found appropriate tuning knobs (range +/-20% in β*) for IP8 (constraints in IP8 and IP6)

1. **Calculate and analyze the response matrix**

   nominal strengths of each usable quad varied 5%-95%with 40 intermediate steps, plot $\beta=f(\Delta k)$:

   a)strongly non-linear b) weakly non-linear c) linear

   use linear fit of b) and c) for **construction of knob vector**

2. **Build up knobs**

   # usable quads < # constraints

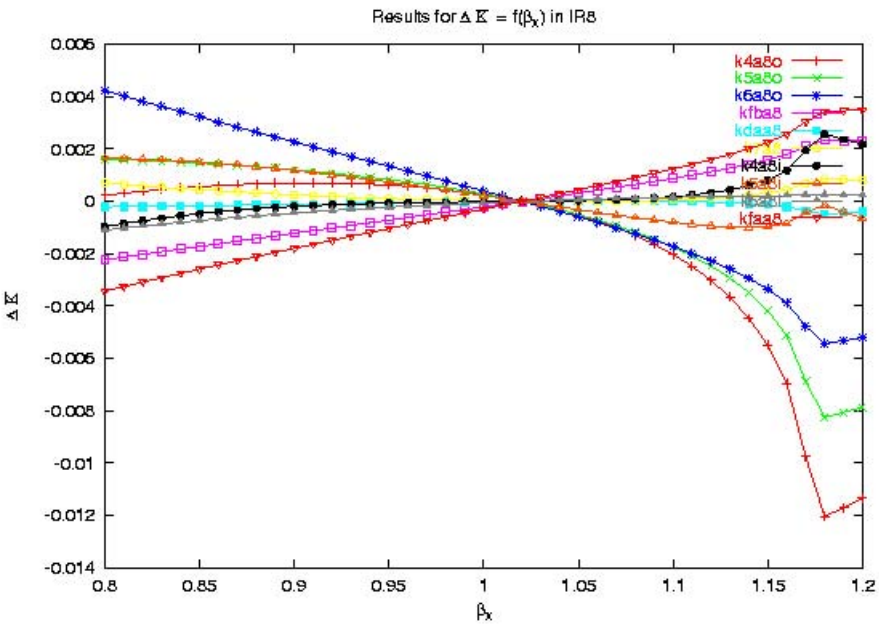
   hard to control dispersion

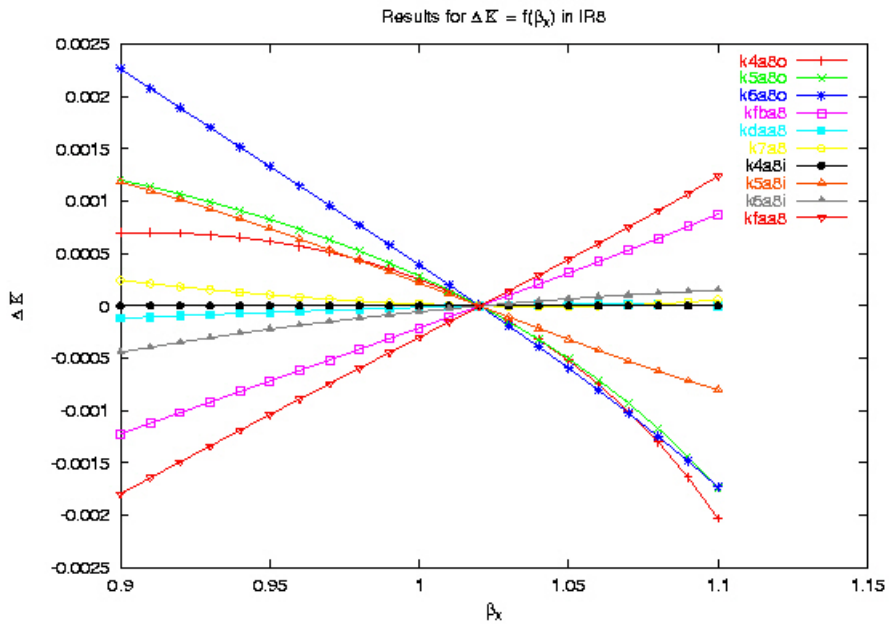
   →knob version 10

   →knob version 11 (optimized to constrain hor. dispersion)

3. **Evaluate knobs performance**

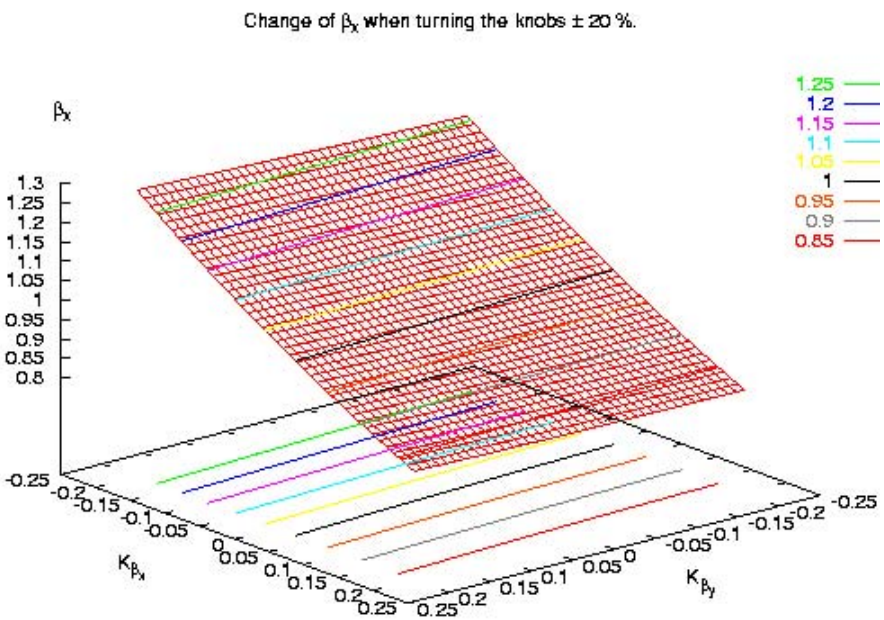
Knobs construction

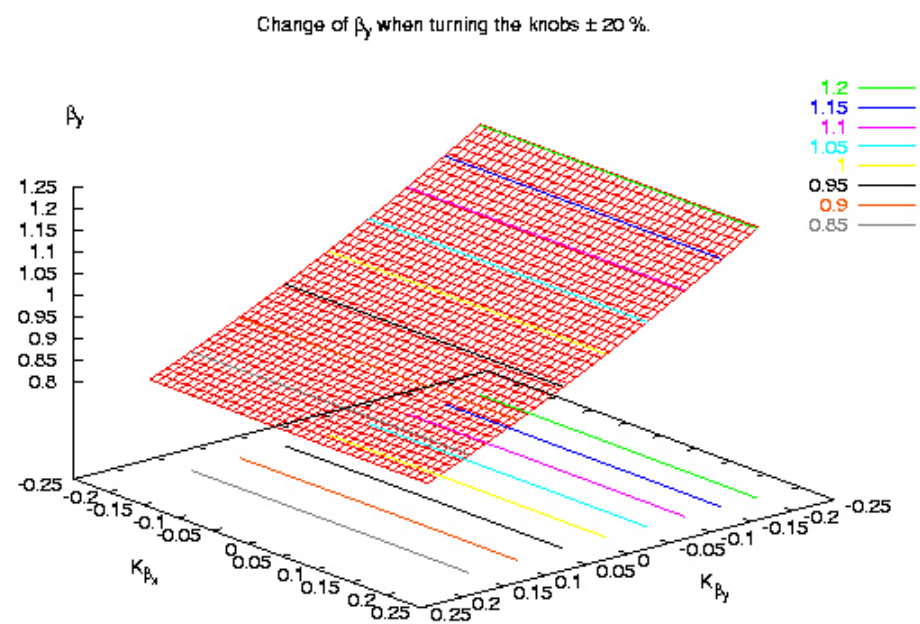




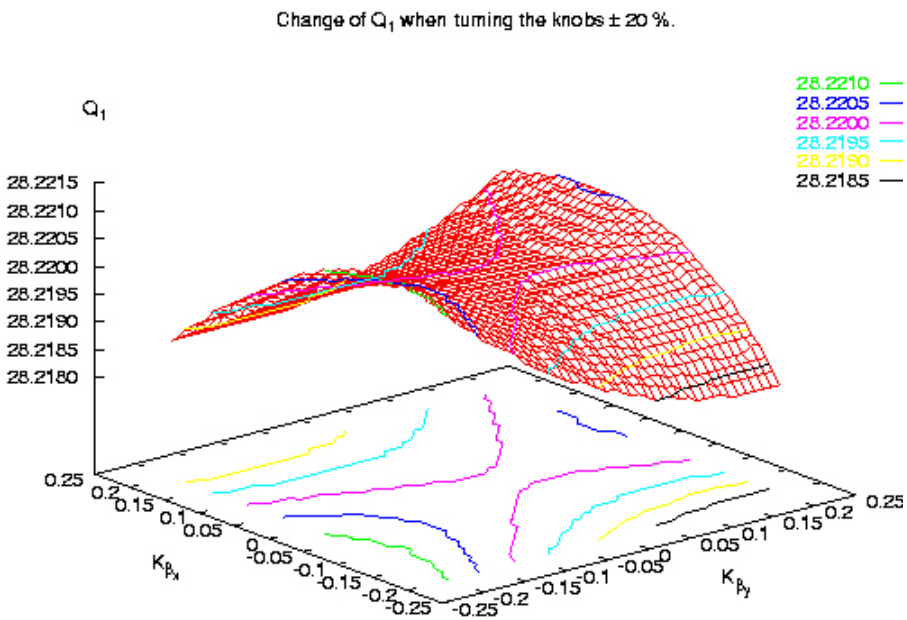
Knobs version 10
DK vs. beta* (knobs construction)
Use only linear part (+/-10%)

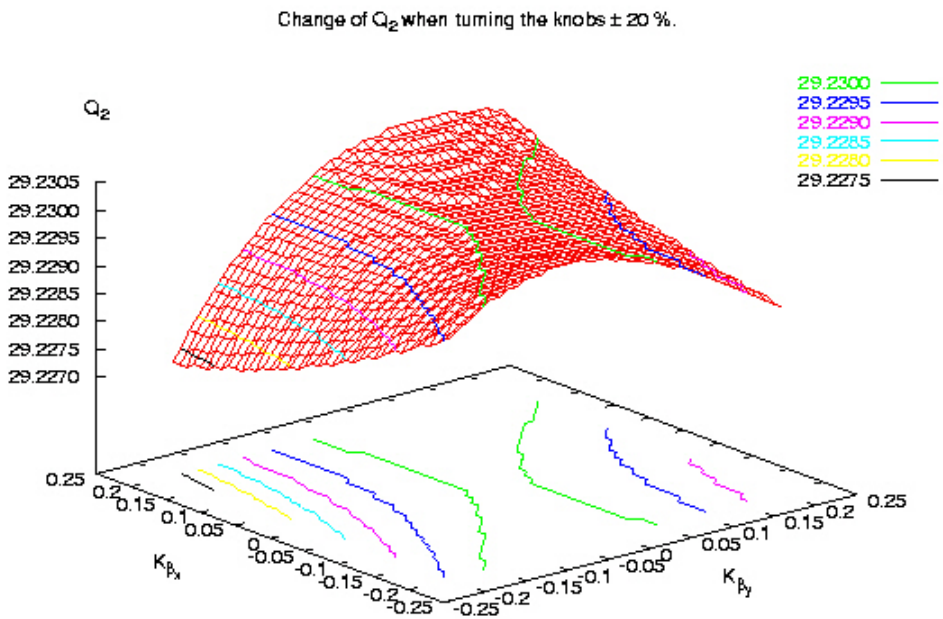
knobs performance betas at IP8



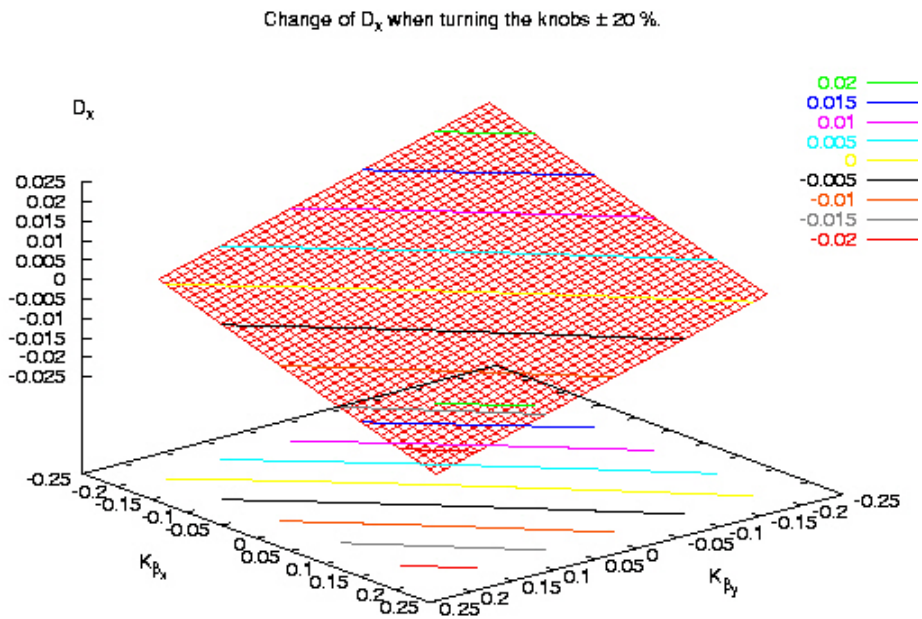


knobs performance tunes

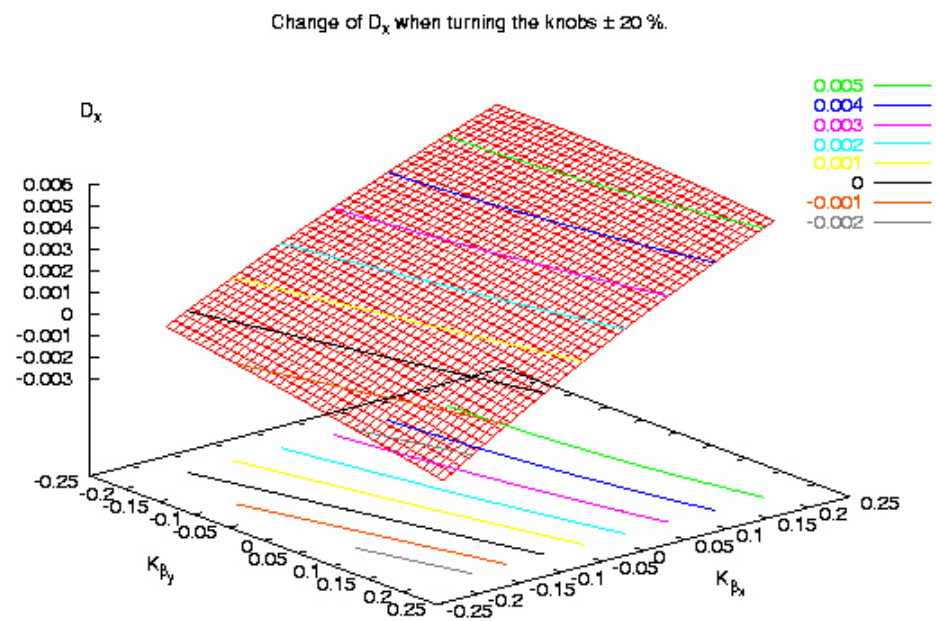




knobs performance dispersion

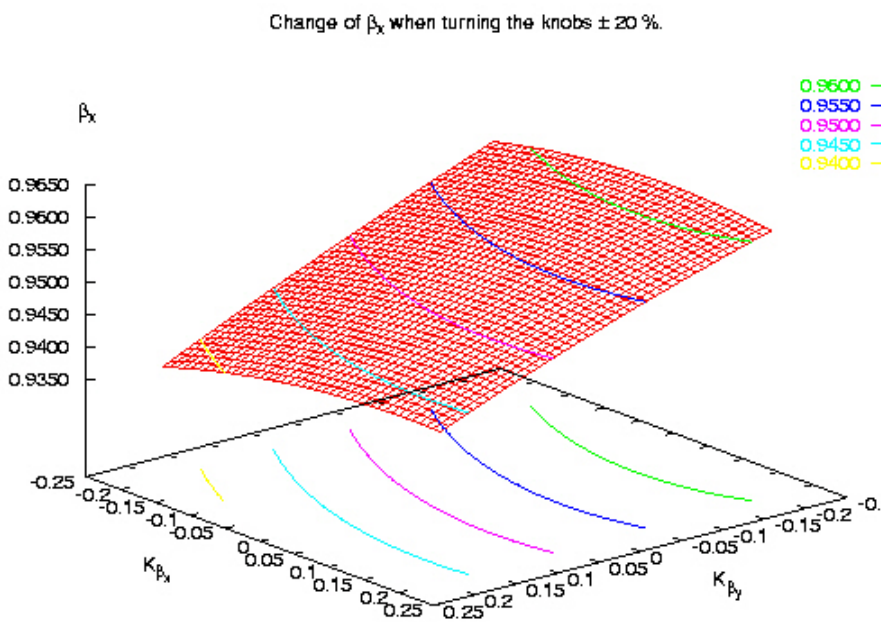


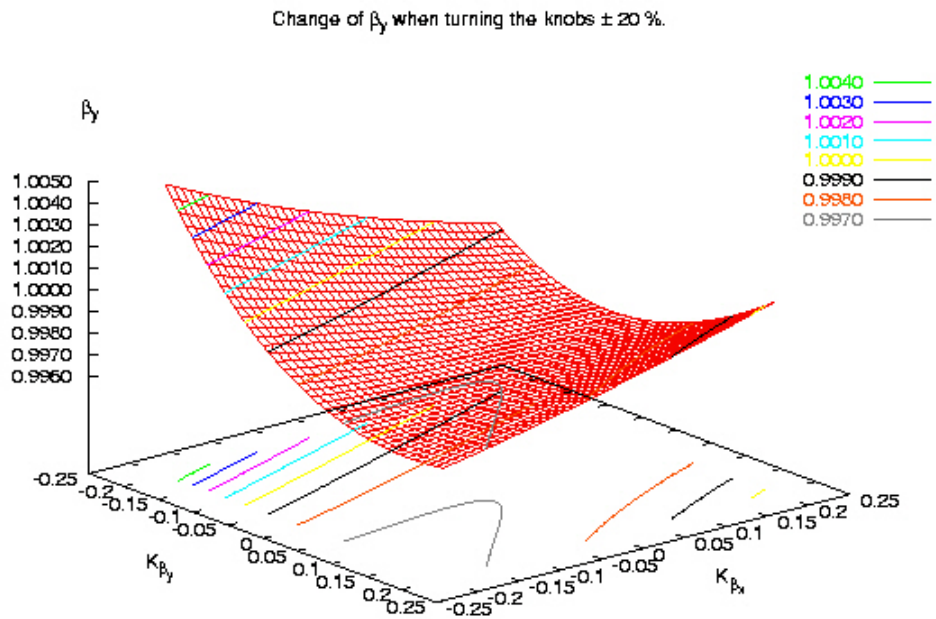
IP8



IP6

knobs performance betas at IP6





IR nonlinear correction methods

Dead reckoning:

action-kick minimization (Wei)
order-by-order prescription, assumes field errors known
(off-line code – "IR filter"- to set corrector strengths)

driving terms compensation (Farthouk)
needs 2 knobs for each multipole to cancel selected DT for both beams:
a2 (1,1) **a2**(1,-1) **b3** (1,2) **a3**(0,3) **b4**(4,0) **b4**(0,4) **a4**(1,3) **a4**(3,1) **b6**(6,0) **b6**(0,6)

operational: beam based + off-line analysis

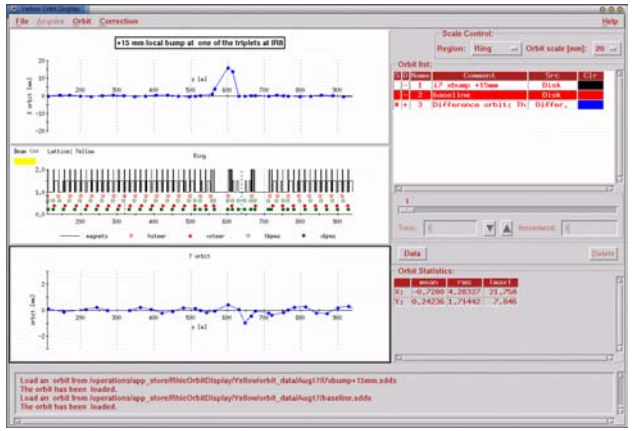
IR bumps:
(Koutchouk)
(Ptitsyn, Pilat)

measure and fit observables vs. bump amplitude:

rms orbit	(BPM's, linear, sextupole)
tunes	(Tune Meter, up to dodecapole)
(tune spread)	(Schottky, octupole, dodecapole?)

frequency analysis: "better FFT" detect and correct nonlinear resonance driving terms
(Schmidt, Tomas)
SUSSIX

IR bumps method - principle



Closed local orbit bump (triplet)
Observable as function of bump amplitude:
rms orbit outside the bump
z=(x,y) $c_n=(a_n,b_n)$ z_{ba}=bump amplitude

$$z(rms) = f(c_n, z_{ba}) = \frac{\sqrt{\beta_{z-arc}}}{2\sqrt{2}\sin \pi Q_z} \frac{B_N}{B\rho} \int \sqrt{\beta_z} c_n \left(\frac{z_{ba}}{R}\right)^{n-1} ds$$

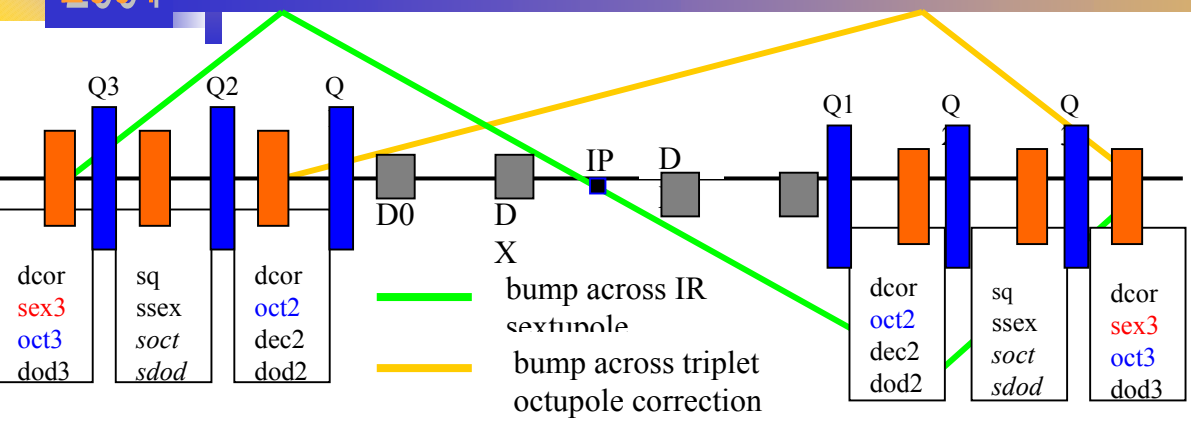
The orbit perturbation depends on the **plane of the bump** (H,V)
And the **parity of the multipole order**

tune shift
Arises from normal gradients (ΔQ) or repelling effect of linear coupling (measured by c)

$$\Delta Q = g(c_n, z_{ba}) = \frac{n-1}{4\pi} \frac{B_N}{B\rho} \int \beta c_n \frac{z_{ba}^{n-2}}{R^{n-1}} ds \qquad \bar{c} = h(c_n, z_{ba}) = \frac{n-1}{2\pi} \frac{B_N}{B\rho} \int \sqrt{\beta_x \beta_y} a_n \frac{z_{ba}^{n-2}}{R^{n-1}} e^{i(\mu_x - \mu_y)} ds$$

Selection of one or the other effect depends on the **plane of the bump**, whether the multipole is **skew or normal** and on the **parity of the multipole order**

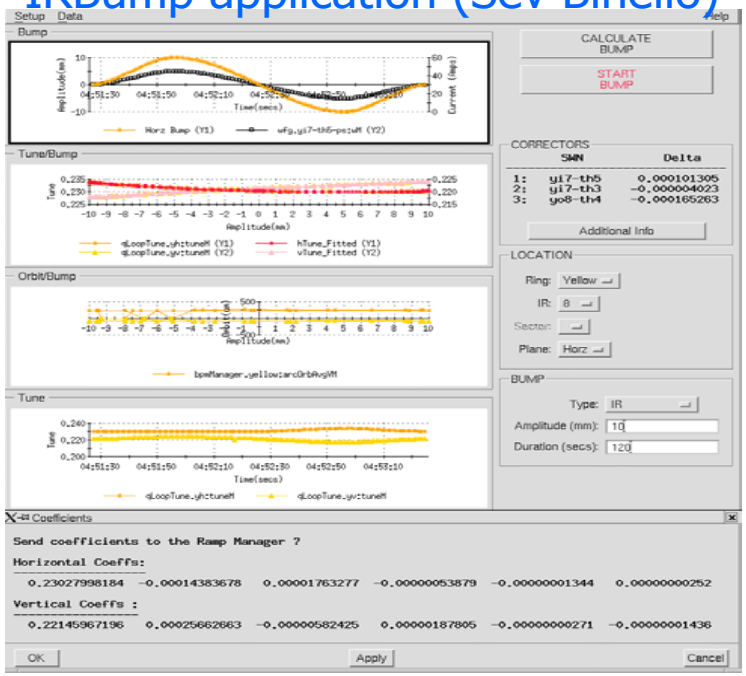
IR corrections: method, app



Motivation:

- Dynamic aperture
- Operations (closure of steering bumps)

IRBump application (Sev Binello)



+Ptitsyn, Pilat, Marusic, VanZejits

Orbit bumps at triplets and across IR
→rms **orbit** and **tunes** vs. bump amplitude

PLL ~10^{-5} resolution

IR bump application:

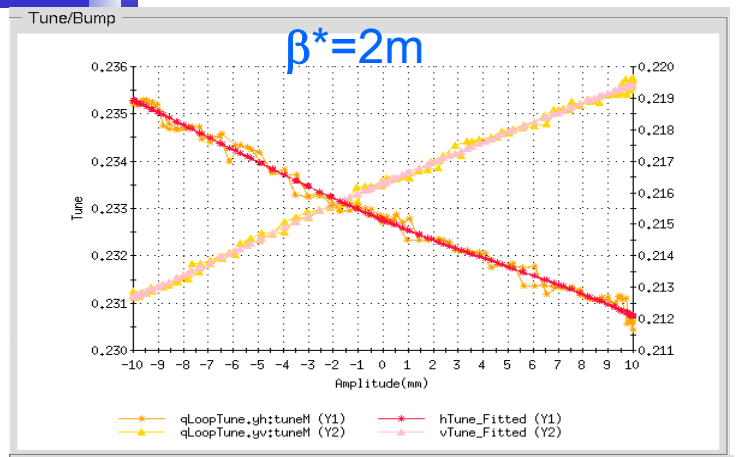
- **set-up** and **ramp-up** of IR and triplet bumps in specified time (1-2 minutes)
- Tune and power supply monitoring
- Plot orbit rms and tunes as a function of bump amplitude
- Polynomial fitting up to 5th order of tunes versus amplitude → **coefficients**→nonlinear **corrector settings**

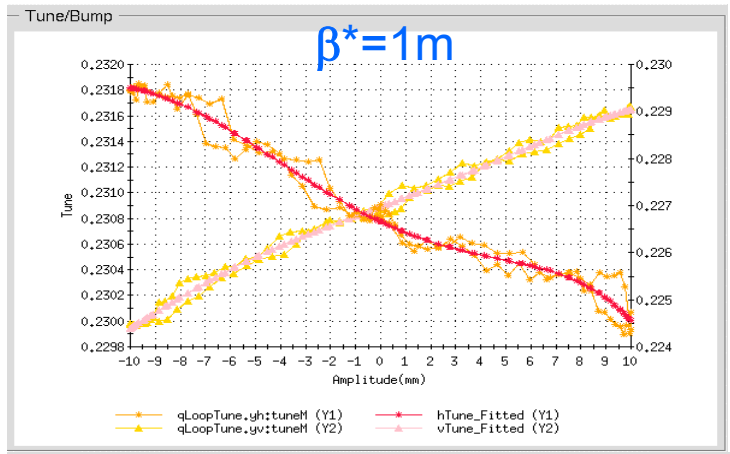
IR correction – β*=2m vs. 1m

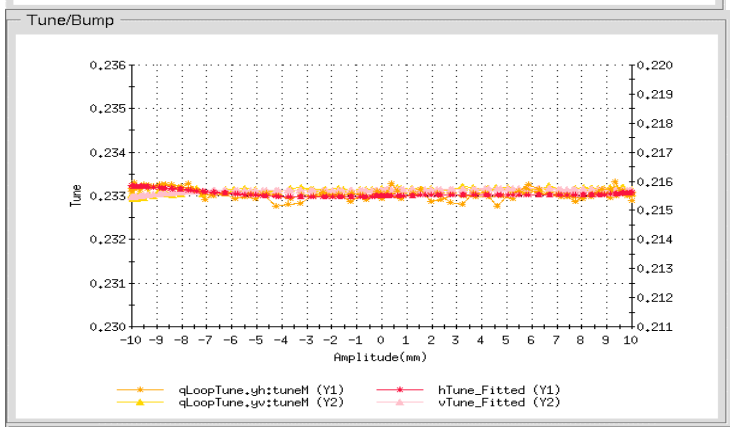
Yellow IR8

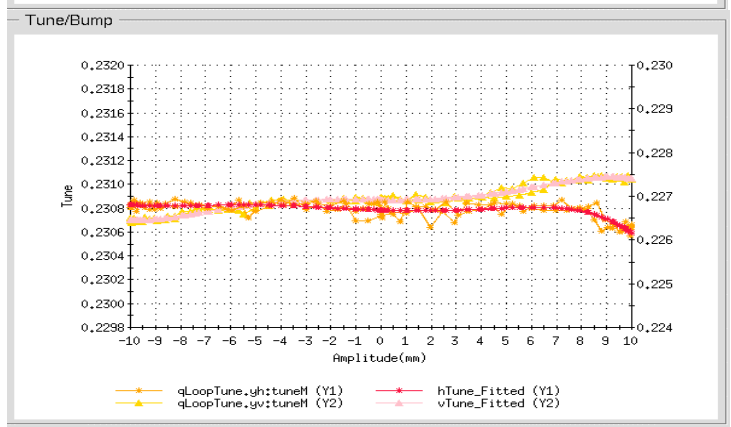
before sextupole correction

after sextupole correction









- **Sextupole correction** at **IR6** and **IR8** – blue and yellow rings beta*=1m and 2m
- test of **octupole correction** at **YIR8** (2 octupoles allow individual triplet correction) feed-down octupole→sextupole, to be repeated: octupole first, then sextupole
- **Current dependence** of field harmonics (left 5000A, right ~2000A)

IR corrector strengths 2m vs 1m

Sextupole corrector	Strength β*=2m ~5000 A	Strength β*=1m ~2000 A
yo5-sx3	-0.014	-0.003
yi6-sx3	0.004	0
yi7-sx3	0.003	0.007
yo8-sx3	-0.01	-0.038
bi5-sx3	0.012	0.001
bo6-sx3	-0.004	-0.003
bo7-sx3	0.0	-0.003
bi8-sx3	0.0	-0.0005

- Difference in strength due mainly to the current dependence of the triplet field errors (if the effect is local).
- The **β*=2m strengths** will be used as a **starting point for correction next year Au-Au run** + readjustment for (**β*=1m at ~5000A**)

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IR (action-kick "Jie") Filter

Jie IR filter based on action-kick minimization across the IR has been rewritten

Fortran→UAL(SMF)→SXF Filter

SXF filter nominally works (with SiteWideNames)

but:

Tracked blue 2004 lattice with IR errors and IR filter correctors and there was no improvement in dynamic aperture – this contradicts old MAC tracking results

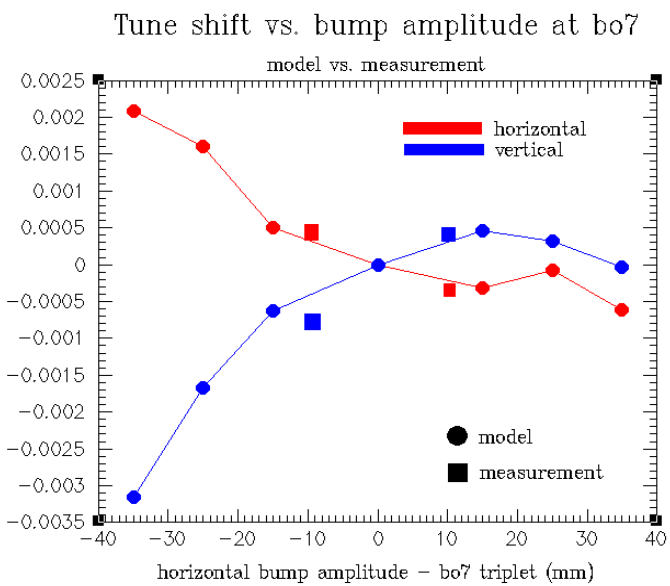
→ Back to debugging the filter

→ Performance simulations (order by order)

Goal to have IR filter working for the run

Model vs. measurement comparisons

- Dynamic aperture/lifetime dominated by triplet errors
  we see <u>lifetime degradation</u> when we bring beams into collision
- <u>Tune shift with amplitude</u> slightly larger than model predictions
  – [caveat: compared only 2 data points with β^*=2m]



- (measured) dynamic aperture with 2m β^*smaller than prediction

Beam Ex related to β* squeeze

(assume IR sextupole correction adjustment done in operations)

Beam Experiments (in logical order)

- Precise (5%) optics measurements (AC dipole+BPMs)
- Test correction setting from the action-kick IR filter prediction,measure tune shifts, observe lifetime
- Operational octupole correction (before sextupole) and readjustment of sextupole
- Dynamic aperture (cfr. Vadim's talk) with β*=1m different tunes, IR correction on and off (if measurements good enough to discriminate)
- Test of β* tuning with tuning knobs, online model
- Test of 0.4m optics in IP8 with polarized protons