TESLA Collaboration meeting, WG#3,
DESY-Zeuthen, 22.1.2004

Emittance measurements at BC2

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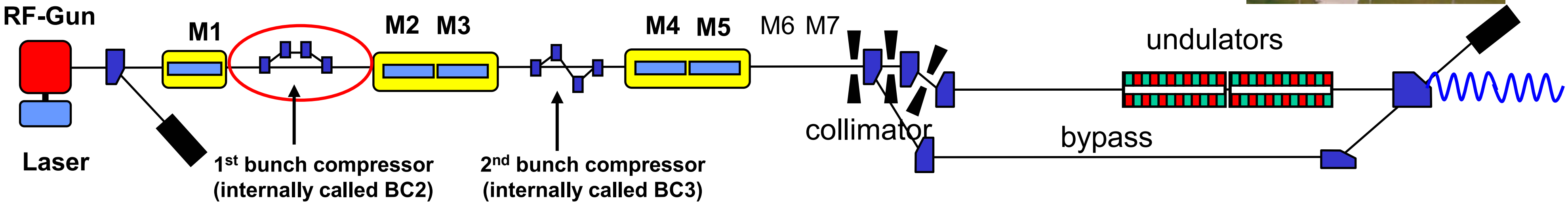
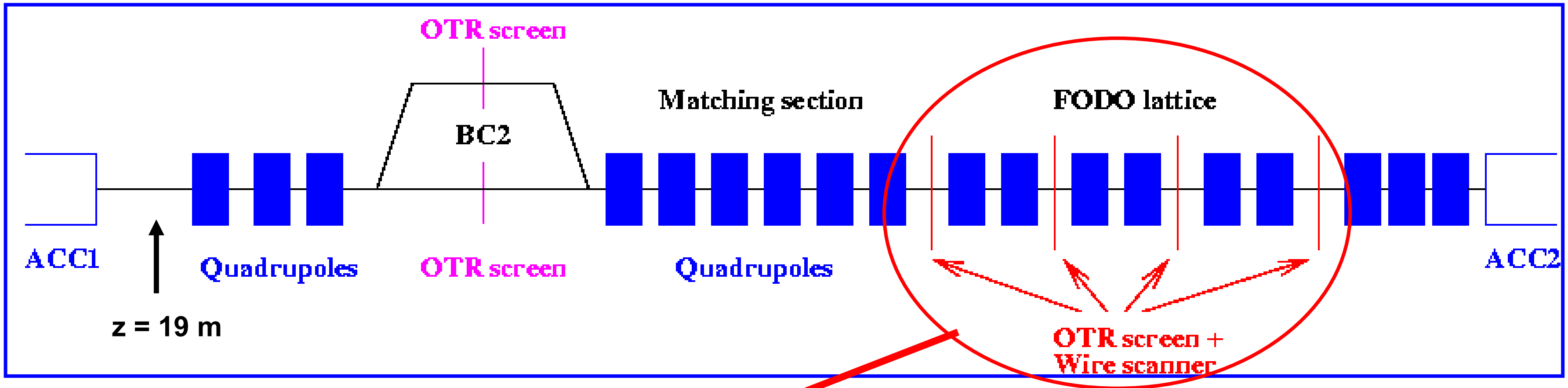
- Layout of the BC2 section
- Methods and tools for emittance measurements
- Four monitor method at BC2
- Quadrupole scan at BC2
- Measurements during the injector run

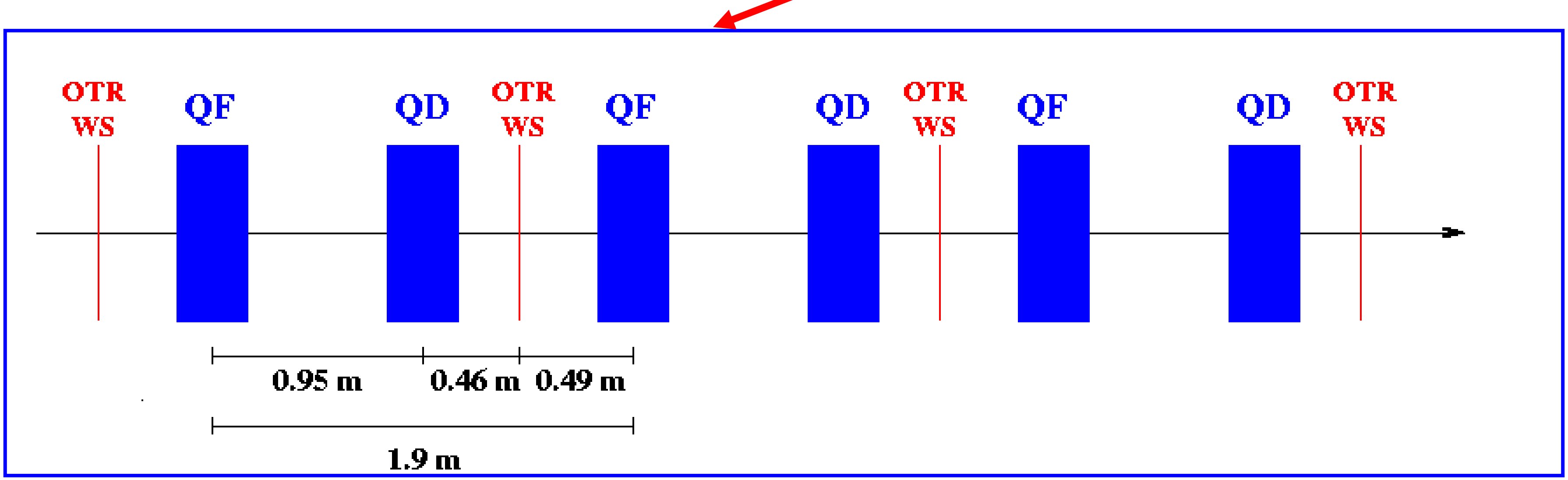
TTF2 linac



250 m

Schematic of the BC2 section



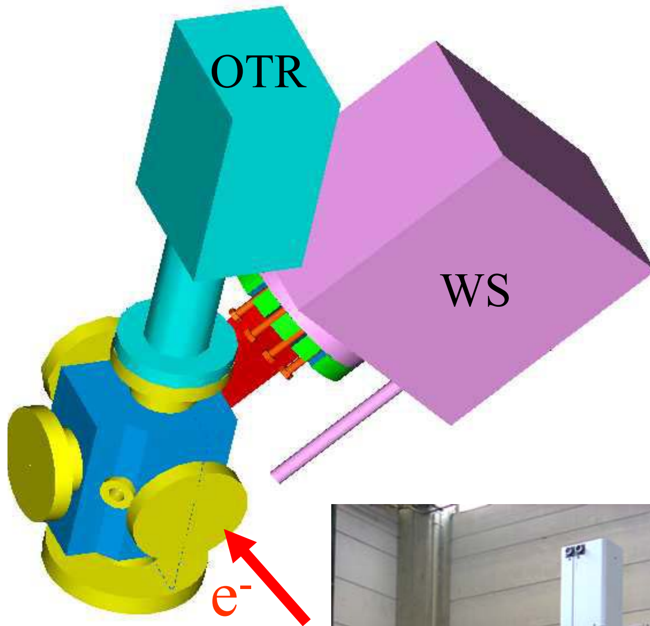


Emittance measurements at BC2

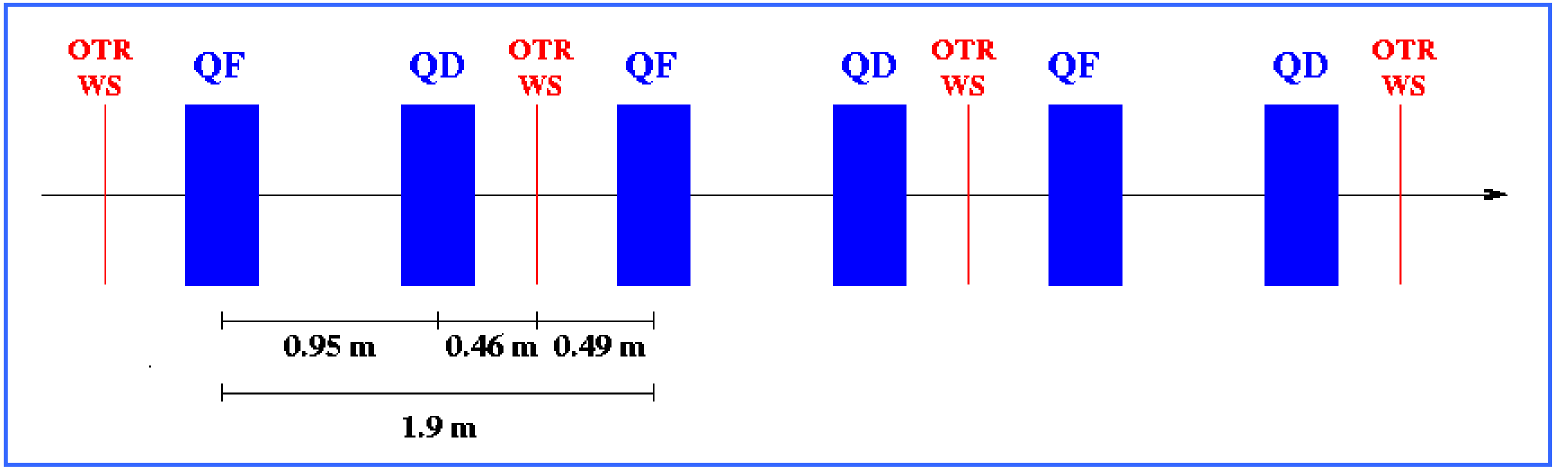
- Goal
  - Fast and reliable (semi)automatic emittance measurement system providing fast estimate of emittance and Twiss parameters for the beam optics optimization (matching) as well as accurate measurement of emittance for beam characterization
- Methods
  - Four (multi) monitor method:
    - Measure beam size at several locations with a fixed beam optics
    - Main method for emittance measurements at BC2
  - Quadrupole scan:
    - Measure beam size at one location with different settings of one or several quadrupoles upstream
- Tools
  - 4 combined OTR and wire scanner monitors in the BC2 diagnostics section (FODO lattice)

OTR + wire scanner station

- Standard OTR monitor
  - Resolution down to ~10 um
- Wire scanner
  - 3 tungsten wires of 18 um diameter mounted into a fork moving at 45 deg with respect to the beam
    - One wire horizontally, one vertically, and one at 45 deg allowing horizontal and vertical measurements with one device
  - Expected resolution 20-30 um



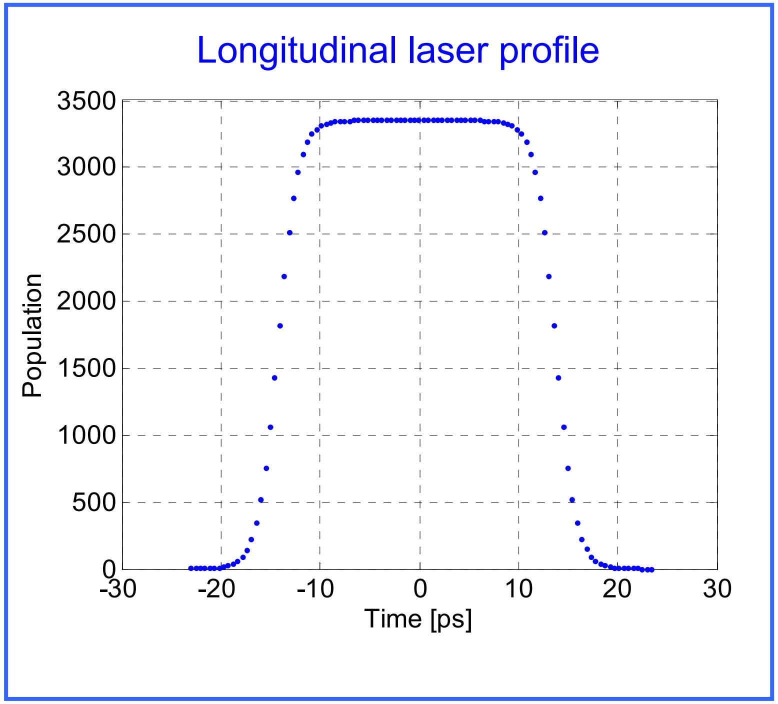
Four monitor method



- Beam size is measured at four OTR screens or by four wire scanners with a fixed value of the quadrupoles in the FODO lattice
- Magnetic length of quadupoles is 270 mm, and they have a common power supply
- Design phase advance of the FODO cell is 45 deg
- FODO lattice with periodic beta function is not a strict requirement for emittance measurements with multi monitor method, but it provides convenient measurements and fast check of matching

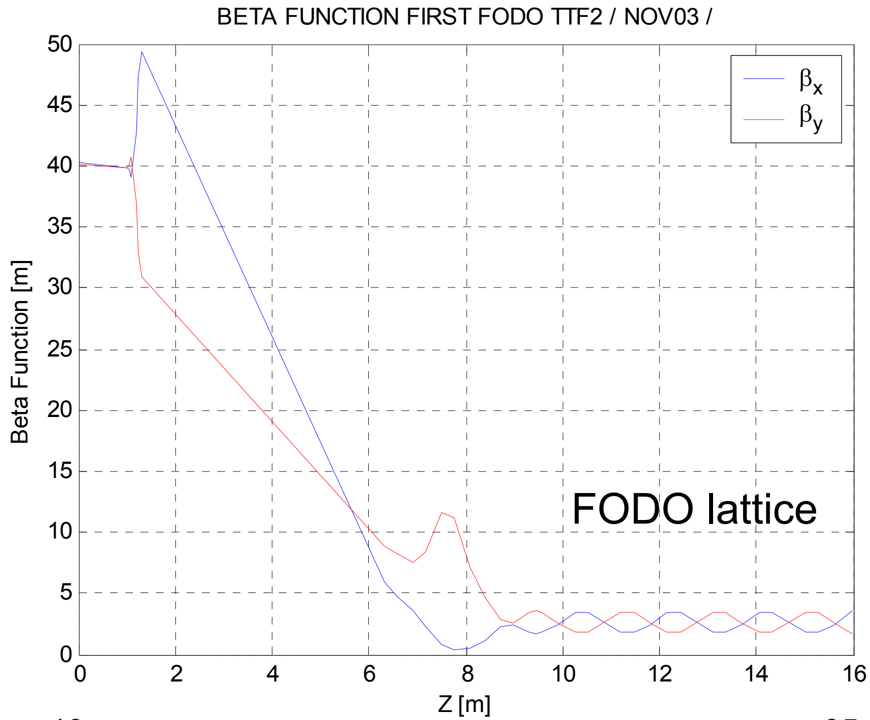
Simulations (J.-P. Carneiro)

- BC2 chicane by-passed
- Simulations by ASTRA (up to 19 m) and Elegant (z = 19 m to 35 m)
  - Elegant used to match optics to the FODO lattice
  - Output: Beam sizes at screen locations for emittance calculations
- Parameters
  - Charge: 1 nC
  - Laser: 20 ps flat top, ~5 ps rise time
  - RF-gun: gradient 40 MV/m, phase 31 deg
  - Module: all cavities on crest, gradient of cavities 1-4: 12 MV/m, 5-8: 20 MeV/m
  - Energy about 143 MeV ($\gamma =$ 279.7)



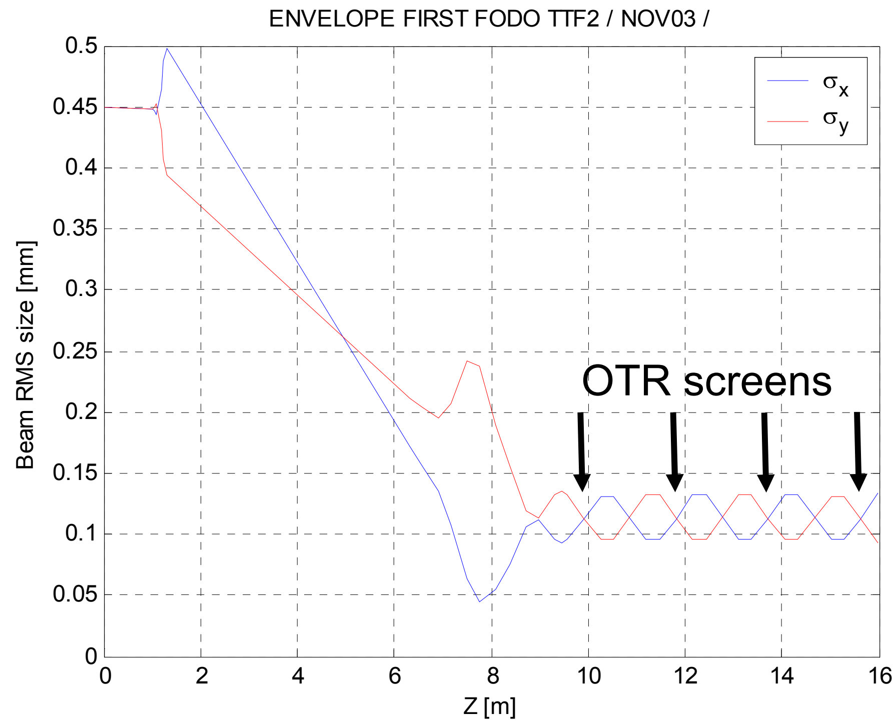
Beta function and beam sizes

Horizontal and vertical beta functions and beam sizes in the matching section and FODO lattice (phase advance 45 deg)



19 m

35 m



Beam	Screen 1	Screen 2	Screen 3	Screen 4
Horizontal	111.5 um	111.7 um	111.9 um	111.7 um
Vertical	113.4 um	113.5 um	113.2 um	113.1 um

Status of emittance calculations

- Calculation of emittance and Twiss parameters understood: Programs by P.Castro (C), P.Emma (MatLab), and K.Honkavaara (MatLab) gives same results
  - Programs of P.E. and K.H. tested with beam sizes simulated by J.-P.Carneiro for several different phase advances
  - Comparison with P.C. program done for the example case in Technical note 03-03 (P. Castro “Monte Carlo simulations of emittance measurements at TTF2”)
- Statistical error from fitting understood (included in P.Emma program)
- Analysis of systematic errors needed

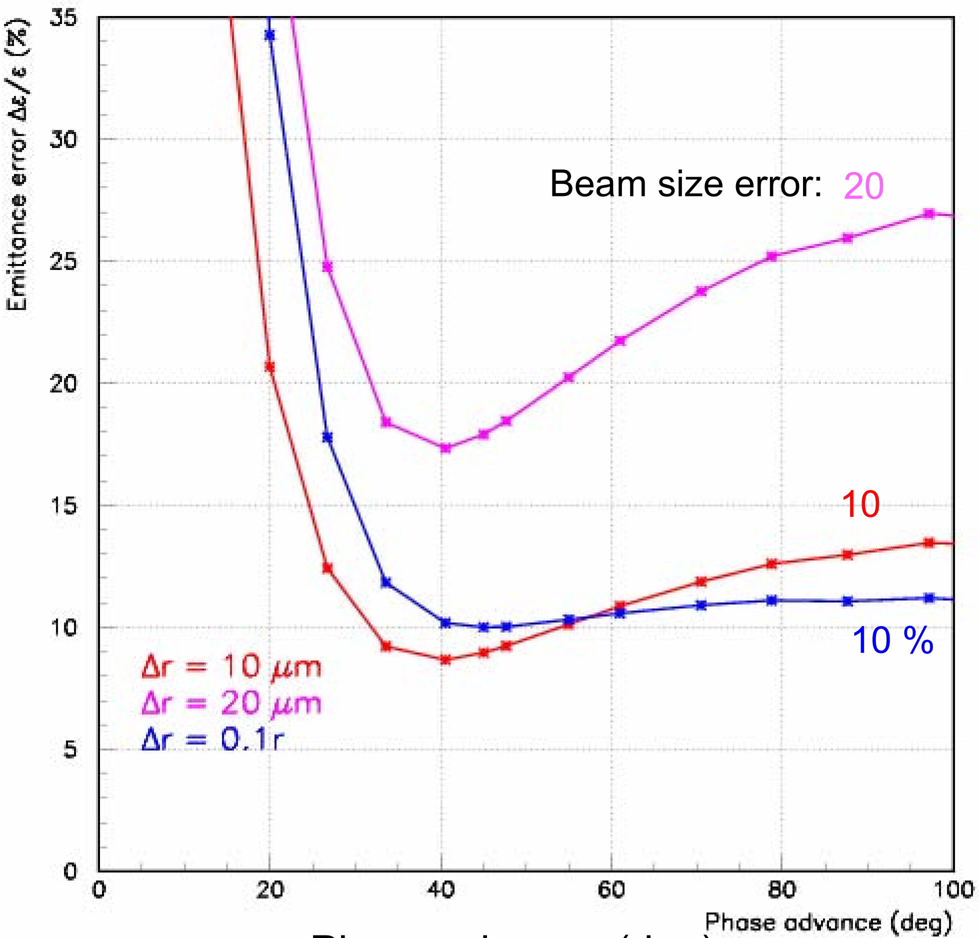
Emittances calculated from simulated beam sizes

Phase advance	Beam size error	Emittance (hor/ver) [mm mrad]	Error (hor/ver) [mm mrad]
20 deg	10 um	1.4114 / 1.4119	0.2916 / 0.2922
40.5 deg	10 um	1.4113 / 1.4120	0.1224 / 0.1208
45 deg	10 um	1.4113 / 1.4119	0.1264 / 0.1246
45 deg	20 um	1.4113 / 1.4119	0.2528 / 0.2492
45 deg	10 %	1.4113 / 1.4119	0.1411 / 0.1412
55 deg	10 um	1.4112 / 1.4146	0.1428 / 0.1406
61 deg	10 um	1.4112 / 1.4119	0.1533 / 0.1506

Emittance (horizontal and vertical) from simulations: 1.40 mm mrad

Emittance error vs. phase advance

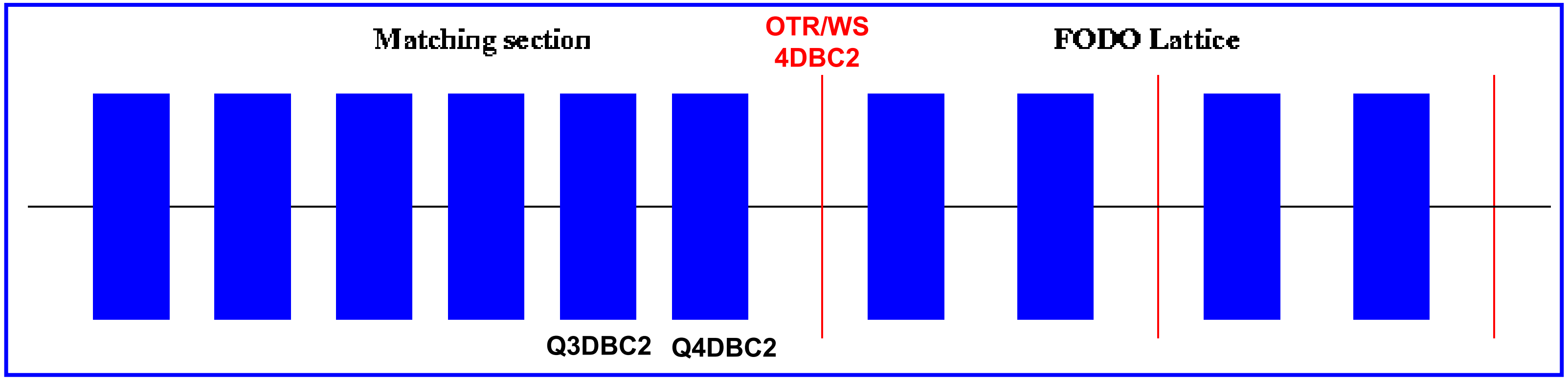
Relative horizontal emittance error



Phase advance (deg)

- Minimum statistical error of the calculated emittance obtained with phase advance of 40 - 50 deg
  - Similar result shown by P. Castro (Technical Note 03-03)
- Calculated emittance independent on the phase advance

Quadrupole scan



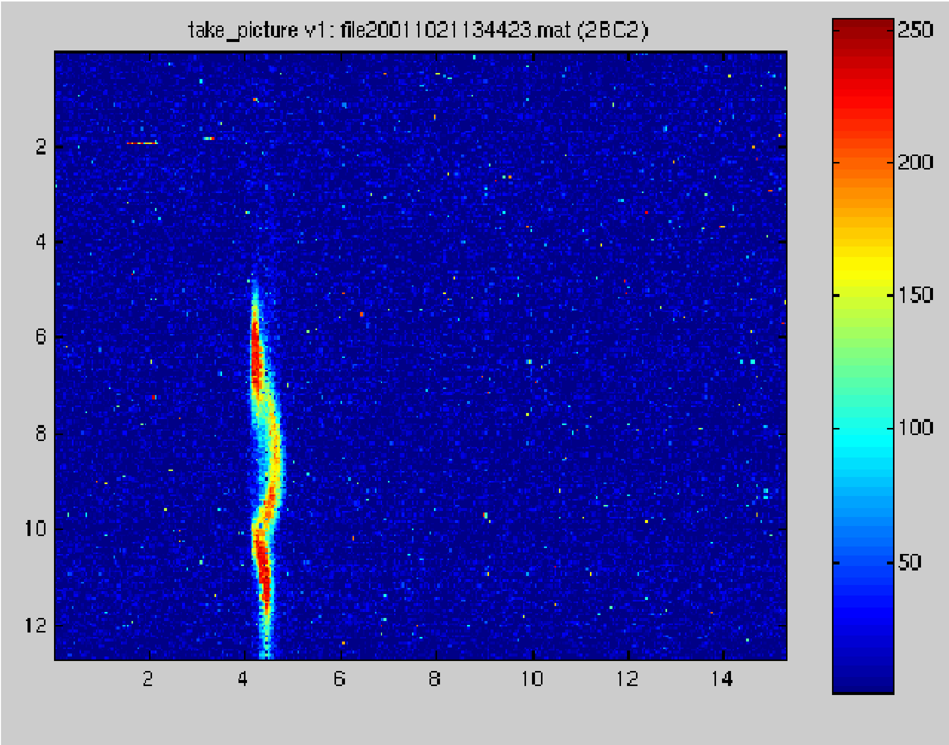
- First OTR screen / wire scanner in the FODO lattice planned to be used
- Easiest scan from analysis point of view by using the first quad upstream of the screen (Q4DBC2)
  - BUT: Q4DBC2 is powered with the same power supply than the quads in FODO lattice
- Use of the second quad upstream (Q3DBC2)
  - Q4DBC2 (and quads in FODO lattice) off
  - Q4DBC2 (and quads in FODO lattice) on; has to be taken into account in analysis
- Current limit of both quads 50 A (by power supply)
  - Has to be checked, if waist can be produced both in horizontal and vertical direction

Possible problems with quad scan

- Waist in beam size needed both in horizontal and vertical directions
- Measurements relatively slow:
  - Quadrupole need to be steering free and cycled
- Irregular beam shapes possible, especially with bunch compression
- Beam transport after the screen not possible

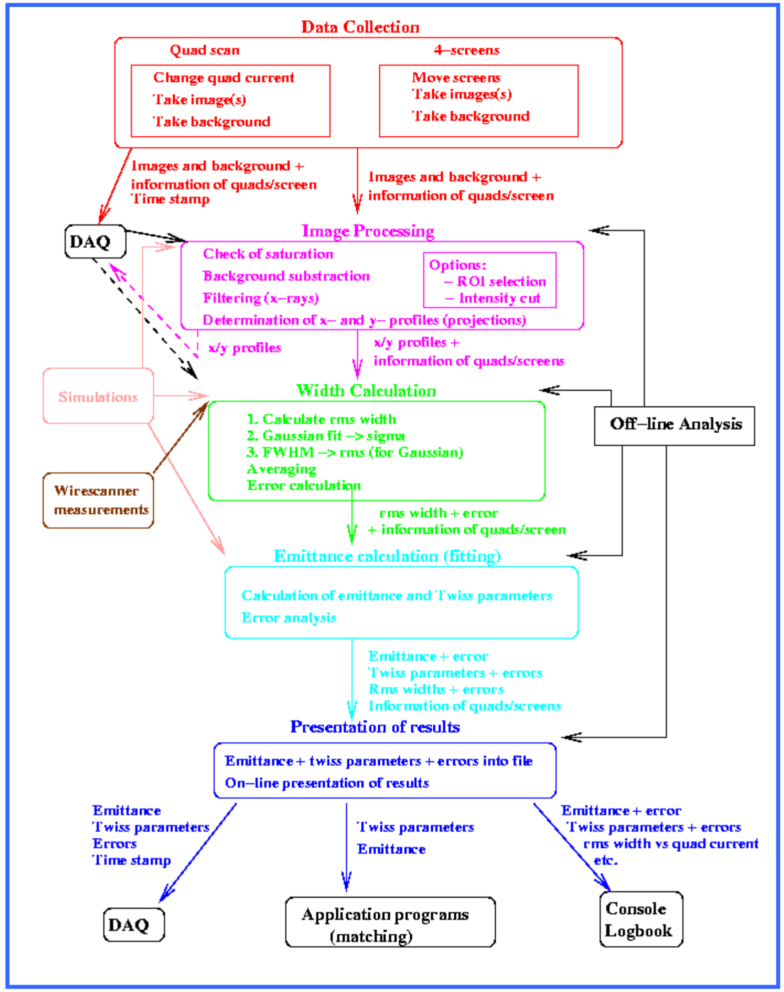
- BUT: Provides complementary measurement with the four monitor method

Beam image measured at TTF1 during quad scan with full bunch compression



Data collection and analysis software

- Goal: Software package for complete emittance measurements from data collection to the presentation of the results
  - To be realized in “modules”
  - Structure of emittance measurements decided
  - User programs and interfaces need to be written



Emittance measurements during injector run

- OTR and wire scanner systems need to be commissioned before starting emittance measurements
- Commissioning of the data collection and analysis software
- Test measurements
  - Settings for the OTR set-ups (magnification, filters, camera settings)
  - Comparison between measurements with OTR and wire scanners
  - Comparison between four screen method and quad scan (?)
  - Measurement with and without BC2 chicane
  - Effect of upstream beam optics
- Systematic measurements of emittance and Twiss parameters to optimize beam optics (matching)
- Accurate emittance measurements (beam characterization)