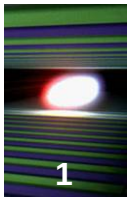


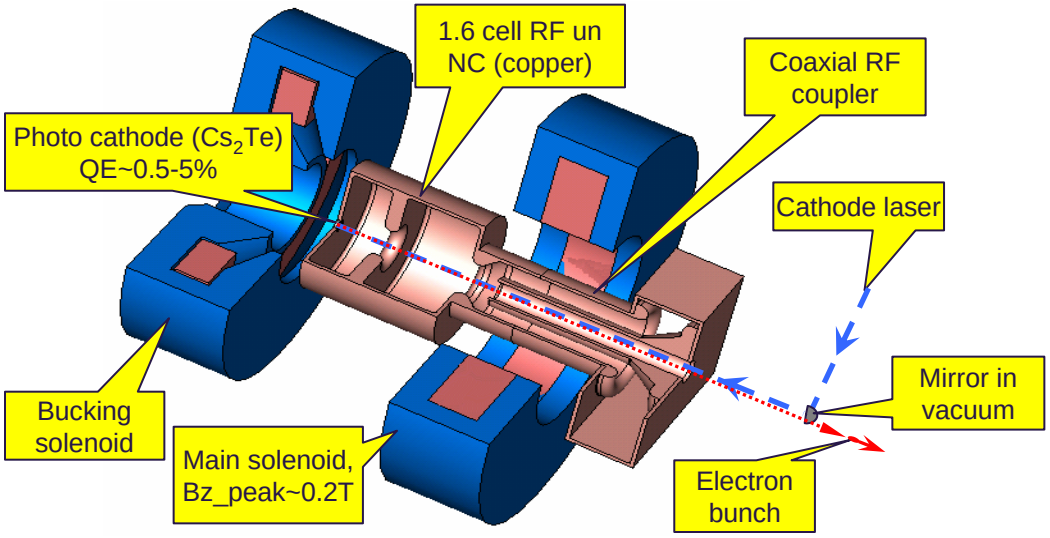
Screen investigations for low energetic electron beams at PITZ

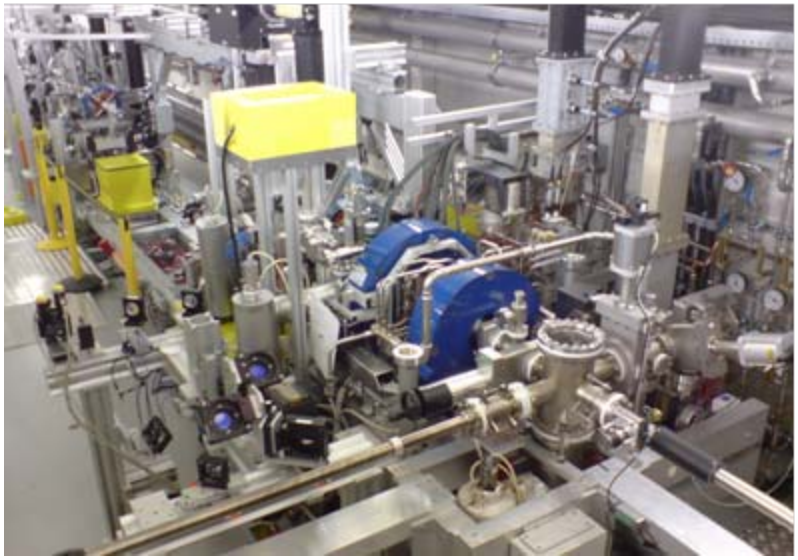
S. Rimjaem, J. Bähr, H.J. Grabosch, M. Groß

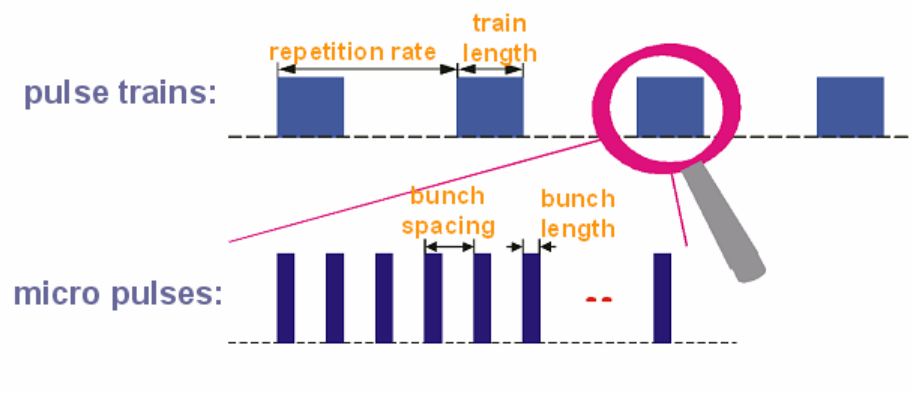
Contents

- Review of PITZ setup
- Screens and beam profile monitors at PITZ
- Test results
- Summary

Optimization of L- band Photo Cathode RF gun @ PITZ



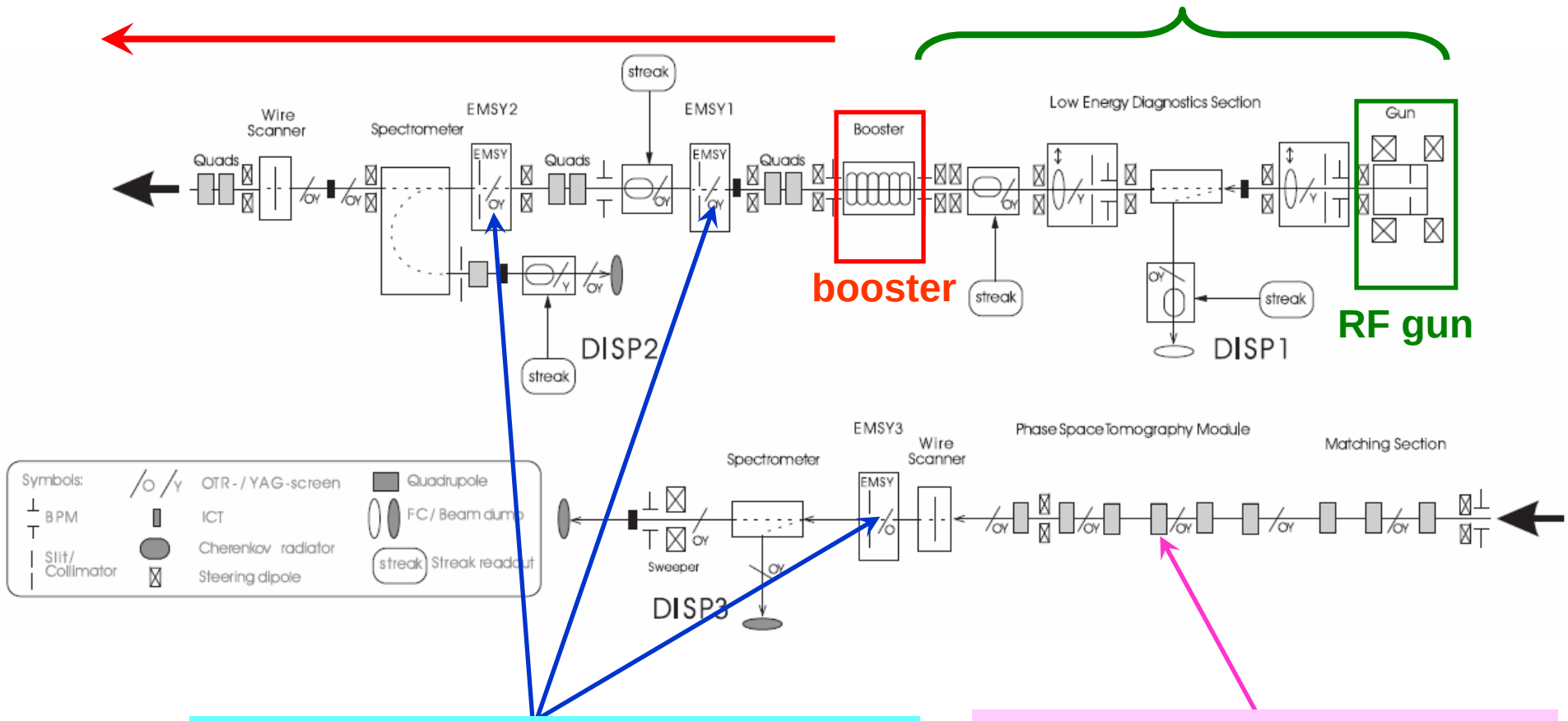




Parameter	Value
Max. RF repetition rate	10 Hz
Max. RF power	6 MW peak power
Max. RF pulse length	800 μs
No. of pulses / train	1 – 800
Bunch spacing	0.2 – 1 μs
Max. bunch charge	a few nC

Current PITZ Setup (PITZ1.8)

high energy section (p_z ~24.8 MeV/c) low energy section (p_z ~6.7 MeV/c)



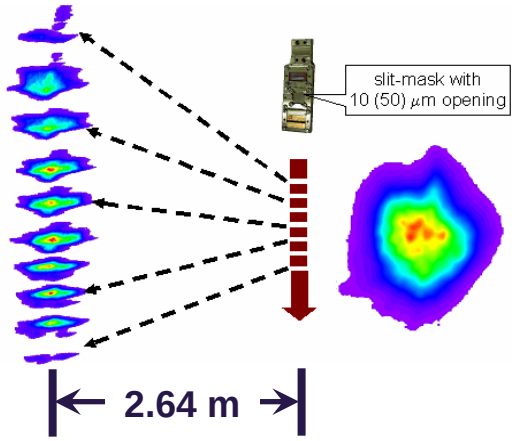
Trans. projected emittance & phase space @ Emittance Measurement SYstem (**EMSY**)

Trans. phase space reconstruction @ **Tomography module**

Measurements of Transverse Projected Emittance & Phase Space

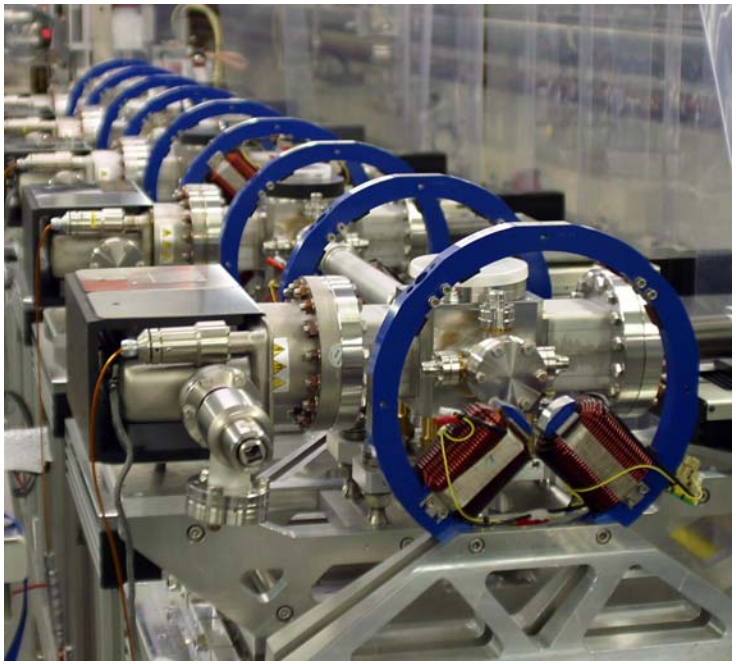
Single slit scan technique

- **EMSY** stations consist of horizontal / vertical actuators with
  - **YAG** / OTR screens
  - **10** / 50 μm slits
- Beam size is measured @ EMSY position
  - Beam RMS sizes: 0.2 – 2.5 mm
- Beam divergence is estimated from beamlet sizes @ observation screen
  - Minimum beamlet RMS sizes: ~50 μm



Phase space reconstruction

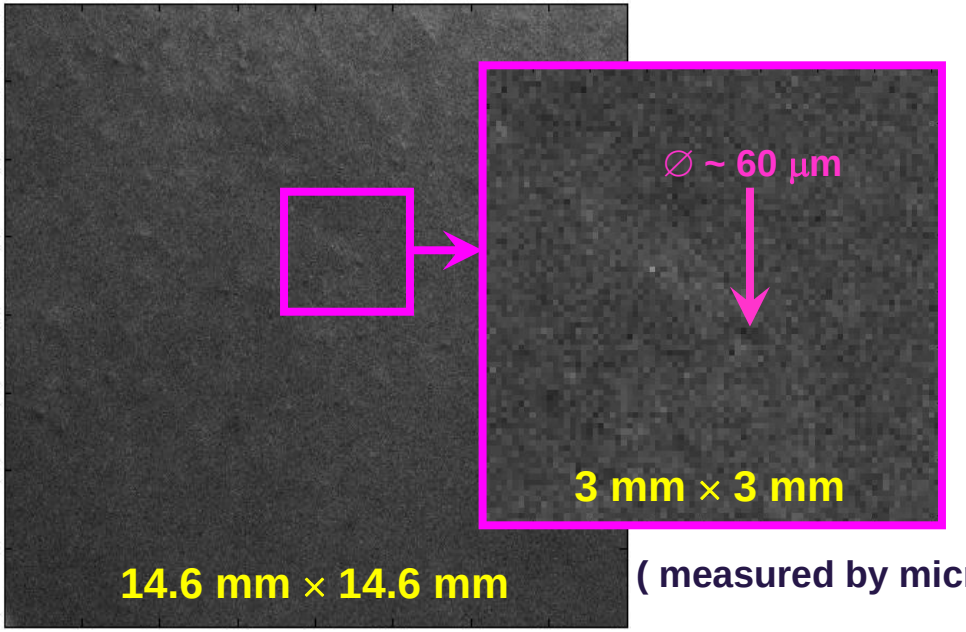
- **tomography module** consists of
  - 3 FODO cells
  - 4 screen station
  - Phase advance of 45°
- Beam size is measured with a **YAG** / OTR screen
  - Minimum beam RMS sizes: 120 μm



Ce-doped Yttrium Aluminum Garnet (YAG) Powder Coating Screen

Chemical formula	$Y_3Al_{2,5}Ga_{2,5}O_{12}$:Ce
Thickness of YAG powder layer	**5 - 20 μm**
Density of YAG power	5.1 g/cm^3
Thickness of silicon substrate	100, **275**, 380 μm
Density of silicon substrate	2.33 g/cm^3
Incident angle	**90°**
Wavelength of peak emission	510 nm

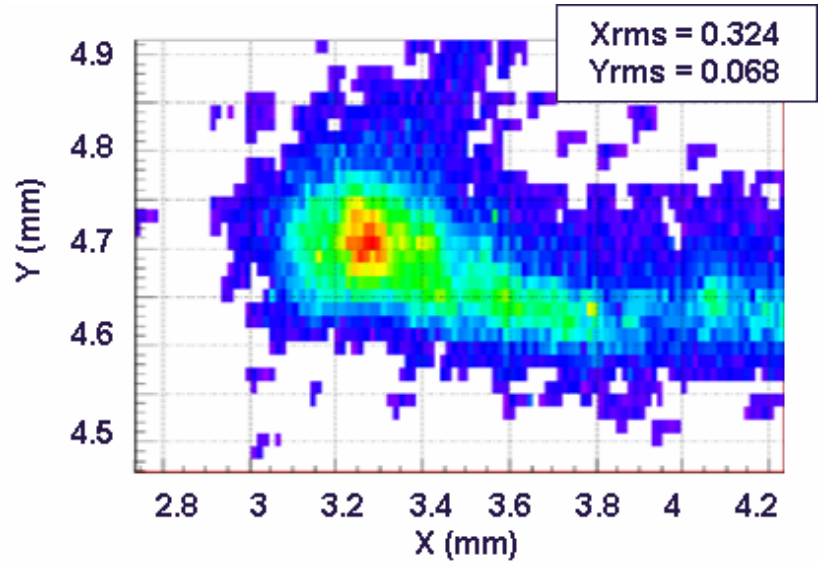
YAG screen viewed by 12 bits camera



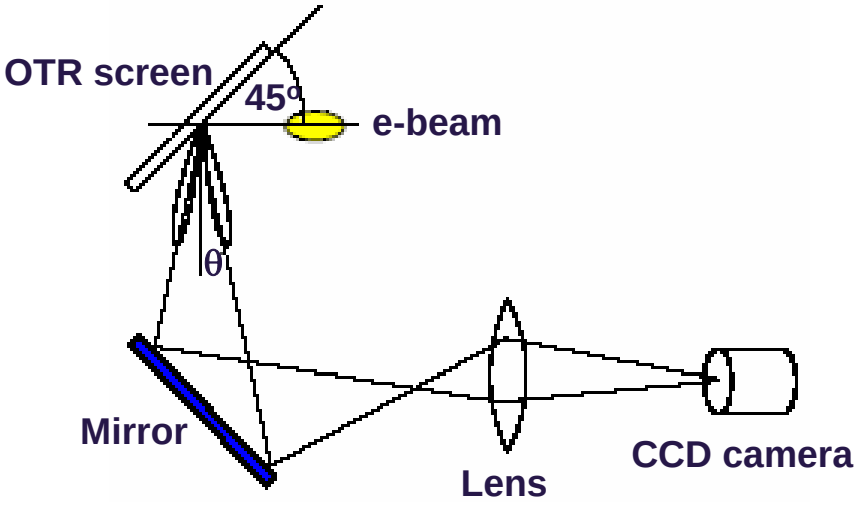
(measured by microscope)

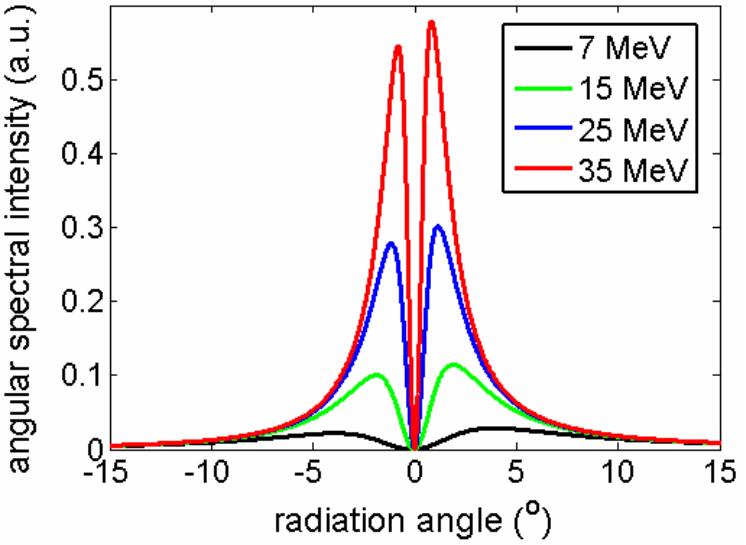
Resolution of beam image

- Beamlet image from 10 μm slit (03.06.2009)
  - Beam momentum ~14.7 MeV/c
  - Measured @ 1.76 m from slit position
- Detail structure of image ~50 μm
- Vertical RMS size <70 μm



Optical Transition Radiation (OTR) Screen

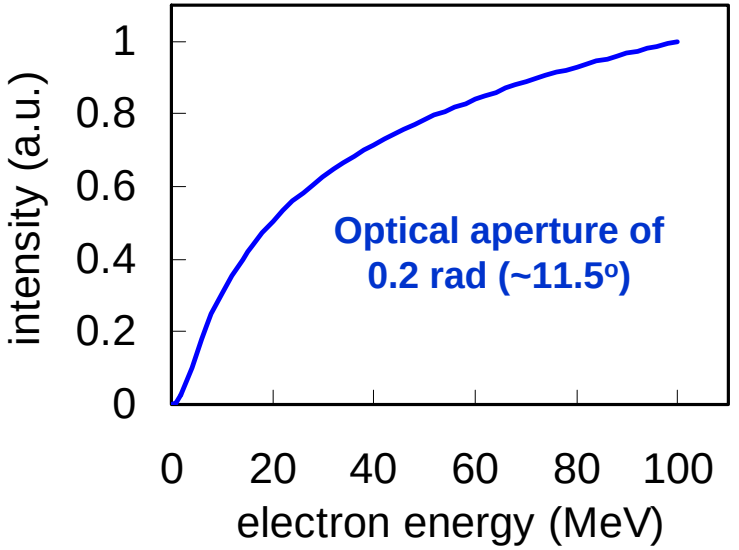




Material	Si-wafer with Al coating
Thickness of silicon wafer	100 or **275** μm
Incident angle	45°
Consider wavelength range	400 – 750 nm

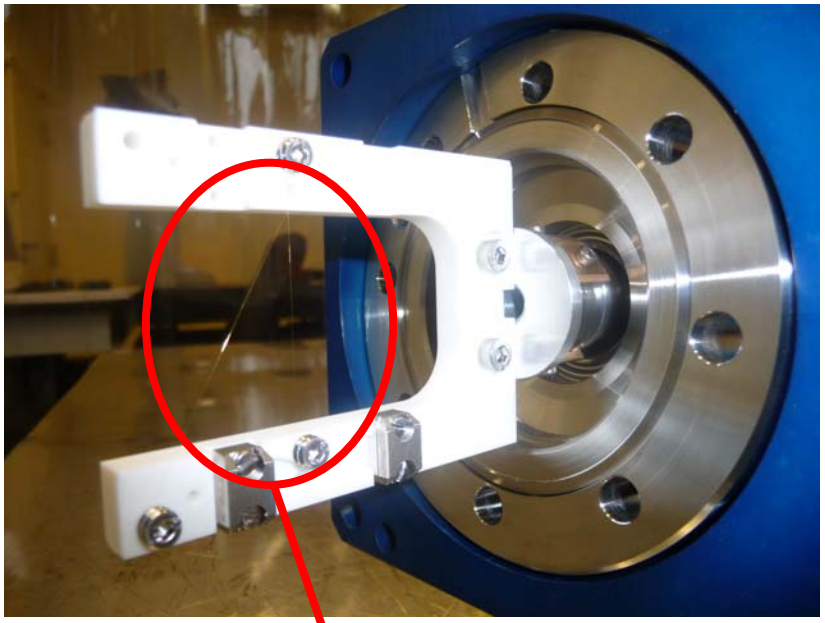
Beam energy increase from ~15 to ~25 MeV

- **Δ(energy) ~10 MeV**
- **Δ(intensity) ~40%**



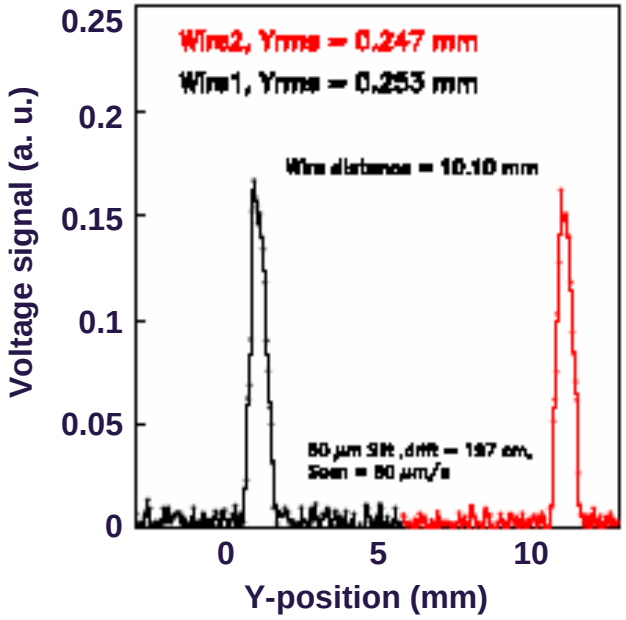
Wire Scanner (WS)

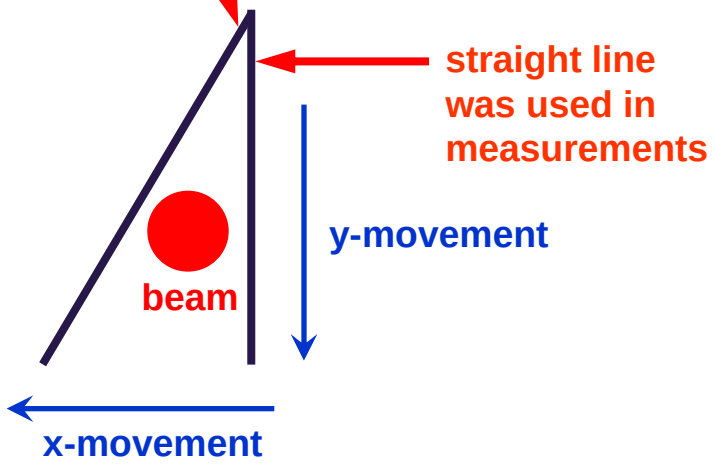
Wire material	tungsten
Wire size	20 μm
Average step size used in measurements	100 μm



Measured beamlet Y-profile from 50 μm slit

Measured with two straight wires (10 mm distance)

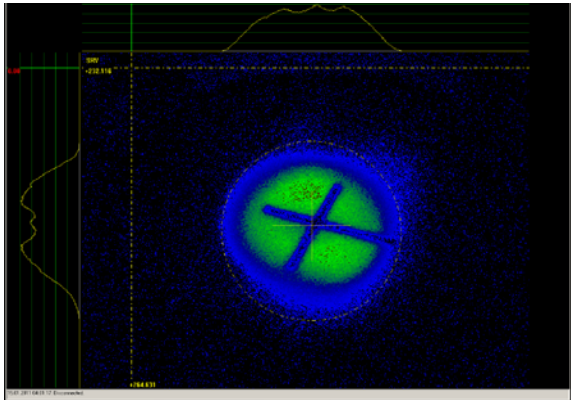


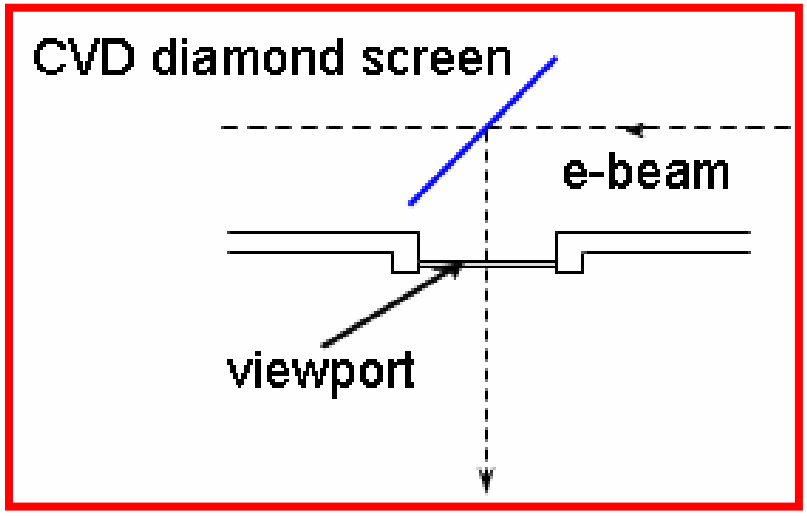


Reference: Grabosch, FEL2007

Chemical Vapour Deposition (CVD) Diamond Screen

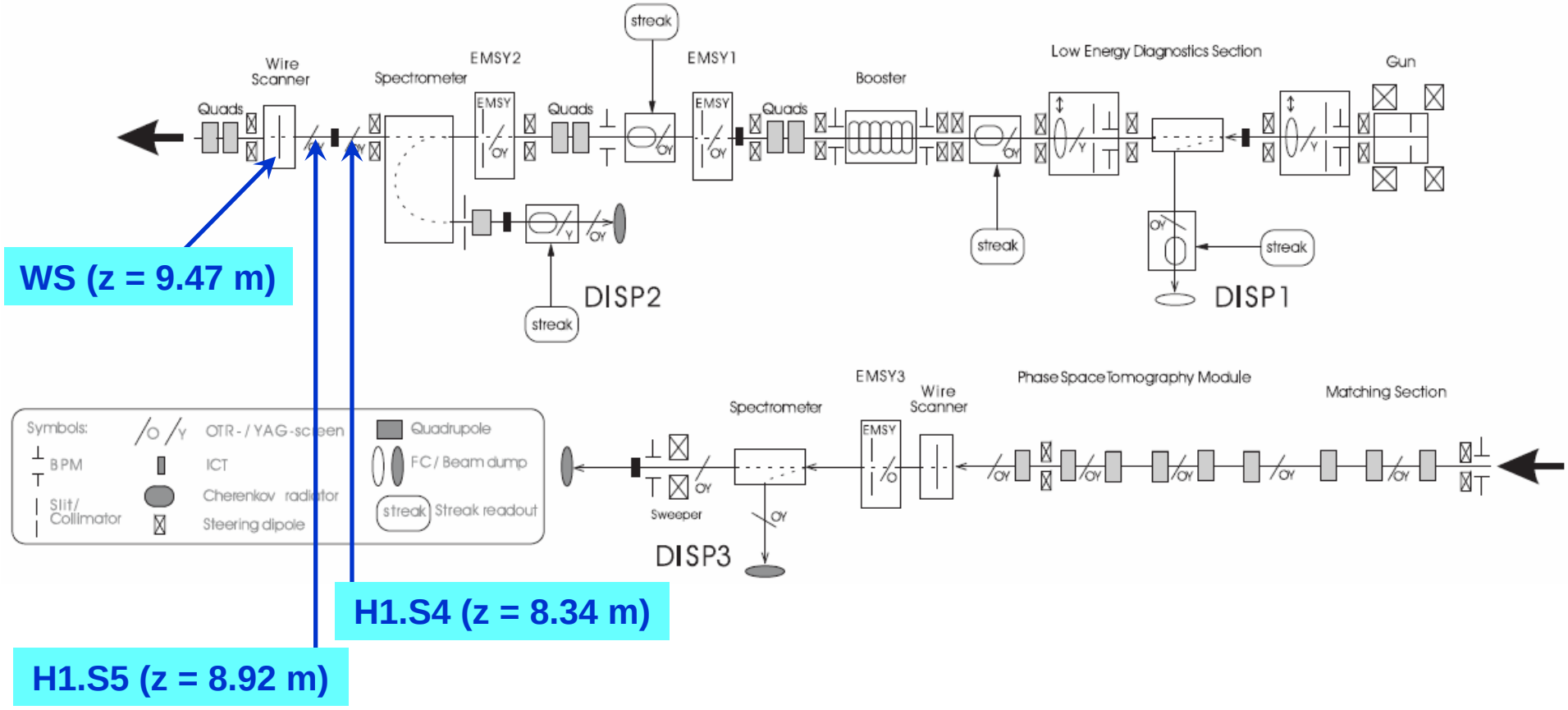
thickness	100 μm
diameter	30 mm
Incident angle	45°
High thermal conductivity	5 times higher than Cu
Emission wavelengths	415 – 478 nm



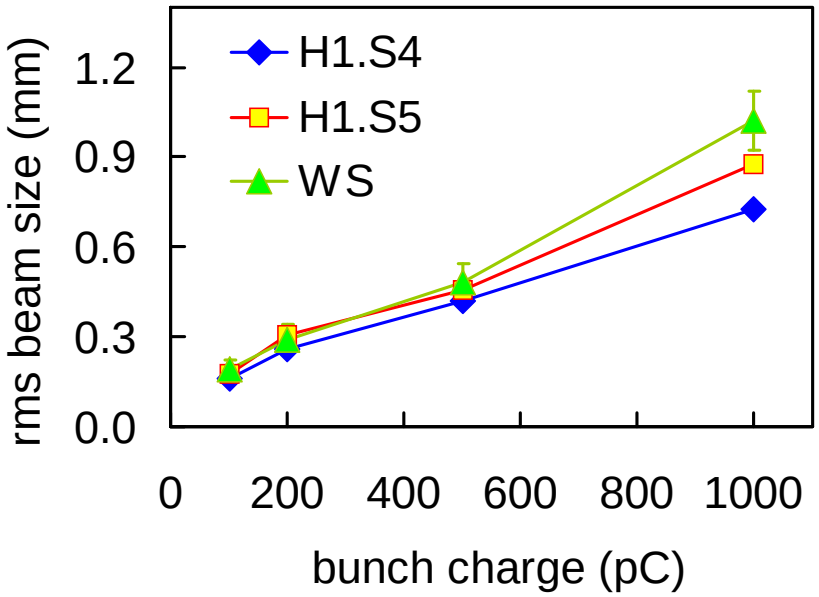


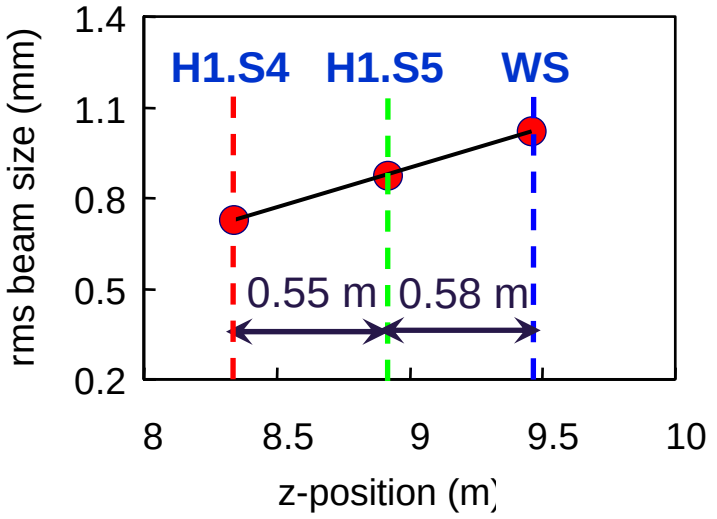
Reference: M. Degenhard, "CVD Diamond Screens for Beamline Diagnosis at PETRA III", not yet publish

Comparison of YAG screen and wire scanner (WS)



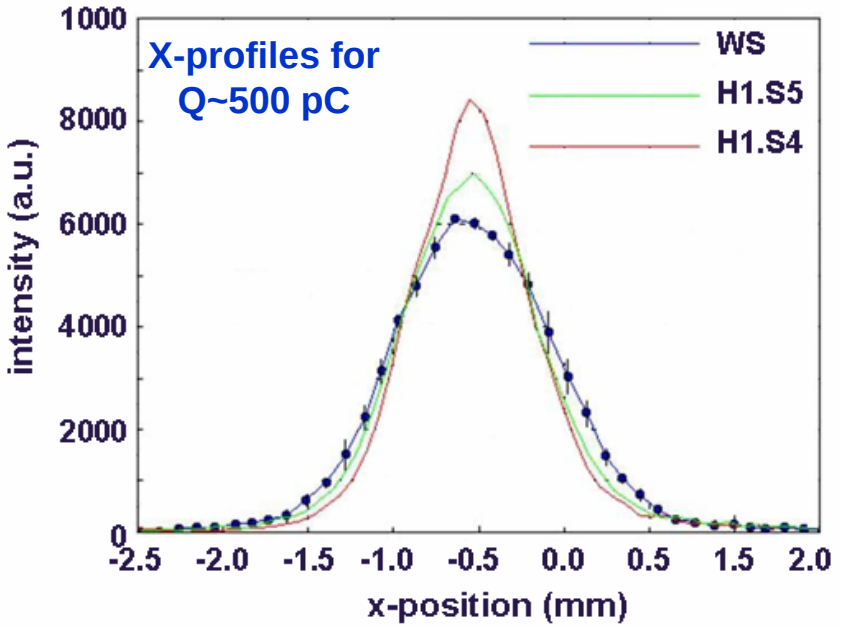
YAG screen and wire scanner (WS): beam size & profile



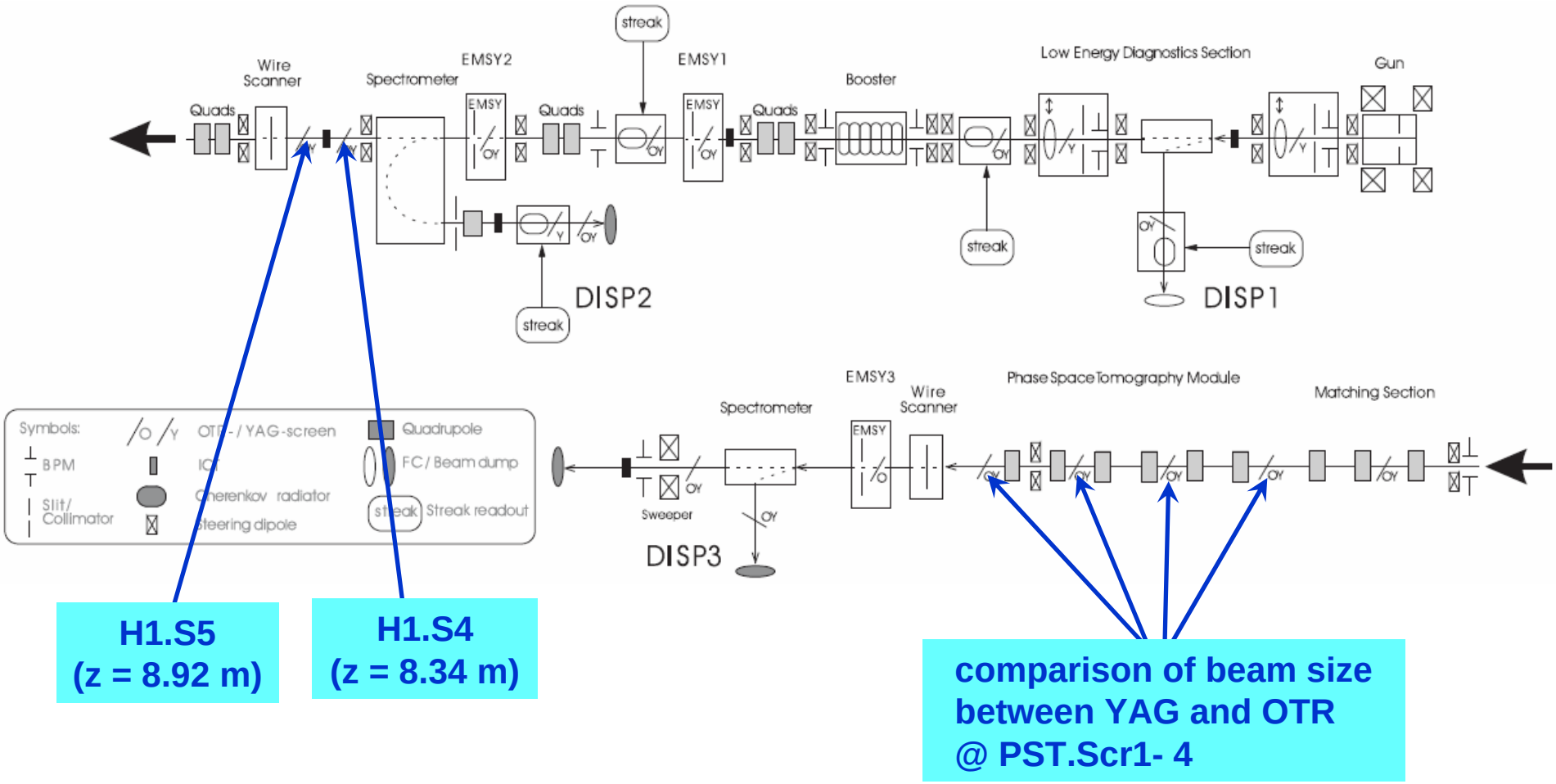


rms beam size: $\sigma_{xy} = \sqrt{\sigma_x \sigma_y}$

- **Fixed parameters:**
  - Momentum ~24.5 MeV/c
  - 1 bunch per train
  - Focusing (fixed main solenoid current)
  - Camera gain: 2 dB for H1.S4, 7 dB for H1.S5
- **Varied parameters:**
  - Bunch charge ~ 0.1, 0.2, 0.4, 0.6, 0.8, 1 nC

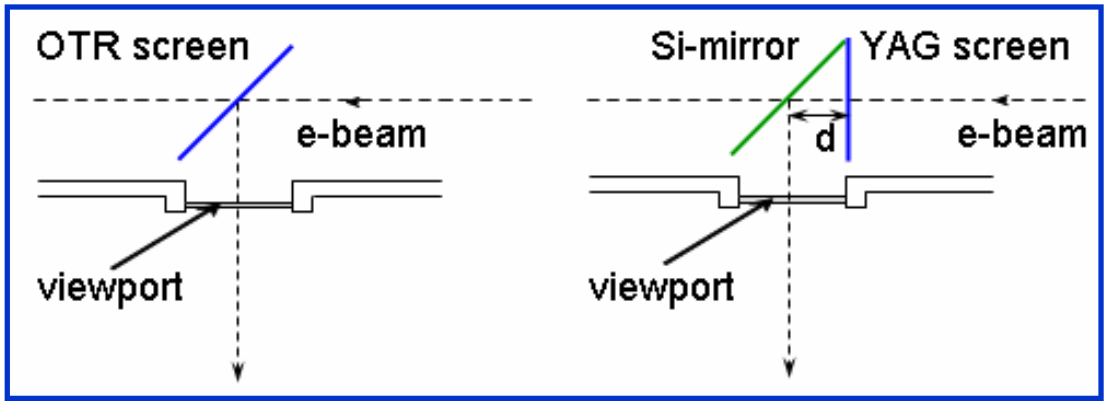


Comparison of YAG and OTR Screens



*** use 12 bit camera and adjusted camera gain and no. of pulses to have intensity a bit below saturation**

YAG and OTR screens: comparison of RMS beam size



RMS beam size: $\sigma_{xy} = \sqrt{\sigma_x \sigma_y}$

σ_{xy}: geometrical mean RMS size
σ_x: horizontal RMS size
σ_y: vertical RMS size

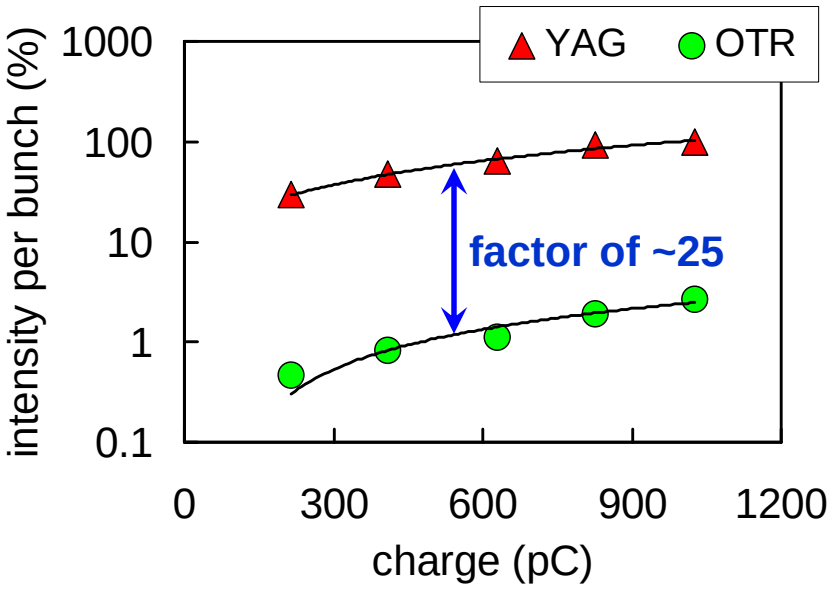
$$\delta\sigma(\%) = \left(\frac{\sigma_{YAG} - \sigma_{OTR}}{\sigma_{OTR}} \right) * 100\%$$

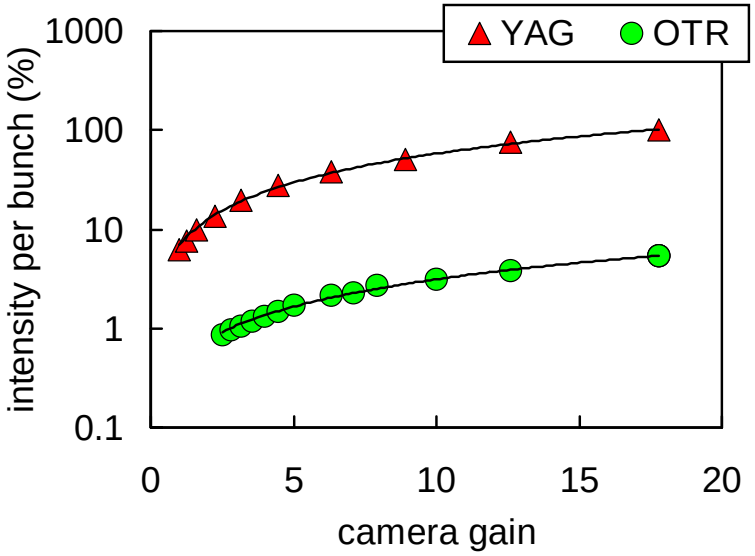
- **Included correction of different optical path length for YAG and OTR**
  - Not yet corrected for depth-of-field from 45° mounting configuration
- **Fixed parameters**
  - Momentum ~24.8 MeV/c
  - No. of bunch per train: 1
  - Camera gain
  - Focusing (solenoid & quadrupole)

$\langle\delta\sigma_x\rangle$ ~ 16.8%, $\langle\delta\sigma_y\rangle$ ~ 14.9%, $\langle\delta\sigma_{xy}\rangle$ ~ 15.8%

Screen station	YAG screen		OTR screen	
	σ_x (mm)	σ_y (mm)	σ_x (mm)	σ_y (mm)
PST.Scr1	0.342	0.280	0.304	0.244
PST.Scr2	0.246	0.229	0.210	0.201
PST.Scr3	0.245	0.266	0.204	0.226
PST.Scr4	0.290	0.257	0.246	0.228

YAG and OTR screens: comparison sensitivity





intensity per bunch = intensity per bunch per charge

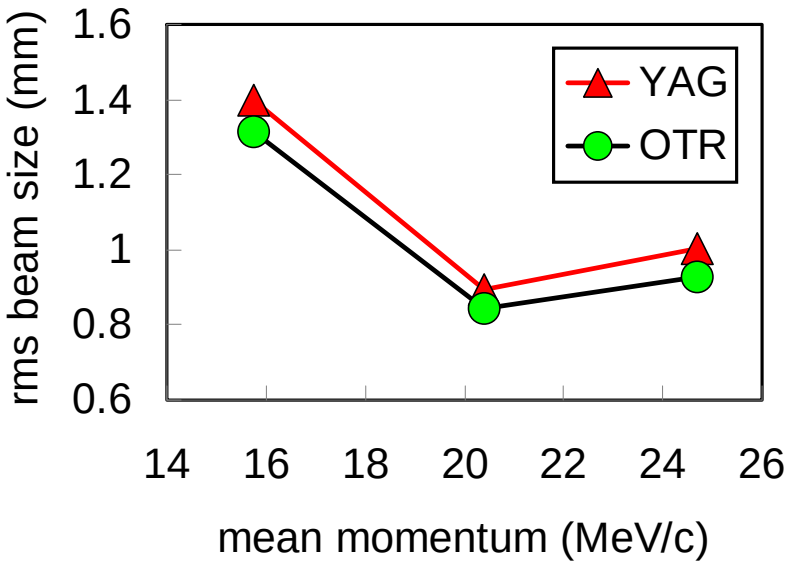
Intensity is linearly proportional to bunch charge

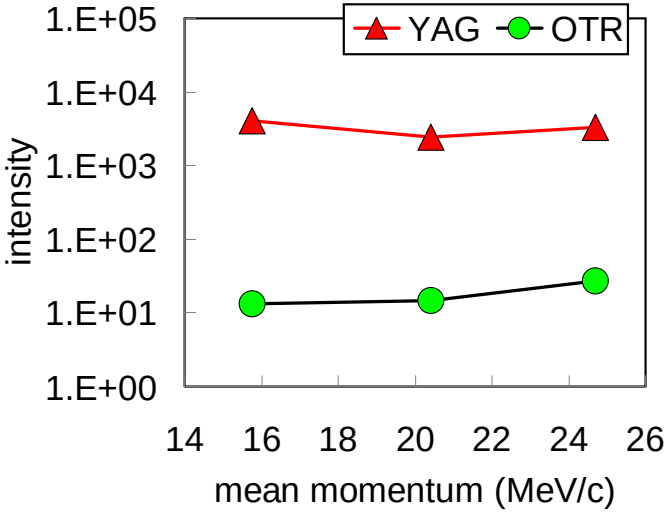
- Measured @ H1.S4
- Fixed parameters:
  - Momentum ~24.8 MeV/c
  - Camera gain: 2 dB
- Varied parameters:
  - No. of bunches per train
  - Focusing (adjusted solenoid current to have the same beam area)

Intensity is linearly proportional to camera gain

- Measured @ H1.S5
- Fixed parameters:
  - Momentum ~24.8 MeV/c
  - Bunch charge: YAG (200 pC), OTR (1 nC)
- Varied parameters:
  - Camera gain
  - No. of bunches per train
  - Focusing

YAG and OTR screens: dependence on momentum





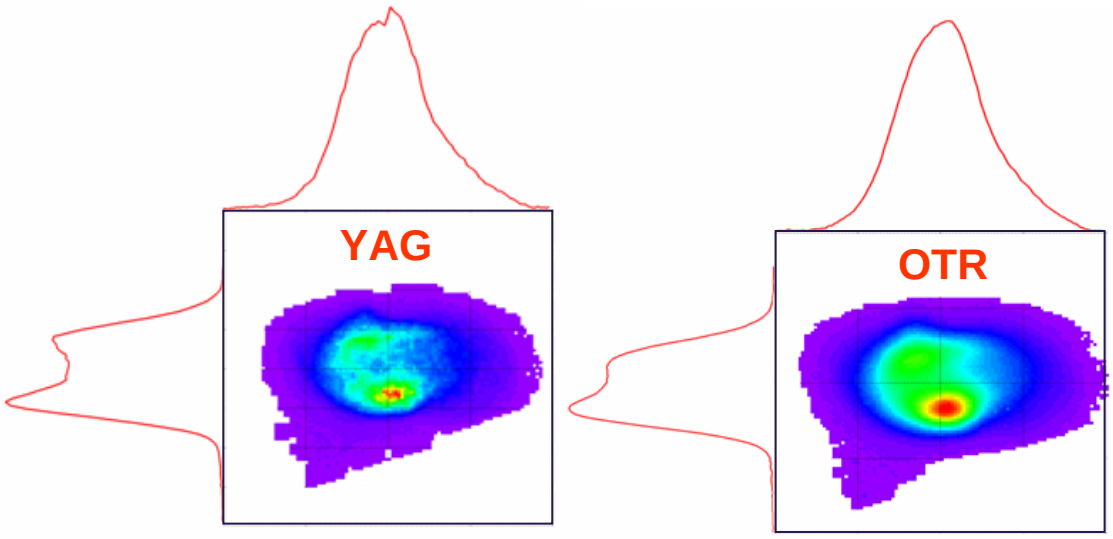
RMS beam size: $\sigma_{xy} = \sqrt{\sigma_x \sigma_y}$

Intensity = integrating intensity per bunch per beam area per charge

RMS beam size and intensity vs. momentum @ H1.S5

- Included correction of beam size due to different optical path length
- Varied parameters:
  - No. of bunches per train
  - Bunch charge per train: YAG (200 pC), OTR (1 nC)
  - Camera gain
  - Focusing (solenoid current)

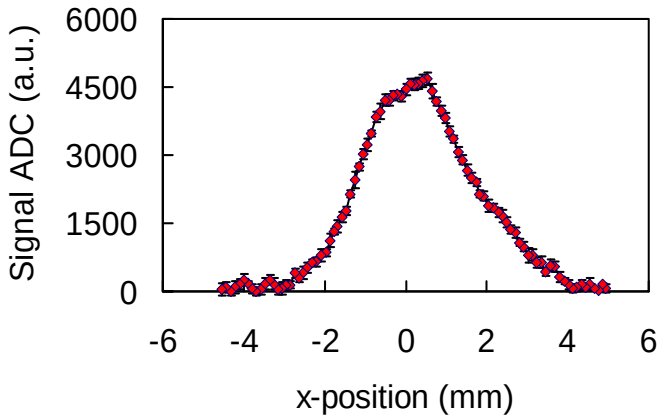
YAG and OTR screens: intensity distribution & projection profiles

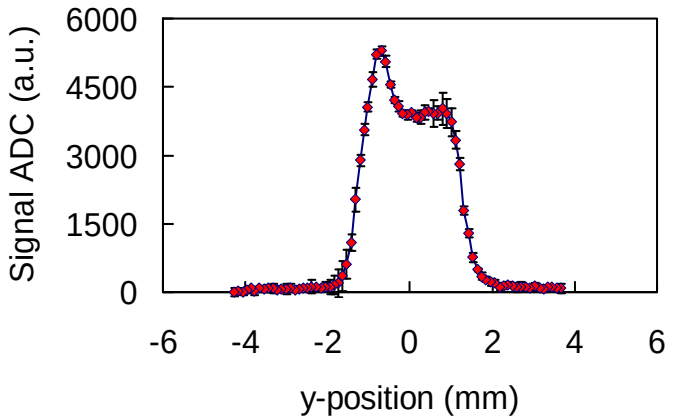


YAG screen shows more detail structure of the beam image & profile (OTR: smoothing image and profiles)

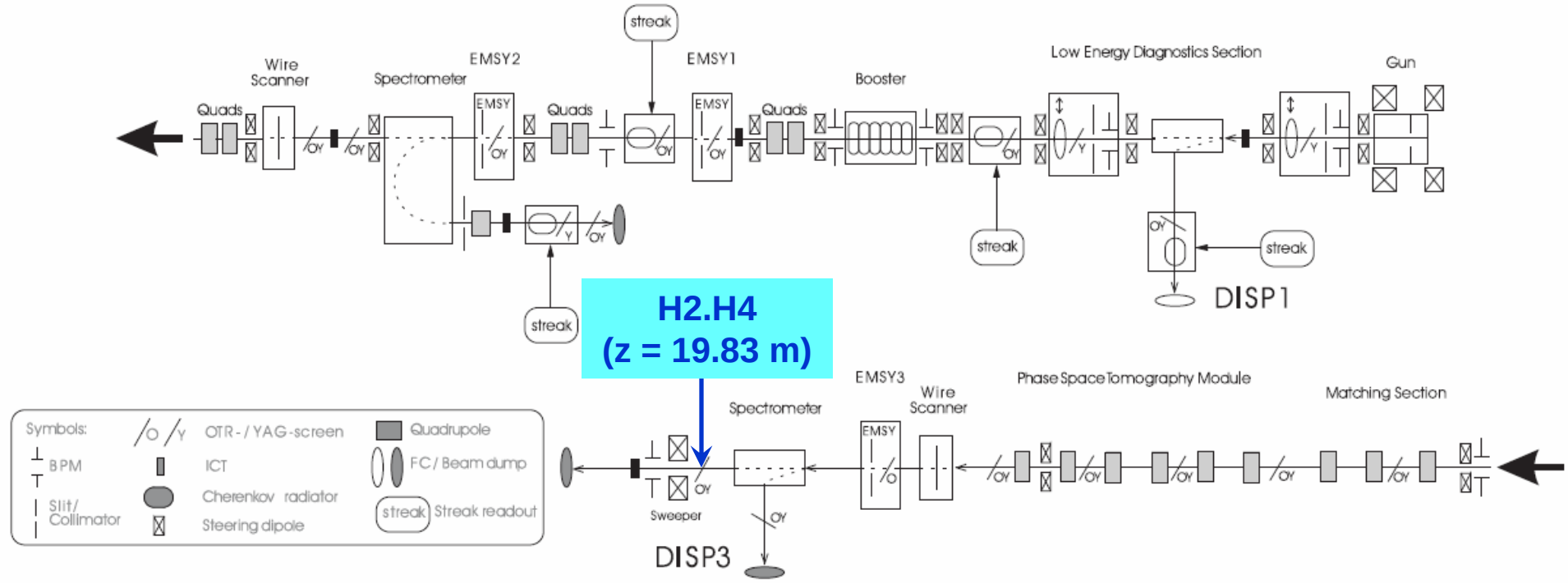
- **Fixed parameters:**
  - Momentum ~24.5 MeV/c
  - Bunch charge: 1 nC
  - Focusing
  - Camera gain: 1 dB
- **Varied parameters:**
  - No. of bunches per train
    - → YAG: 1 bunch
    - → OTR: 24 bunches

wire scanner profiles

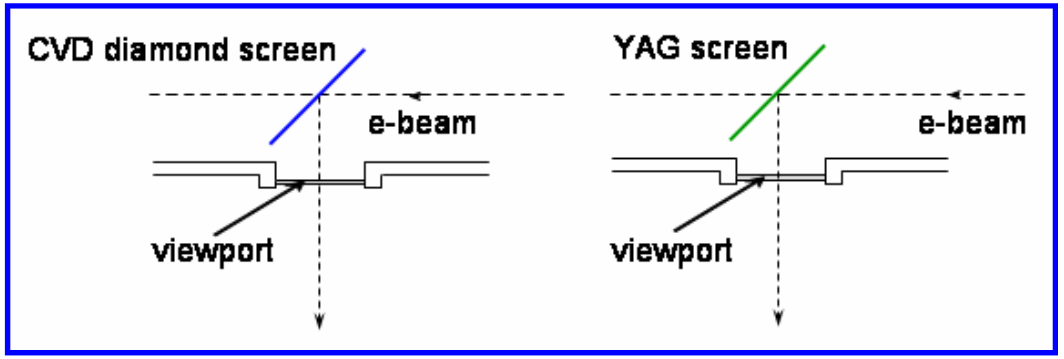




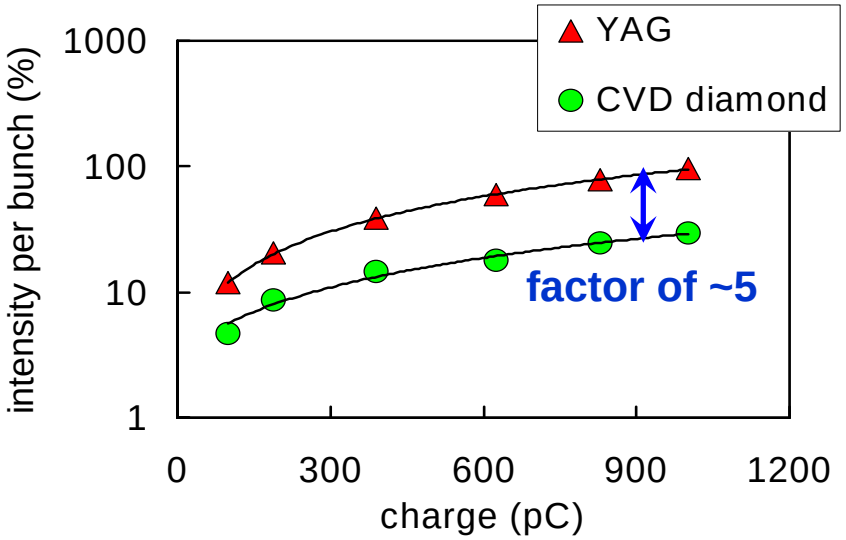
Comparison of YAG and CVD diamond Screens

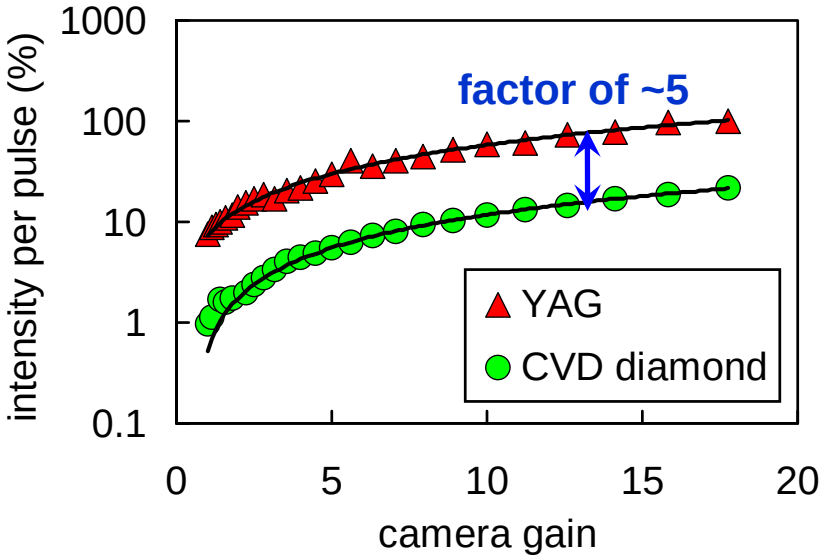


Optical system is not yet optimized: measured beam size value was not yet reliable



YAG and CVD diamond screens: sensitivity

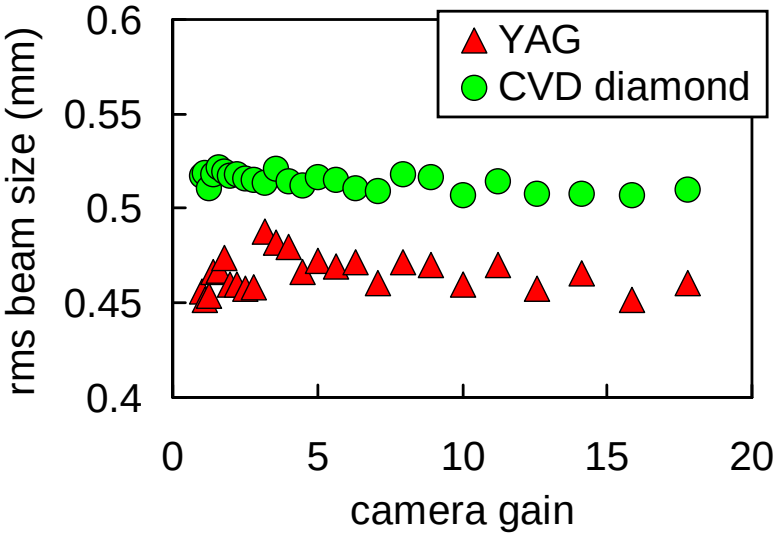




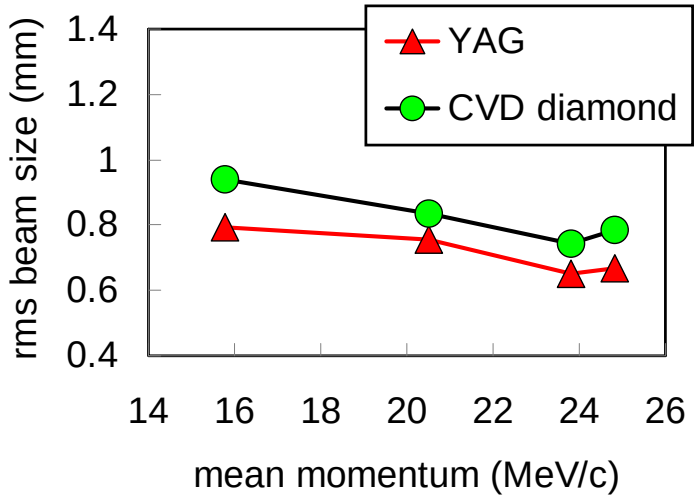
Integrating intensity vs. bunch charge @ H2.S4

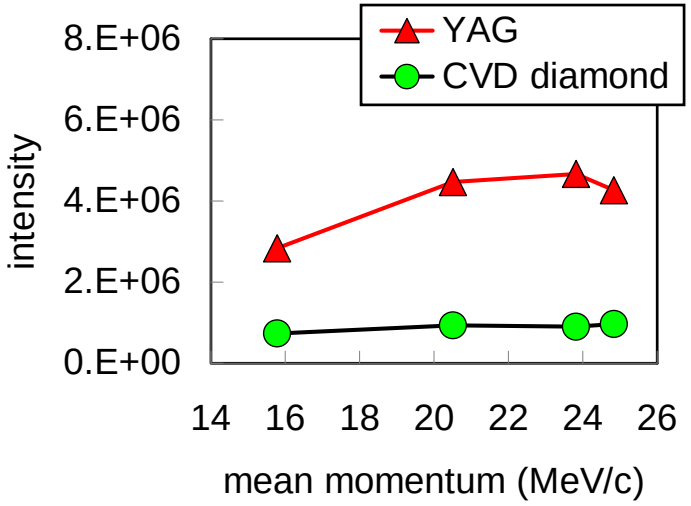
- Fixed parameters:
  - Momentum ~24.8 MeV/c
  - Camera gain: 20 dB
- Varied parameters:
  - No. of bunches per train
  - Focusing

$$\delta\sigma = \left(\frac{\sigma_{YAG} - \sigma_{CVD-diamond}}{\sigma_{CVD-diamond}} \right) \approx 36\% \quad ?$$



YAG and CVD diamond screens: dependence on momentum

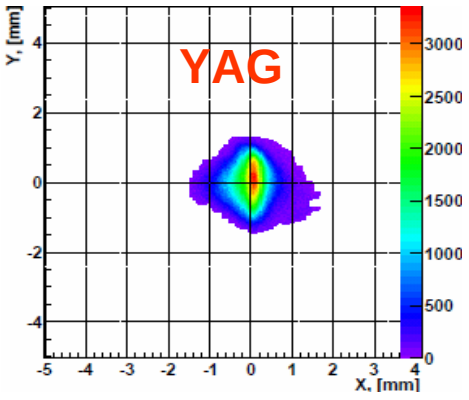


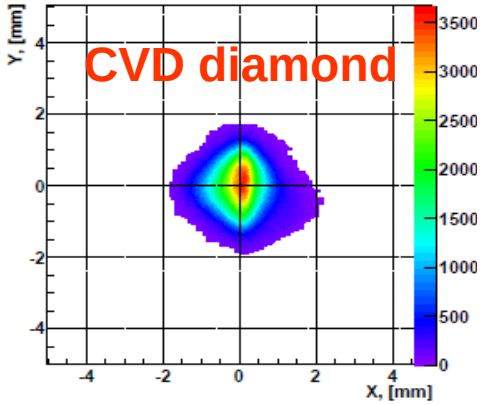


Intensity = integrating intensity per bunch per beam area

RMS beam size vs. beam momentum @ H2.S4

- Fixed parameters:
  - Momentum: ~24.8 MeV/c
  - Bunch charge: 1 nC
  - Camera gain: 20 dB
- Varied parameters:
  - No. of bunches per train: YAG (1 bunch), CVD diamond (5 bunches)
  - Focusing (solenoid)





CVD diamond screen has more smoothing image and profiles

Summary & Outlooks

- Properties of YAG powder coating, OTR and CVD screens @ PITZ were summarized
- Test results of different screen type were presented
  - Sensitivity: **YAG > CVD diamond > OTR**
  - OTR provided smaller RMS beam size than YAG

Screen	Sensitivity	RMS beam size
YAG	100 %	100 %
OTR	4 %	84 %
CVD diamond	20 %	to be investigated

- Experimental tests to compare RMS beam sizes and beam profiles from wire scanner and from YAG screen at two locations were performed with different bunch charges
  - Results showed good agreement for both beam size and projection profiles

Acknowledgements

- G. Asova for data taken at the tomography module
- Y. Ivanisenko and G. Vaschenko for information and discussions about optical systems
- PITZ members

Thank you for your attention !