Instrumentation for HiRadMat Experiments

S.Burger BE-BI-PM

BI Day - Best Western/Chavannes de Bogis (CH)
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Thanks to the colleagues:
M.Bergamaschi (BE-BI), Aymeric Bouvard (EN-EA), E.Bravin (BE-BI), V.Clerc (EN-EA), A.Fabich (EN-EA), A.Goldblatt (BE-BI), A.Guerrerro (BE-BI), JJ.Gras (BE-BI), L.Jensen (BE-BI), K.Kessi (BE-BI), S.Mazzoni (BE-BI), C.Rinaldi (BE-BI), F.Roncarolo (BE-BI), A.Sounas (BE-BI), T.Lefevre (BE-BI), G.Trad (BE-BI), etc...
& OP-SPS team !!

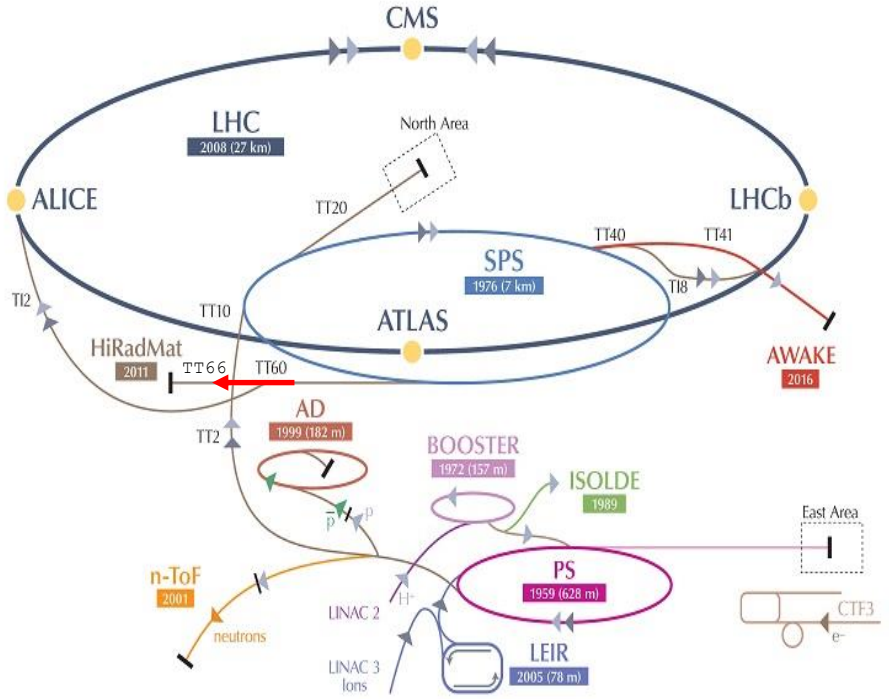
Content

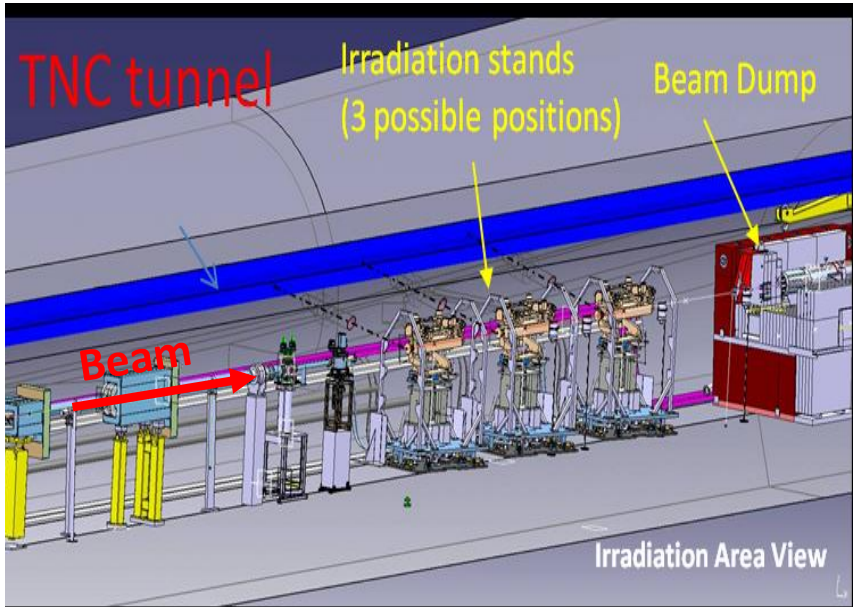
- What is HiRadMat (HRM) ?
- HRM Layout
- Combined instrumentation: BTV/BPKG
  - BPKG principle
  - BTV description
  - Performance
- Ongoing development of a new BTV for HRM
- Conclusion

What is HiRadMat (HRM) ?

The High Radiation to Materials facility - hereafter HiRadMat - was designed for testing accelerator components, in particular those of the LHC and its injectors, with the impact of high-intensity pulsed beams

"HiRadMat is **not** an irradiation facility where large doses on equipment can be accumulated. It is rather **a test area** designed to perform single experiments to evaluate the effect of high-intensity pulsed beams on materials or accelerator component assemblies in a controlled environment."





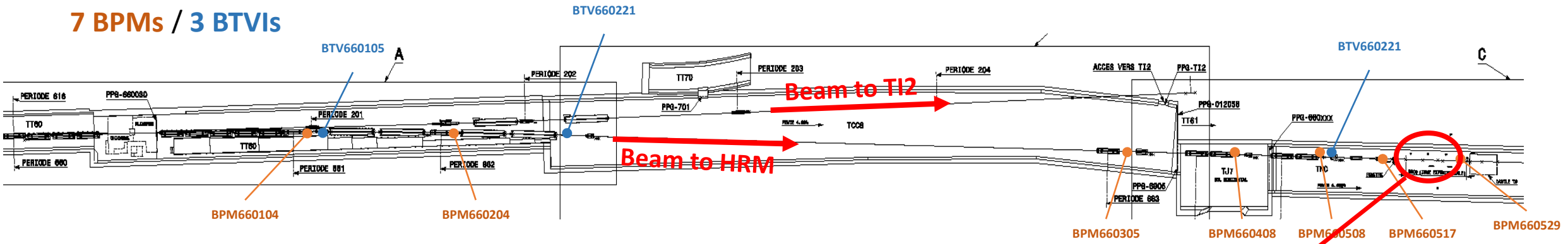
HiRadMat beam specs	
Beam Energy	440 GeV
Pulse Energy	up to 3.4 MJ
Bunch intensity	3E9 to 1.7E11 p
Number of bunches	1 to 288
Maximum pulse intensity	4.9E13 p
Bunch length	11.24 cm
Bunch spacing	25, 50, 75 or 150 ns
Pulse length	7.2 µs
Minimum cycle length	18 s
Beam size at target	0.1 to 1.5mm (σ)

https://espace.cern.ch/hiradmat-sps/Wiki%20Pages/Home.aspx

HiRadMat Layout

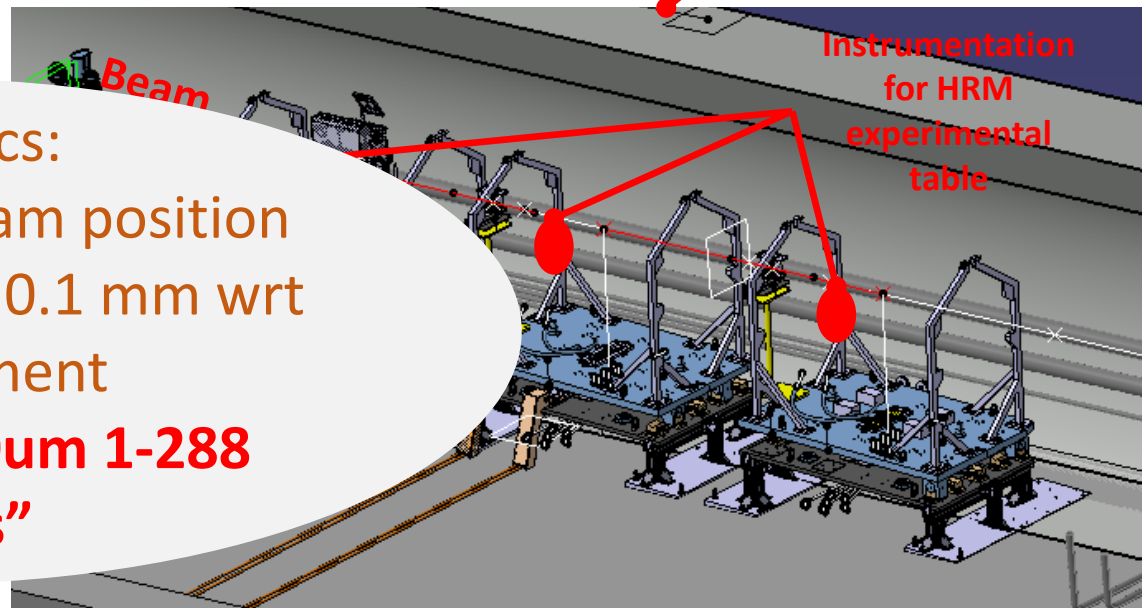
HiRadMat
High-Radiation to Materials

7 BPMs / 3 BTVIs



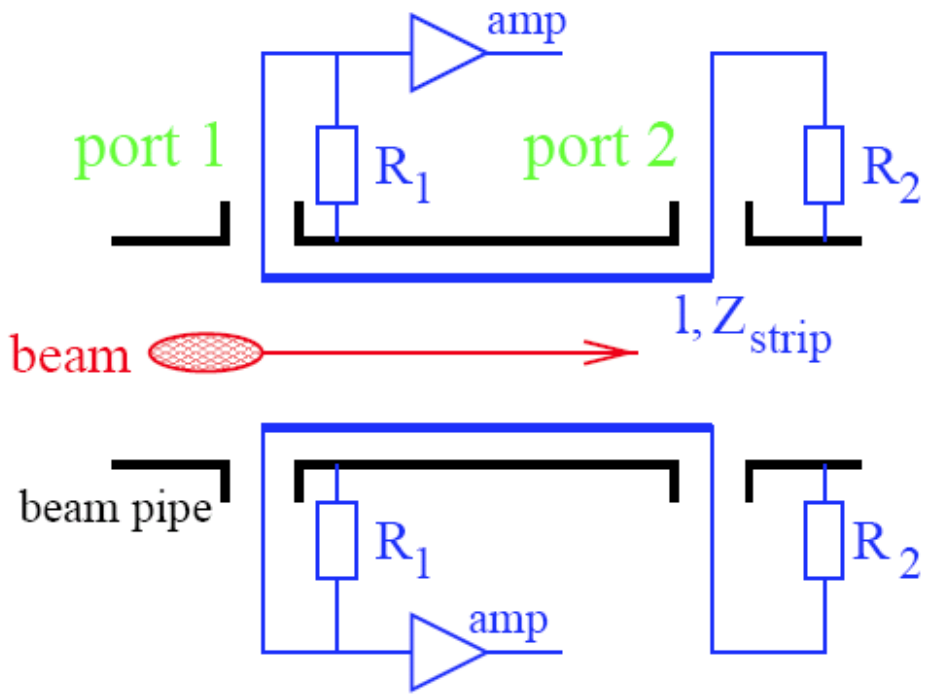
Experimental tables

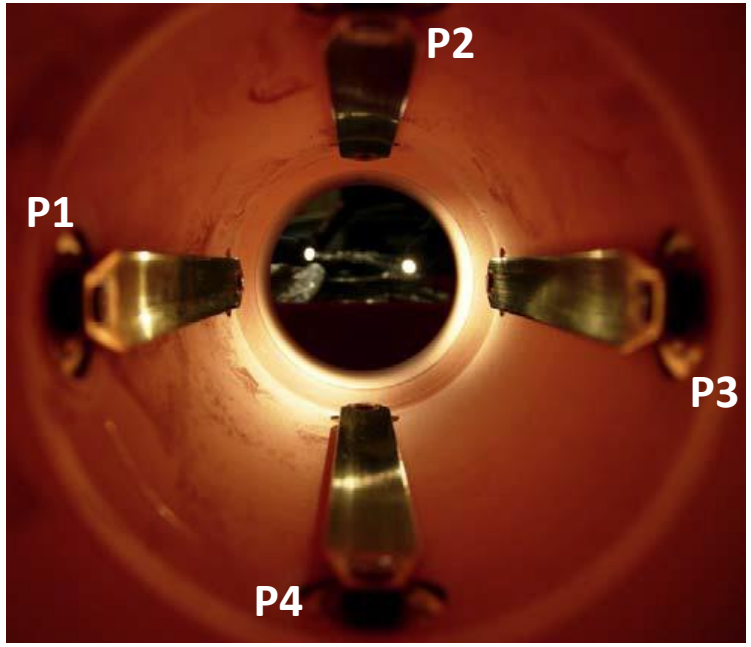
Main specs:
Determine the beam position with a precision of 0.1 mm wrt the experiment
“Beam size >200um 1-288 bunches”



Combined instrumentation: BTV/BPKG: BPM principle

BPM strip lines description (BPKG)





4 insulated strip lines sensitive to charged particles passage
→ Beam position H & V giving by:

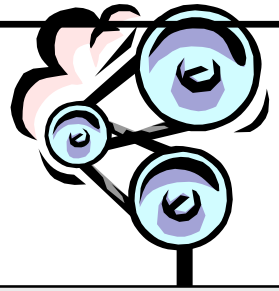
$$\text{Pos H} = Kx.\frac{P1-P3}{P1+P3} + x_{offset}$$

$$\text{Pos V} = Ky.\frac{P2-P4}{P2+P4} + y_{offset}$$

Combined instrumentation: BTV/BPKG: BTV description

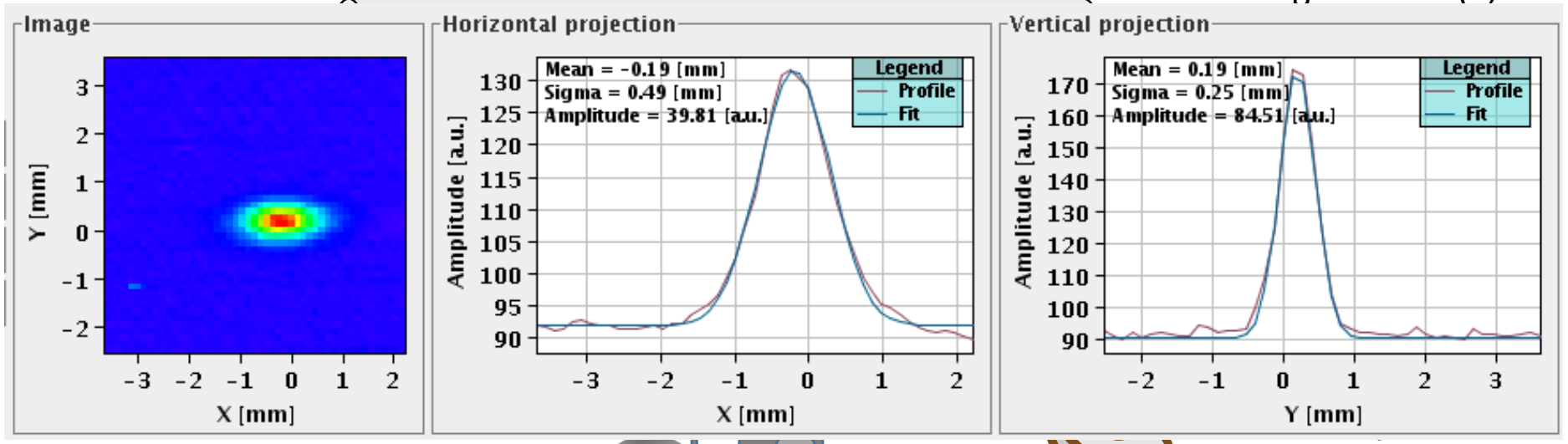
Insertion device

Holding an
in-vacuum radiator



Radiator

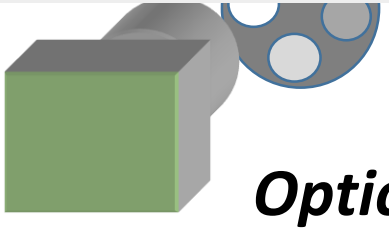
Can be scintillating (Al_2O_3, ZrO_2 etc…) or reflecting material (C,



calibration and
beam steering

Camera

Can be standard CCD or special Rad hard (CMOS, CID, Vidicon tube)

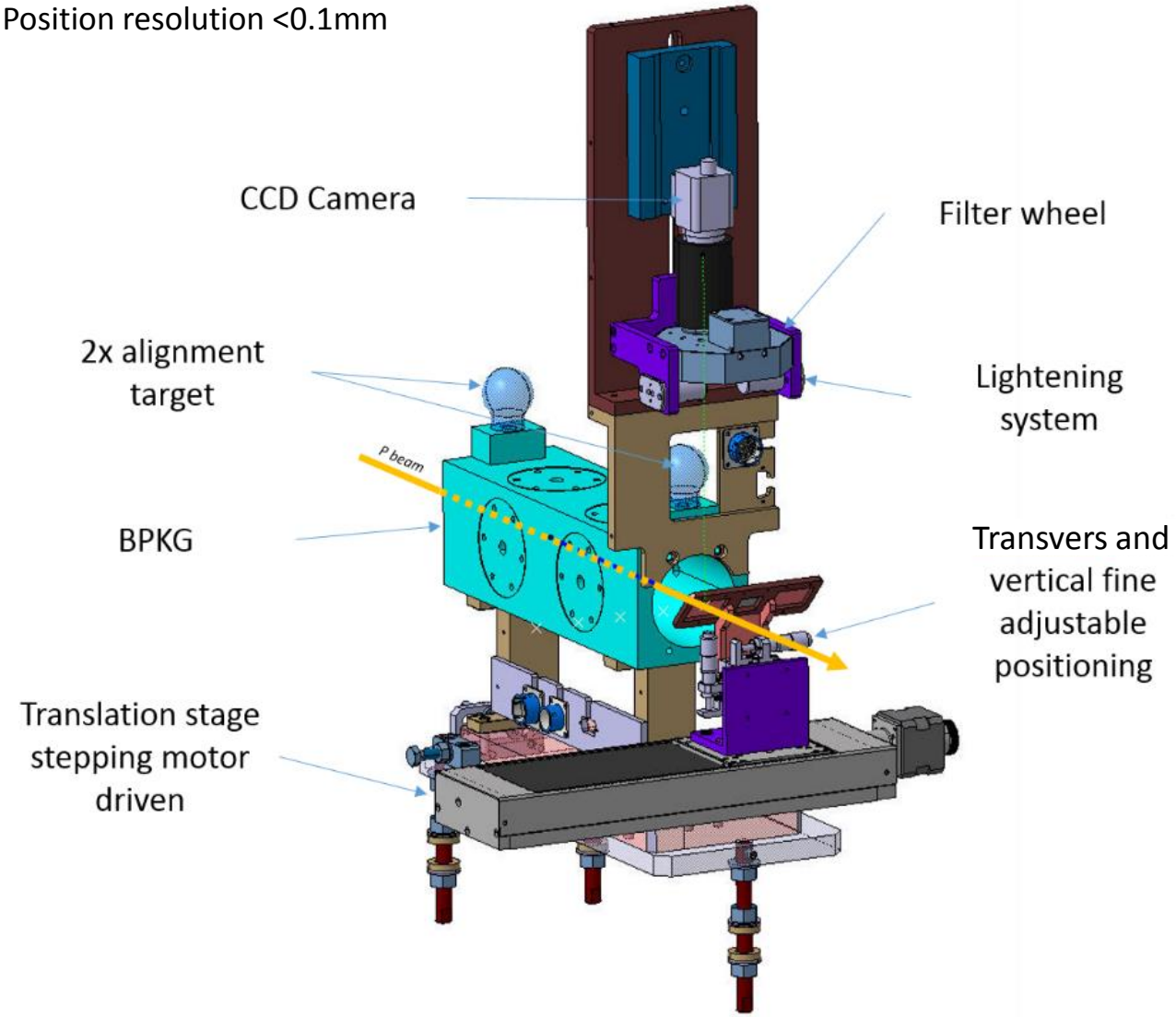


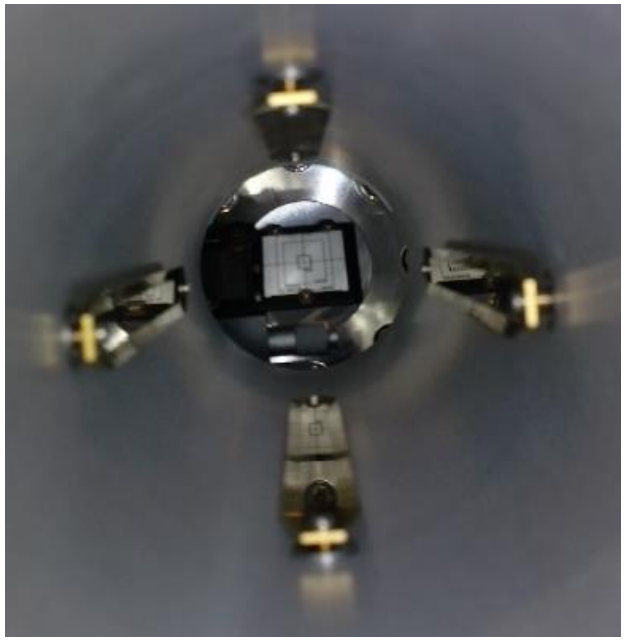
Optical density filters

Can be added in front of the camera to increase the dynamics of the system

Combined instrumentation: BTV/BPKG: Design

- BPKG gives a permanent non invasive beam position measurement for each extraction to be correlated with the HiRadMat experiment.
- BTV is used to define BPKG offsets (+ first tests for profile measurement)
- Position resolution <0.1mm





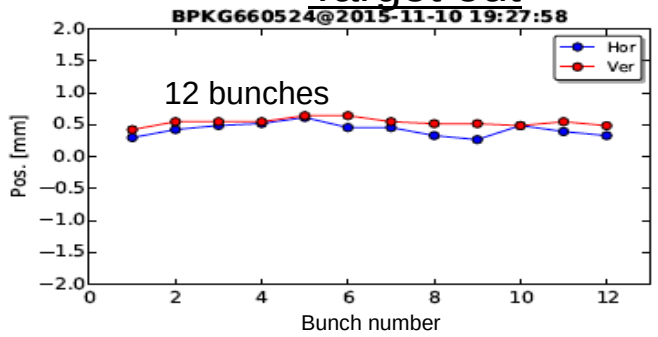
Strips of the BPKG and BTV screen at the back

Al2O3:CrO2, SiC and Al2O3 (target) screens

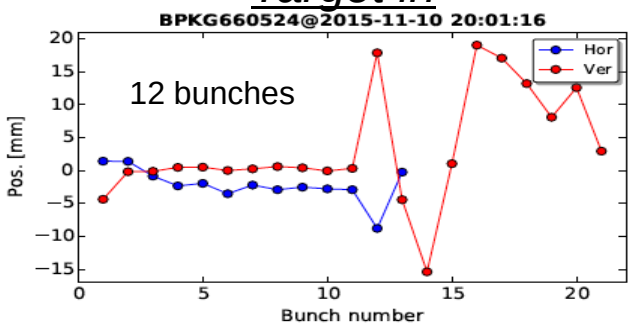
BTV/BPKG performance (2)

BPKG reading improvement

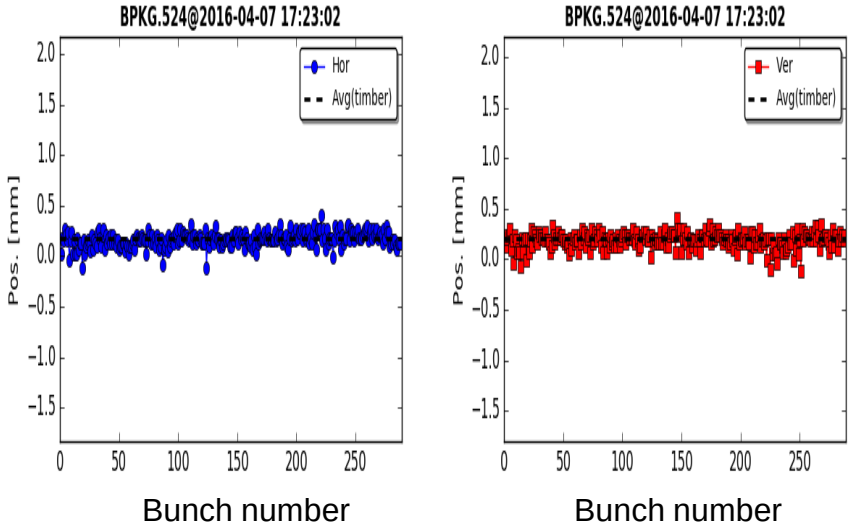
Target out



Target in



- Strong perturbations coming after the first 11 bunches
- Seen on all BPMs down to the BPM408 in TJ7
- Perturbations compatible with backscattered shower affecting the electronic → *Confirmed by time of flight (275ns → 82.5m !)*
- *Relocation of BPM electronic in less exposed area during EYETS 15-16*



→ **Noise from radiation effects still occurs using high Z materials (further improvements are under investigation)**

→ **Resolution given between 50 – 100 um**

BTV/BPKG performance (2)

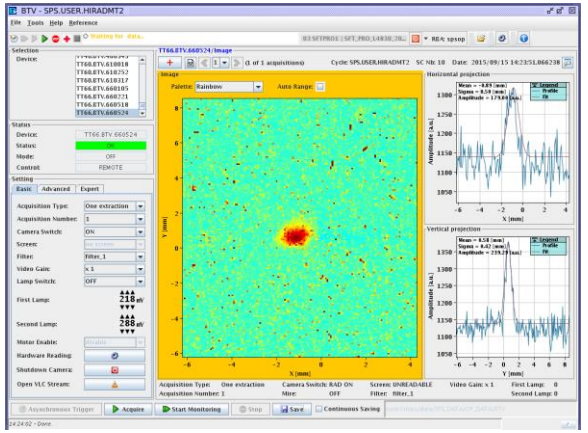
→ **Use of scintillating screens:**

- to delay the acquisition on the decay time of the scintillation
  above a few E12p/mm2 → non linearity
- for low intensity beam
  above 1E13p/mm2 → damage

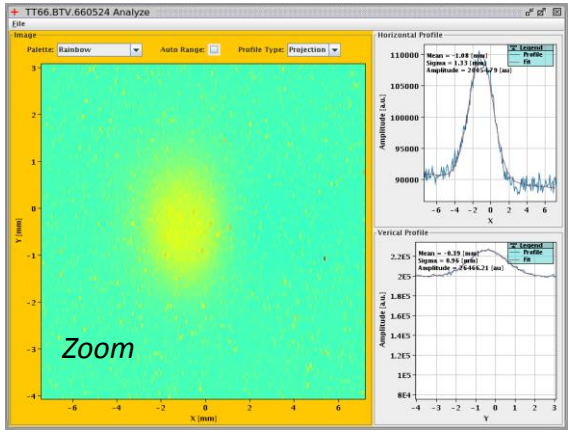
→ **Use of OTR screens** is limited as acquisition must be synchronized with beam (backscattering particles gives high background on camera !)

→ **Can not be used above 12 bunches (not made for anyway)**

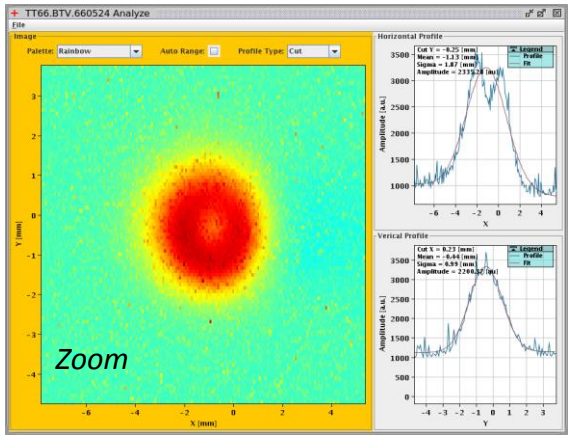
→ **Works fine for BPKG offset setup up**



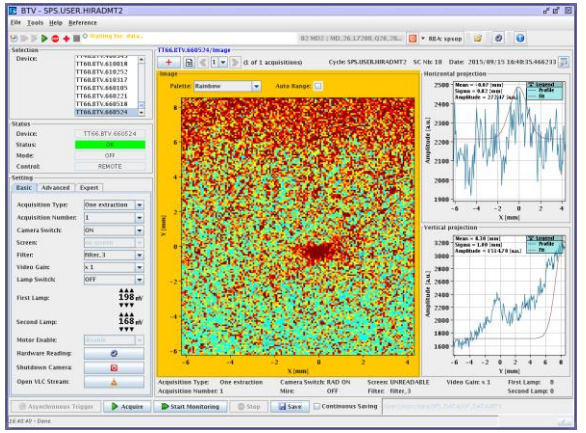
Single bunch (1E11p)
Al2O3 screen



12 bunches (1.2E12p)
Al2O3 screen
T 0.1%
Delay 60ms



24 bunches (2.4E12p)
Al2O3 screen
T 100%
Delay 280ms



12 bunches (1.2E12p)
SiC screen
T 0.001%

BTV/BPKG performance (2)

Results with the BTV/BPKG motivated the request to have reliable profile measurements of all beam extractions for OP & HRM users!!

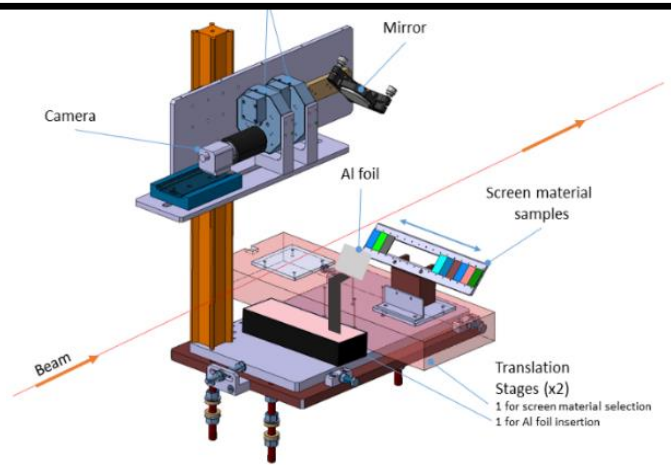
→ Need for **screen** and **optical line** studies…

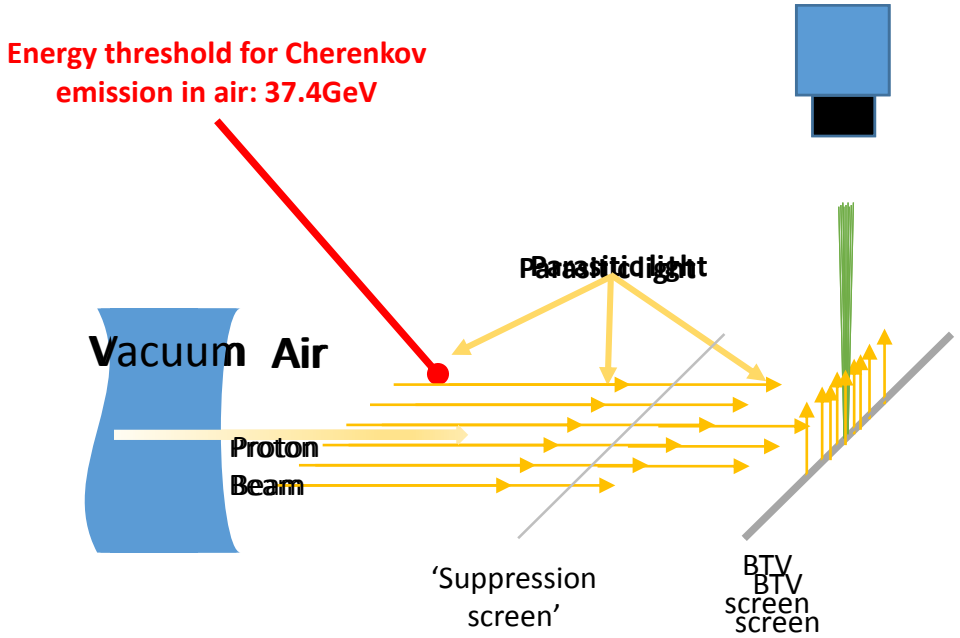
Ongoing development of a new BTV for HRM (1)

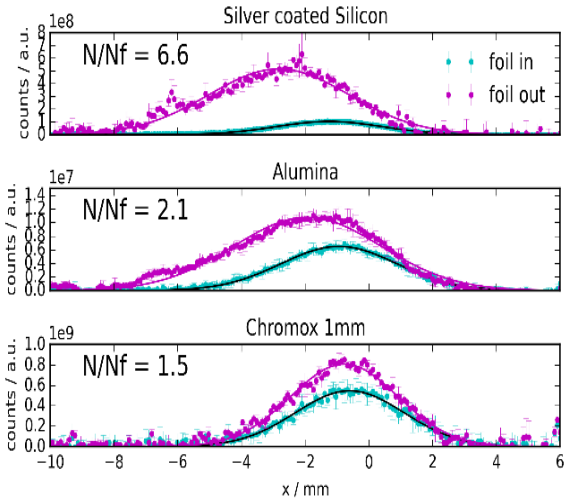
Study of the screen performance* as an experiment in HRM shows:

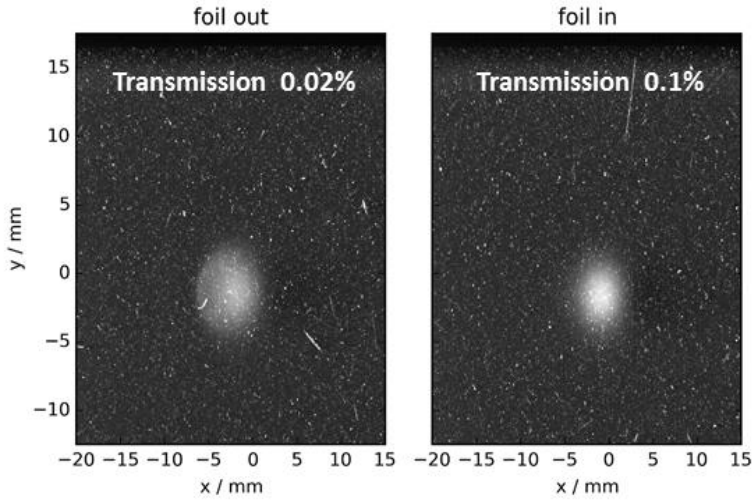
→ Unexpected light emission (Cherenkov) that perturbs the measurements

- *Larger beam size*
- *non linearity*
- *screen reflectivity dependency*









Silver coated Si OTR screen without (left) and with (right) blocking foil in place. The change of intensity as well as beam size is clearly visible.

*** SCINTILLATION AND OTR SCREEN CHARACTERIZATION WITH A 440 GEV/C PROTON BEAM IN AIR AT THE CERN HIRADMAT FACILITY**

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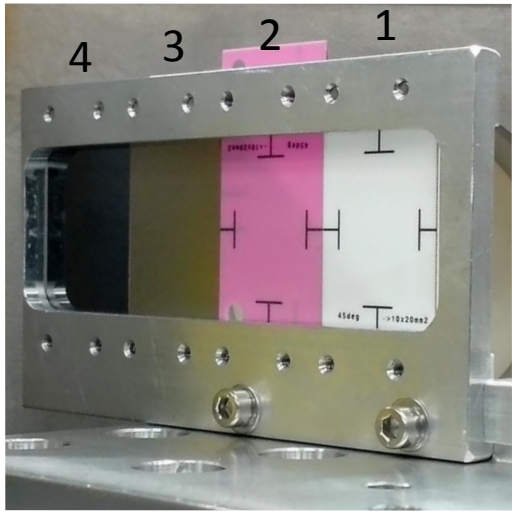
[1]also at Czech Technical University, Prague, Czech Republic
[2]also at Graz University of Technology Theoretical Physics Institute, Vienna, Austria

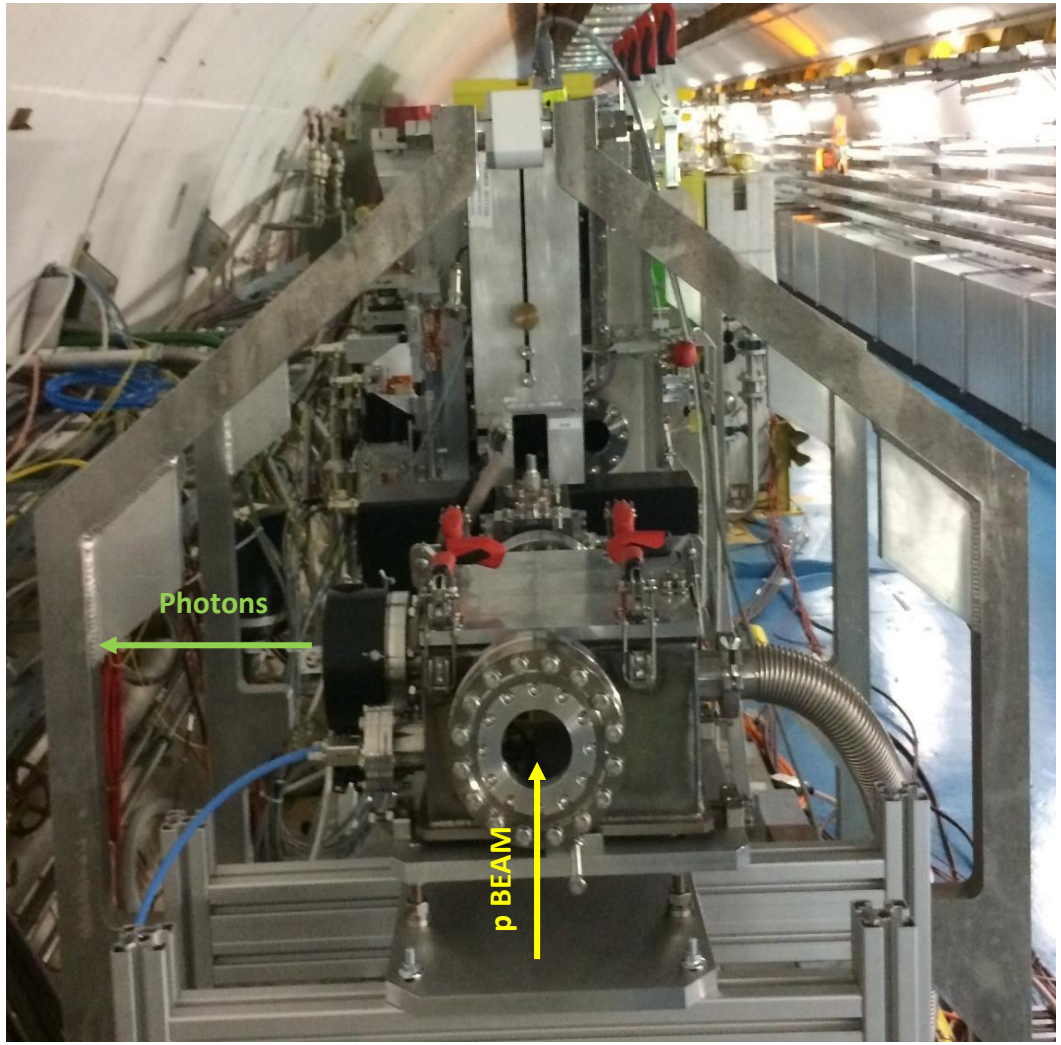
Ongoing development of a new BTV for HRM (2)

→ Screen in vacuum
(primary vacuum <7mbar for 440GeV particles)

→ Resisting to the max beam power (density) → **polished amorphous SiC**



New HRM BTV screen setup				
Position	**Material**	**Size [mm2]**	**Thickness [mm]**	**Fonction**
1	Al2O3	10x20	1	- Calibration reference - Measure low int. < 1E12p / mm2
2	Al2O3:CrO2	10x20	0.5	- Measure int. < 1E13p / mm2
3	Ti	10x20	0.1	- Measure int. < 1E14p / mm2
4	SiC (amorphe)	10x20	0.5	- Measure high int. > 1E14p / mm2

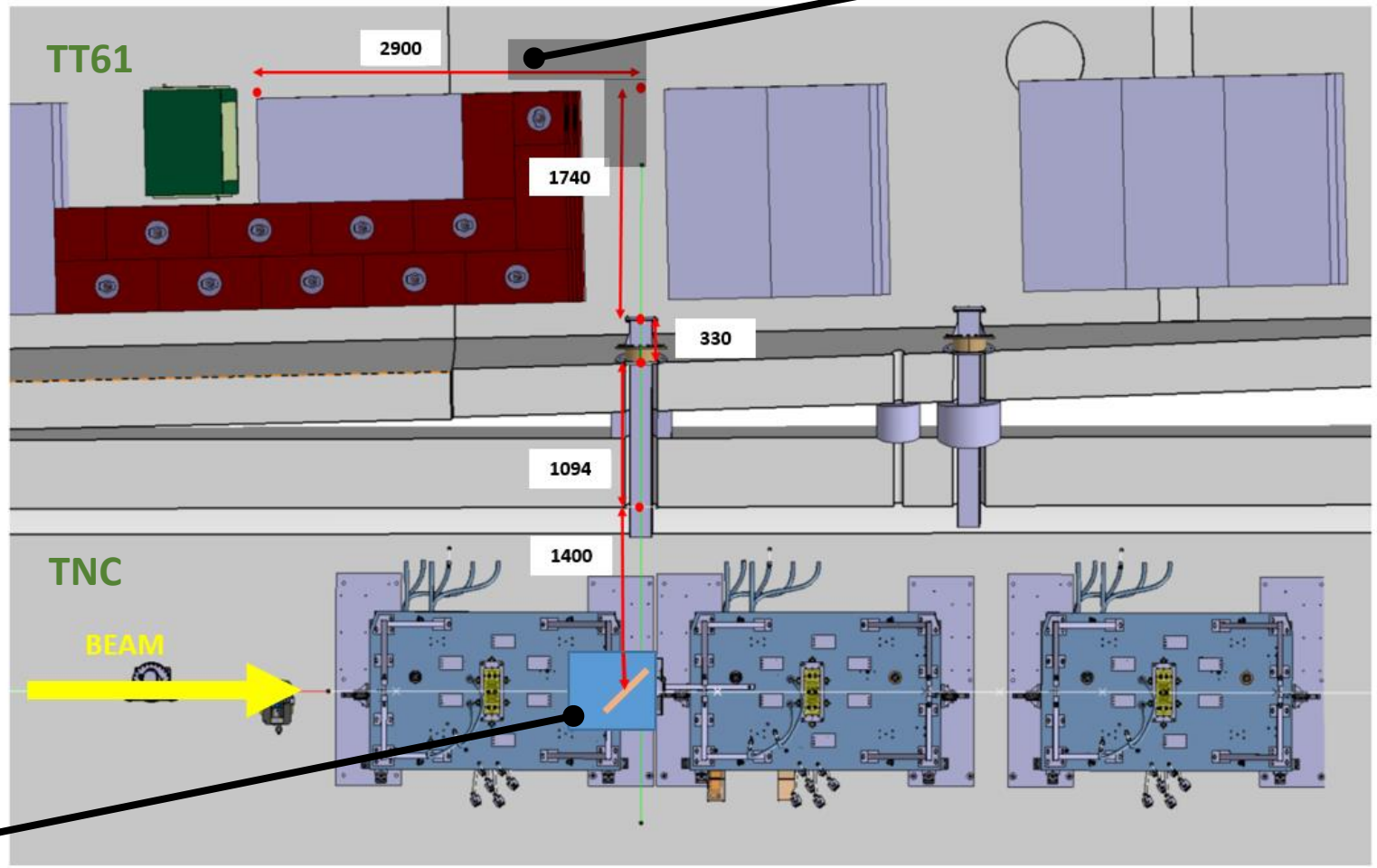


Ongoing development of a new BTV for HRM (3)

→ **Optical line**

To move away the camera from the irradiated zone (TT61)

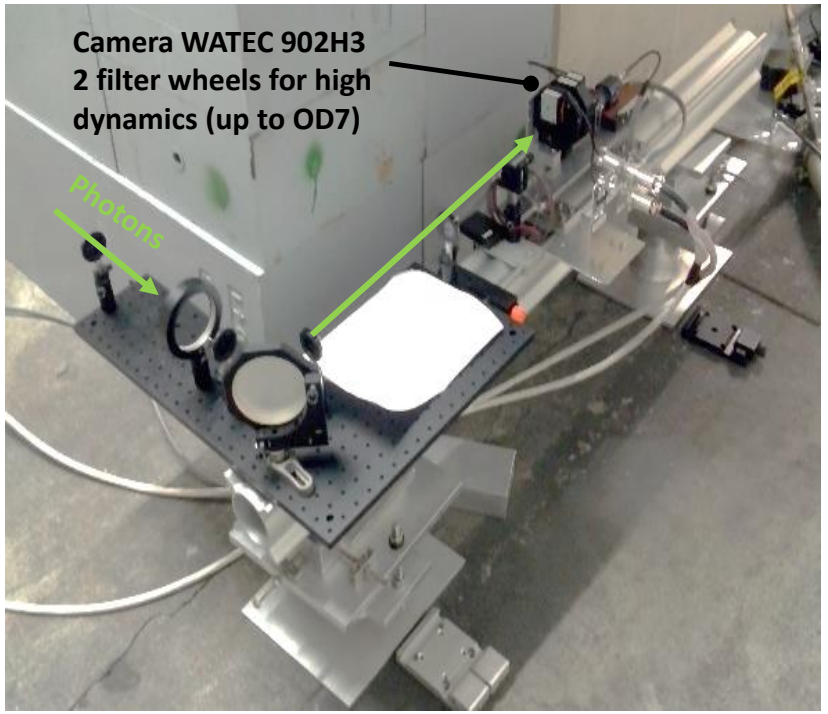
→ Optical line up to TT61, behind shielding

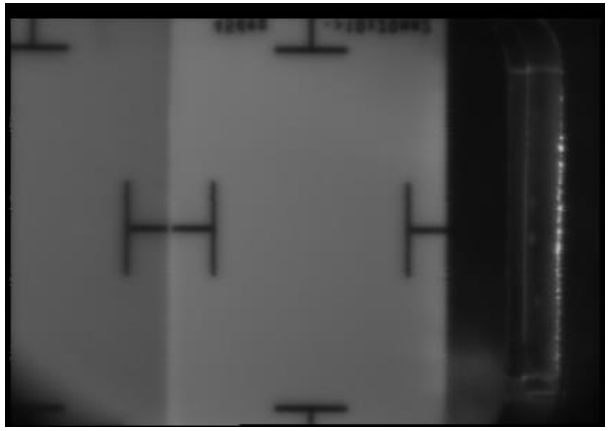


Ongoing development of a new BTV for HRM (4)

Optical line setup

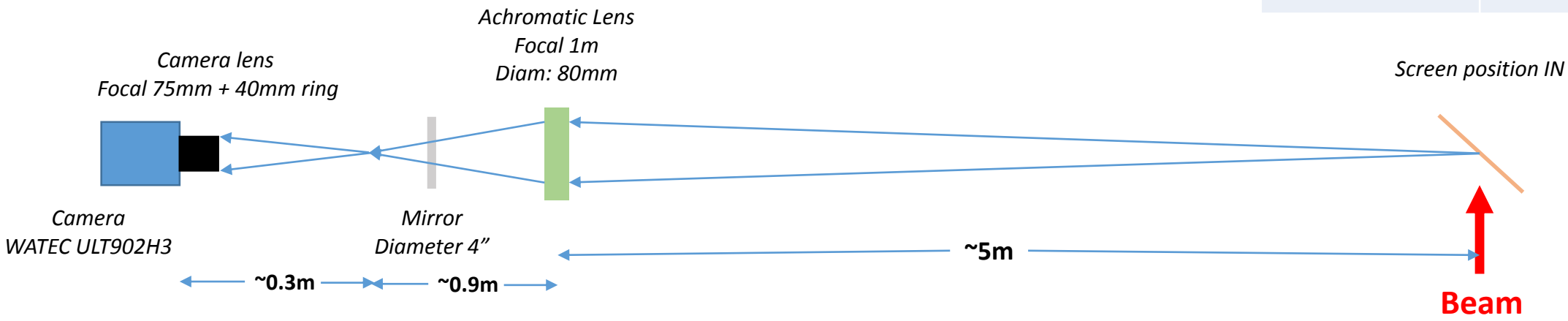
- A single lens (Focal length 1m).
- Magnification of ~0.2





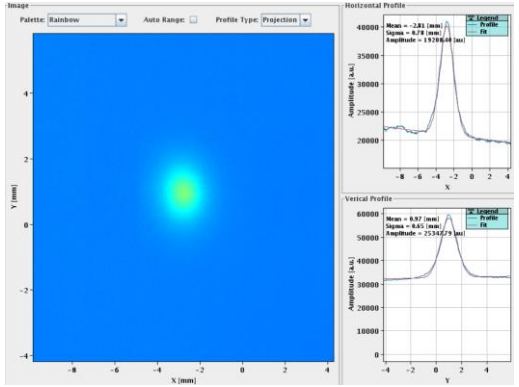
Reference image for calibration

Resolution [um/px]	
Horizontal	72
Vertical	79



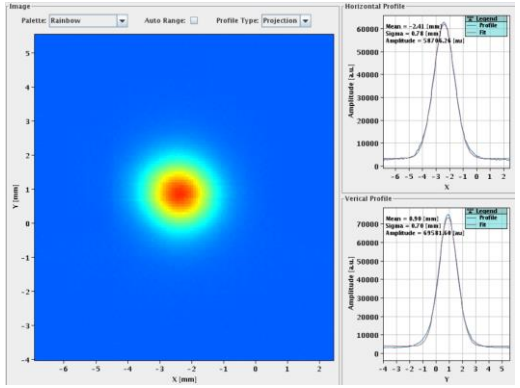
Ongoing development of a new BTV for HRM (5)

Screen: Alumina 1mm
Filter NO



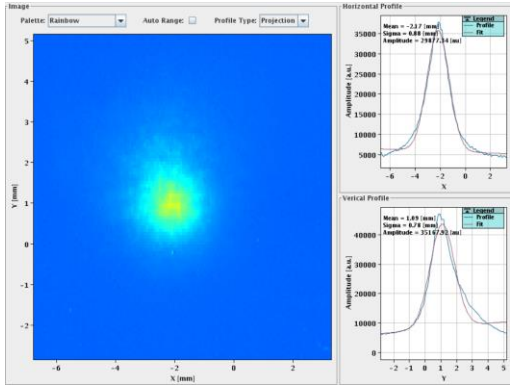
Single bunch (~1E11p)
FP2_0.5mm

Screen: Chromox 0.5mm
Filter OD4



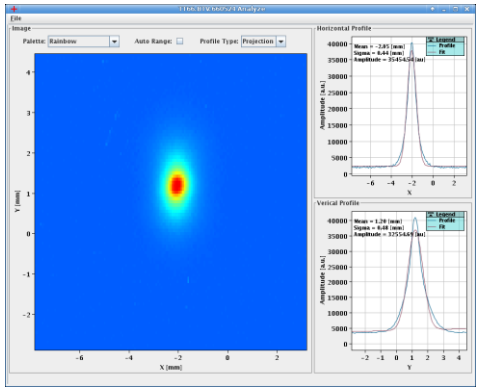
12bunch (~1.2E12p)
FP2_0.5mm

Screen: Ti 0.1mm
Filter OD1



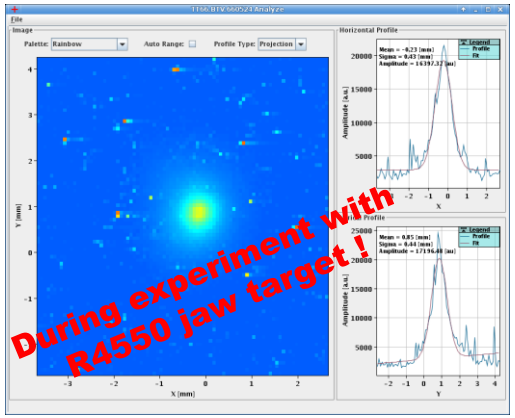
72bunch (~7.2E12p)
FP2_0.5mm

Screen: SiC 0.5mm
Filter OD3



216bunch (~2.4E13p)
FP2_0.25mm

Screen: SiC 0.5mm
Filter OD4



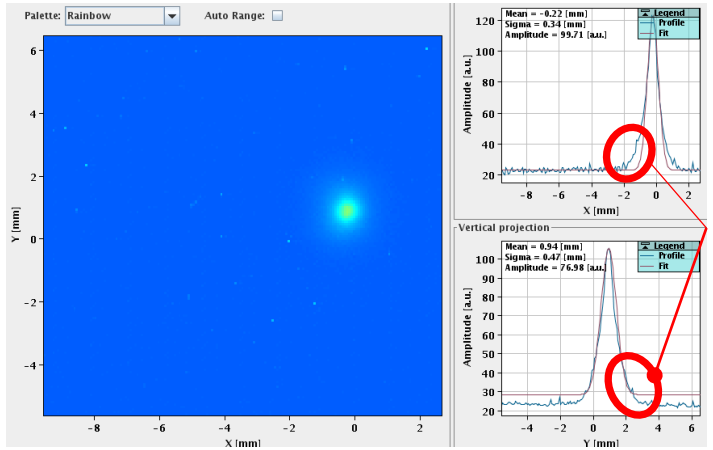
288bunch (~3.2E13p)
FP2_0.25mm

Light Emission type	Screen type	Bunch number (x1E11p)						
		Optics FP2_0.5mm					Optics FP2_0.25mm	
		1	12	36	72	144	216	288
Scintillation	Al2O3 (1mm)	NF	x	x	x	x	x	x
	Chromox (0.5mm)	3	4	x	x	x	x	x
OTR	Ti (100um)	NF	0.3	0.7	1	1.3	x	x
	SiC (0.5mm)	0.3	1.3	2	2	3	3	4

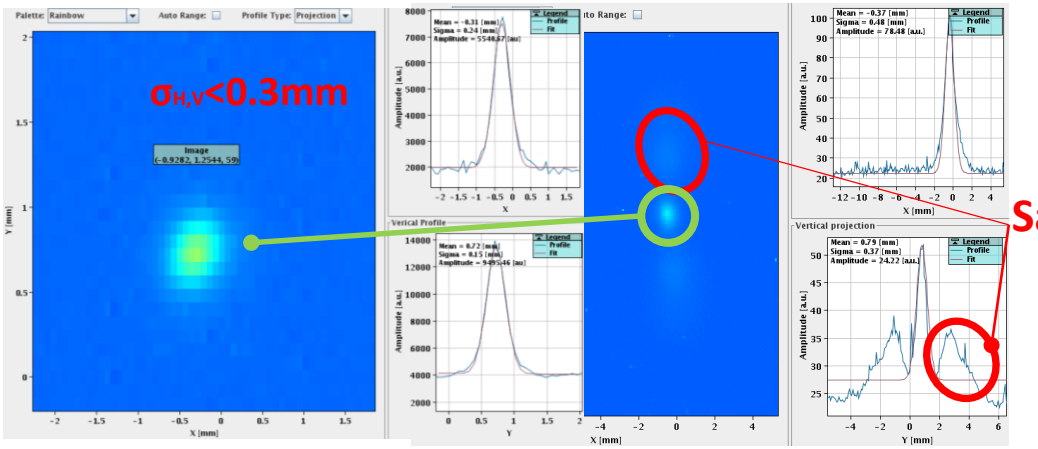
Screen to use VS beam type (intensity + optics)

Ongoing development of a new BTV for HRM (6)

Doubt on the beam sigma measured Always ~30% larger than the model (!?)



Tails



Satellites

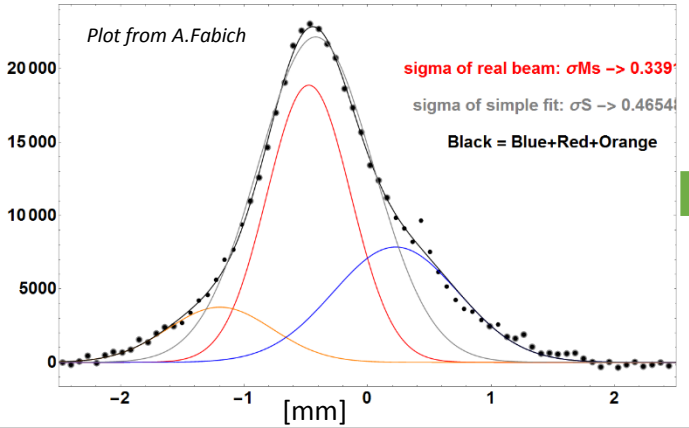
Measurements until Tuesday June 13th 18H27 → give tails

From Tuesday June 13th 18H43 → give satellites

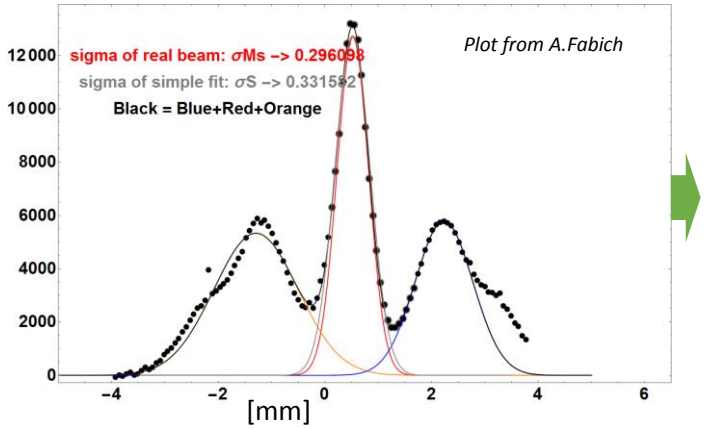
If tails and satellites are not beam but 'reflections' or forward OTR from entrance vacuum window (expected negligible from Zemax simulations):

→ work ongoing to define the source (mask, color filters, etc…)

→ Some post processing to derive the real beam size (optics used 0.25 & 0.3)



Tails
Error on beam size could be >35%



Satellites
Error on beam size could be >11%

Conclusion

Beam position measurement – BTV/BPKG

→ 3 has been produced and 6 experiments already used it from summer 2015

→ Offset calibration using BTV as close as possible works fine up to 12 bunches beam

→ BPKG performs over the all intensity range of the extracted beam within specifications

→ Investigations ongoing to get rid off the remaining noise due to backscattering effect

→ This **BTV/**BPKG is not suitable for profile measurement (in air device, camera submitted to radiation, screen limitations, etc…)

Beam profile measurement - BTV

So far the new BTV can be used to measure all the beam range of HiRadMat (from 1 to 288 bunches) solving the following issues:

→ radiation issue (optical line)

→ screen robustness (polished amorphous SiC) which permits to operationally measure both small & intense beam

→ Still few issues to work on (remove tails / satellites to be understood) to derive the right beam size

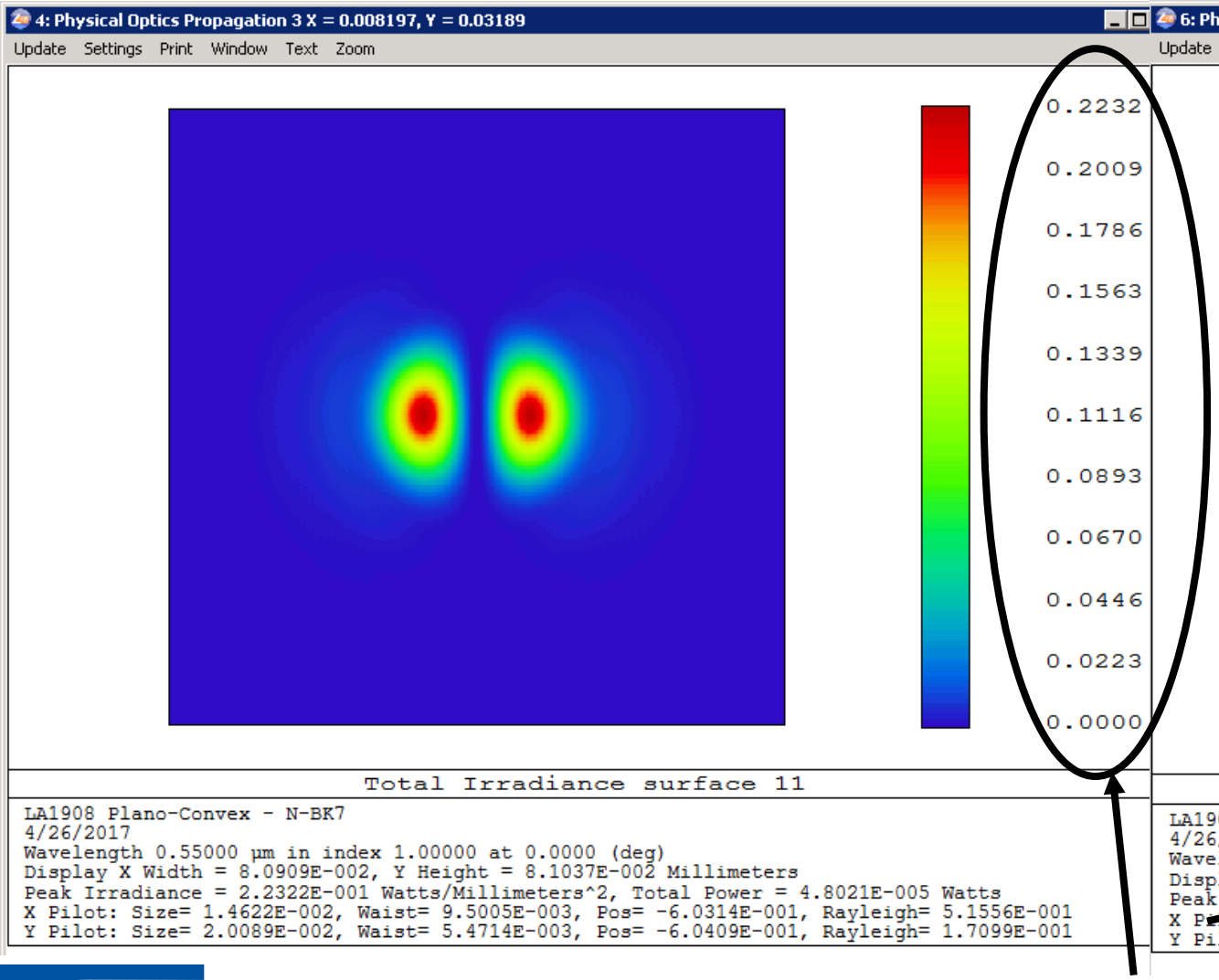
→ Upgrade

- make this system operational (optimize filter settings and build a dedicated GUI?)
- use of digital camera

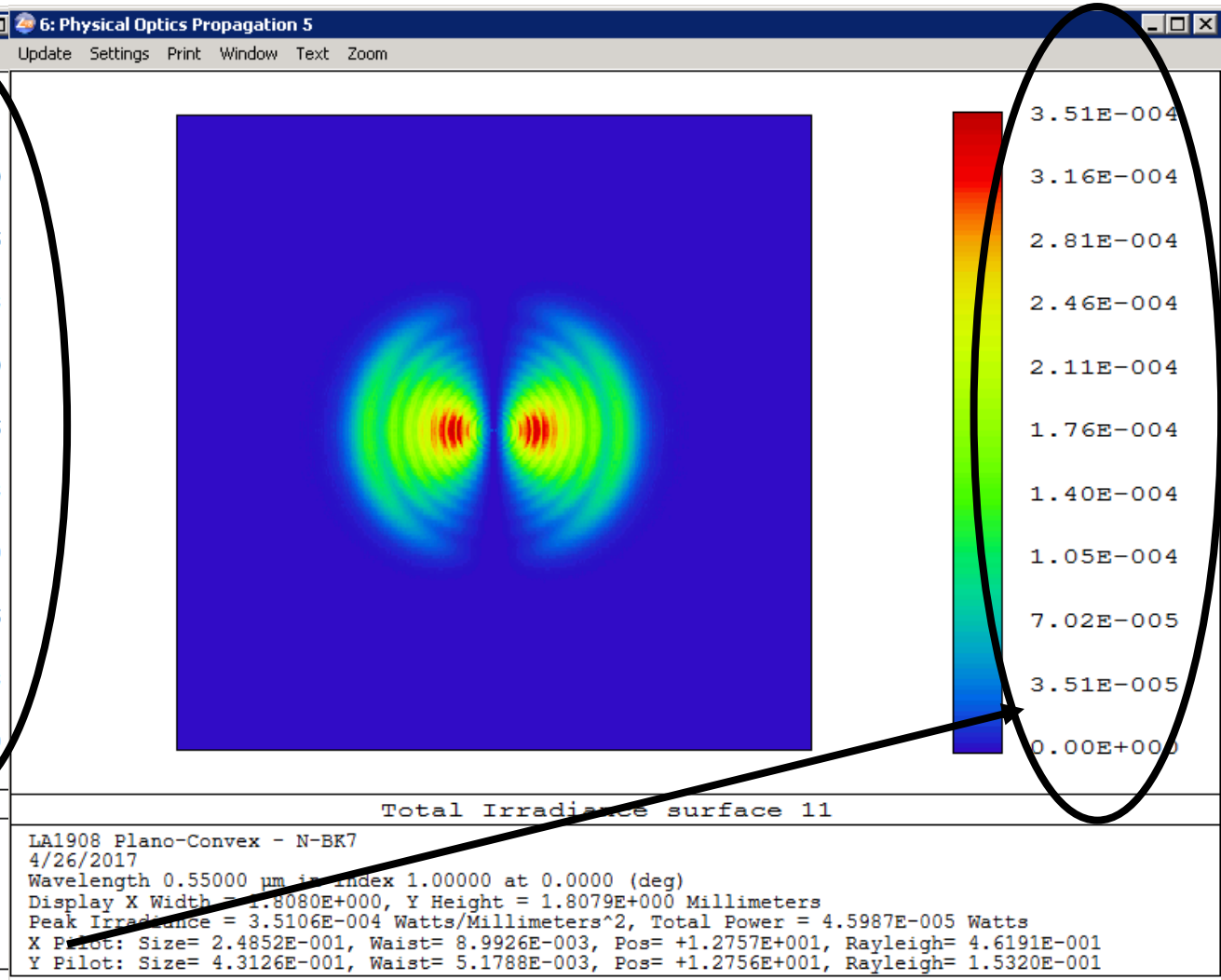
Thanks !!

Effect of forward OTR of vacuum entry window has been simulated → **negligible** as off focus by >226mm

On Focus



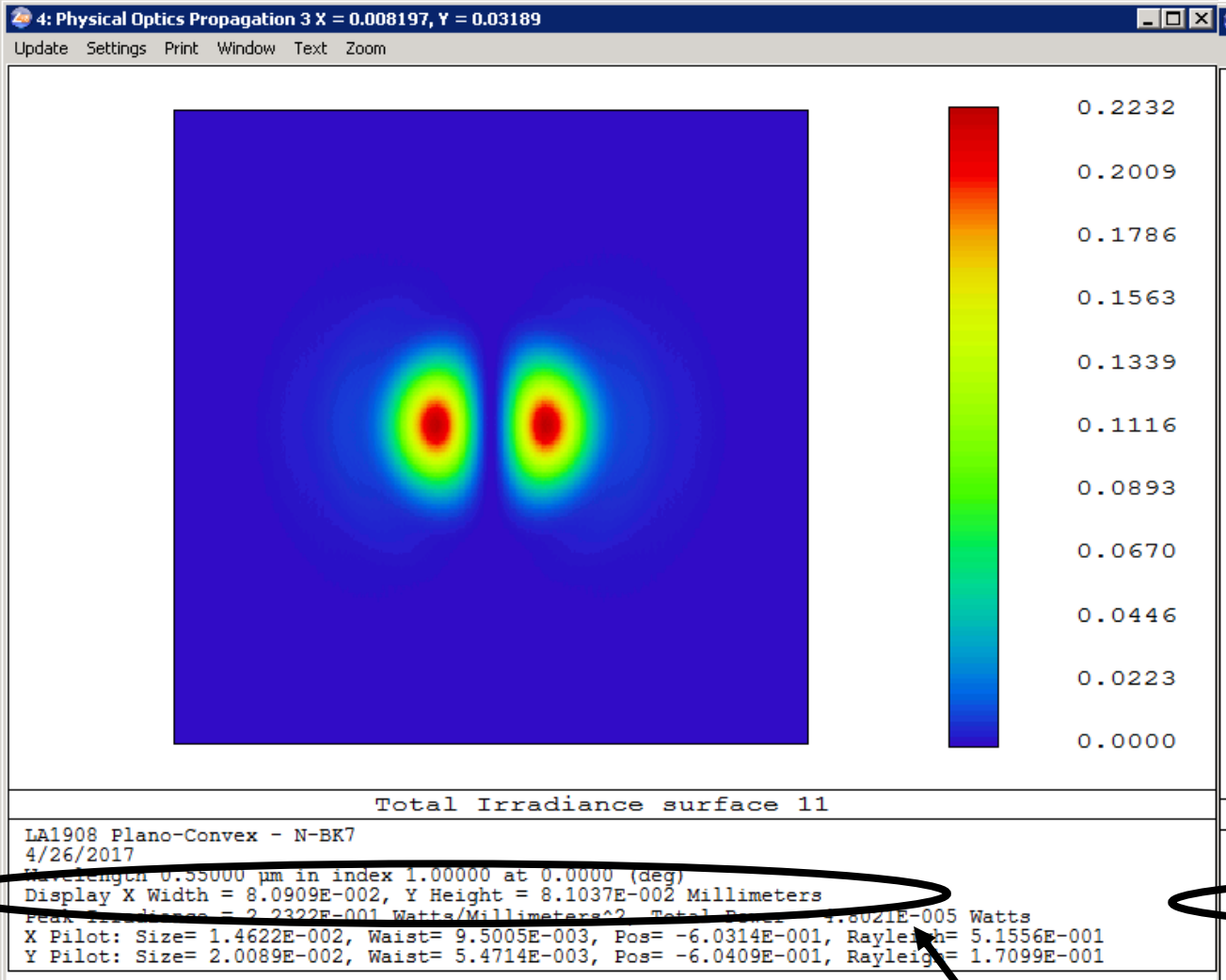
Off Focus



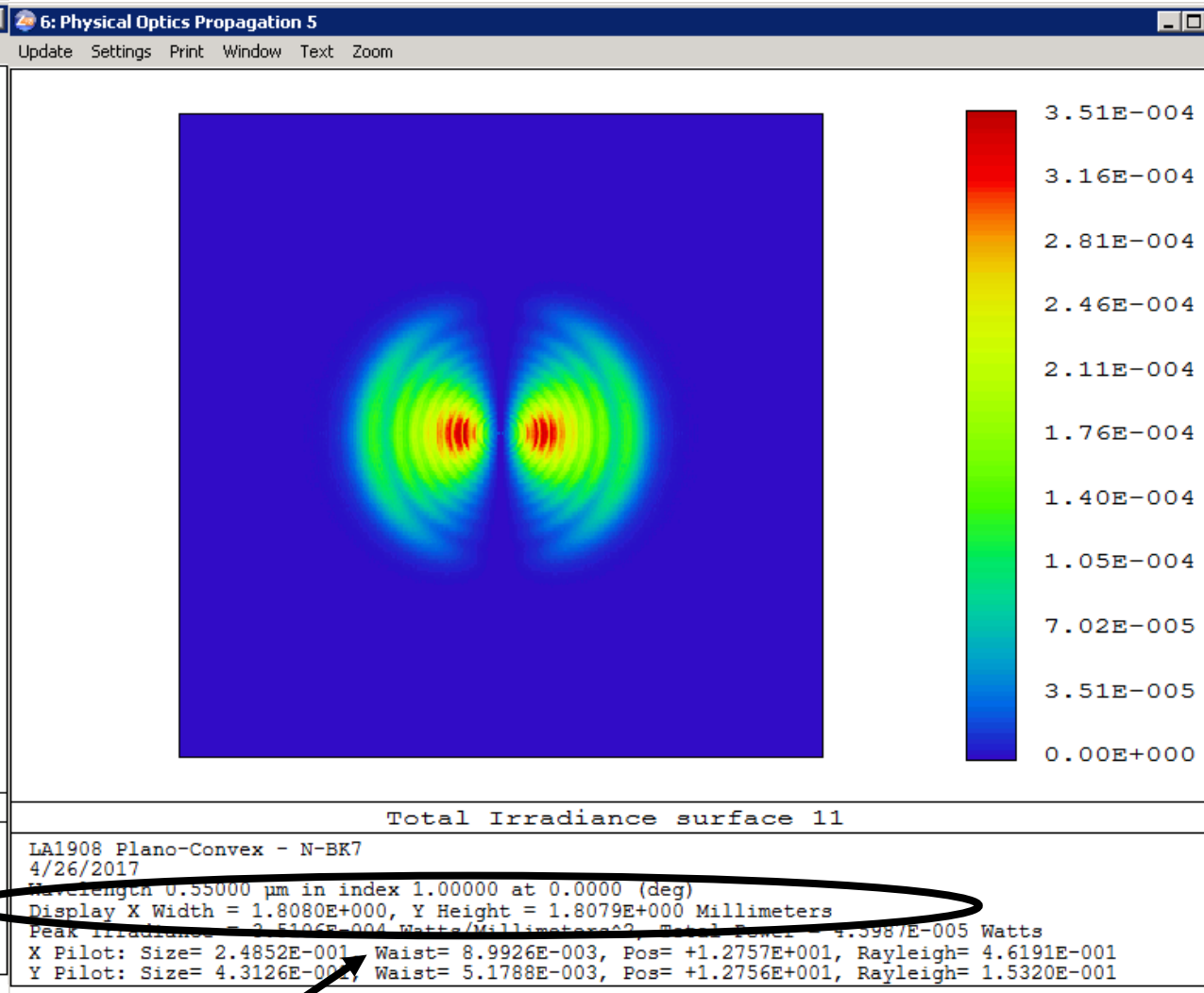
Different Scale

From same initial intensity

On Focus

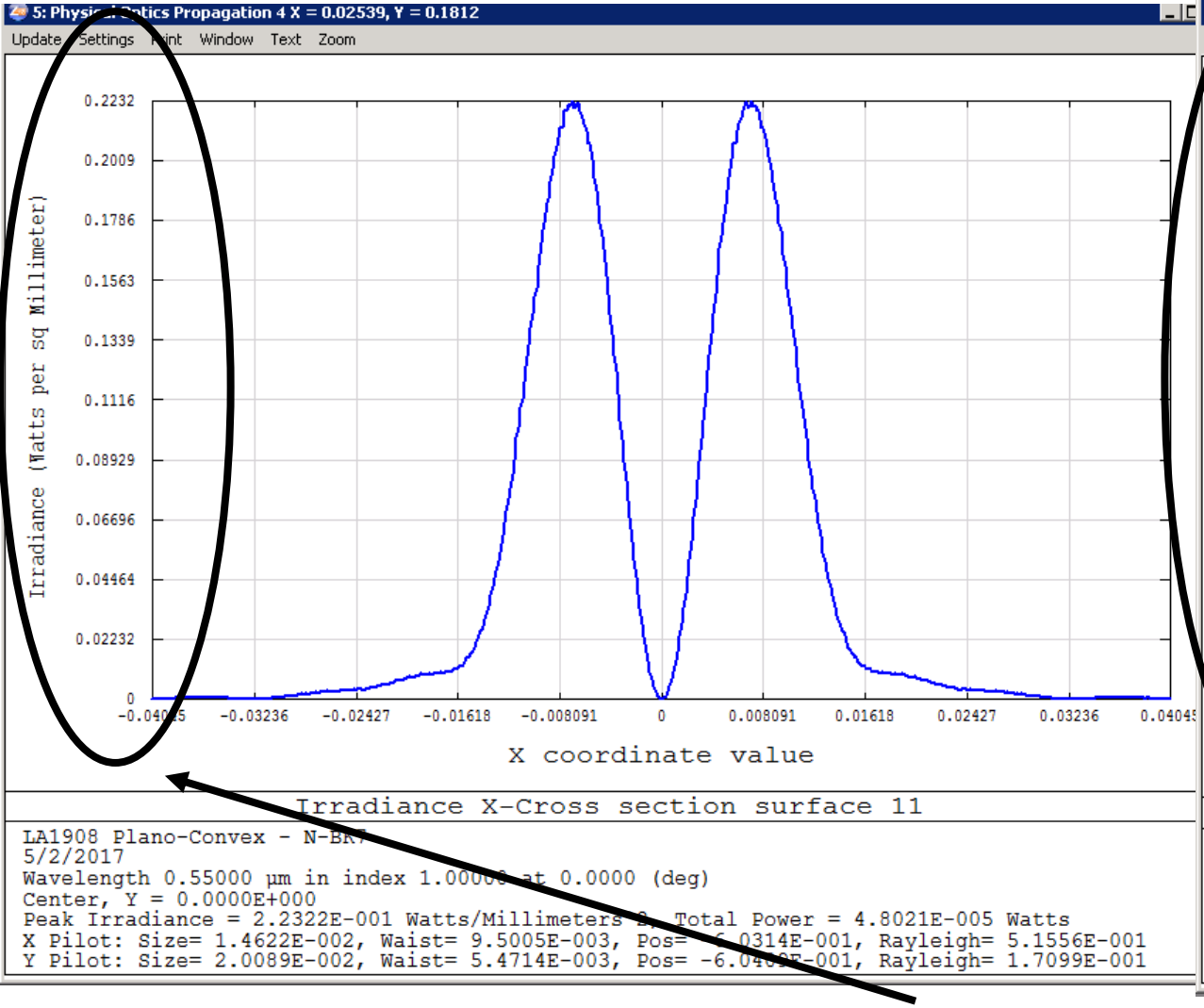


Off Focus

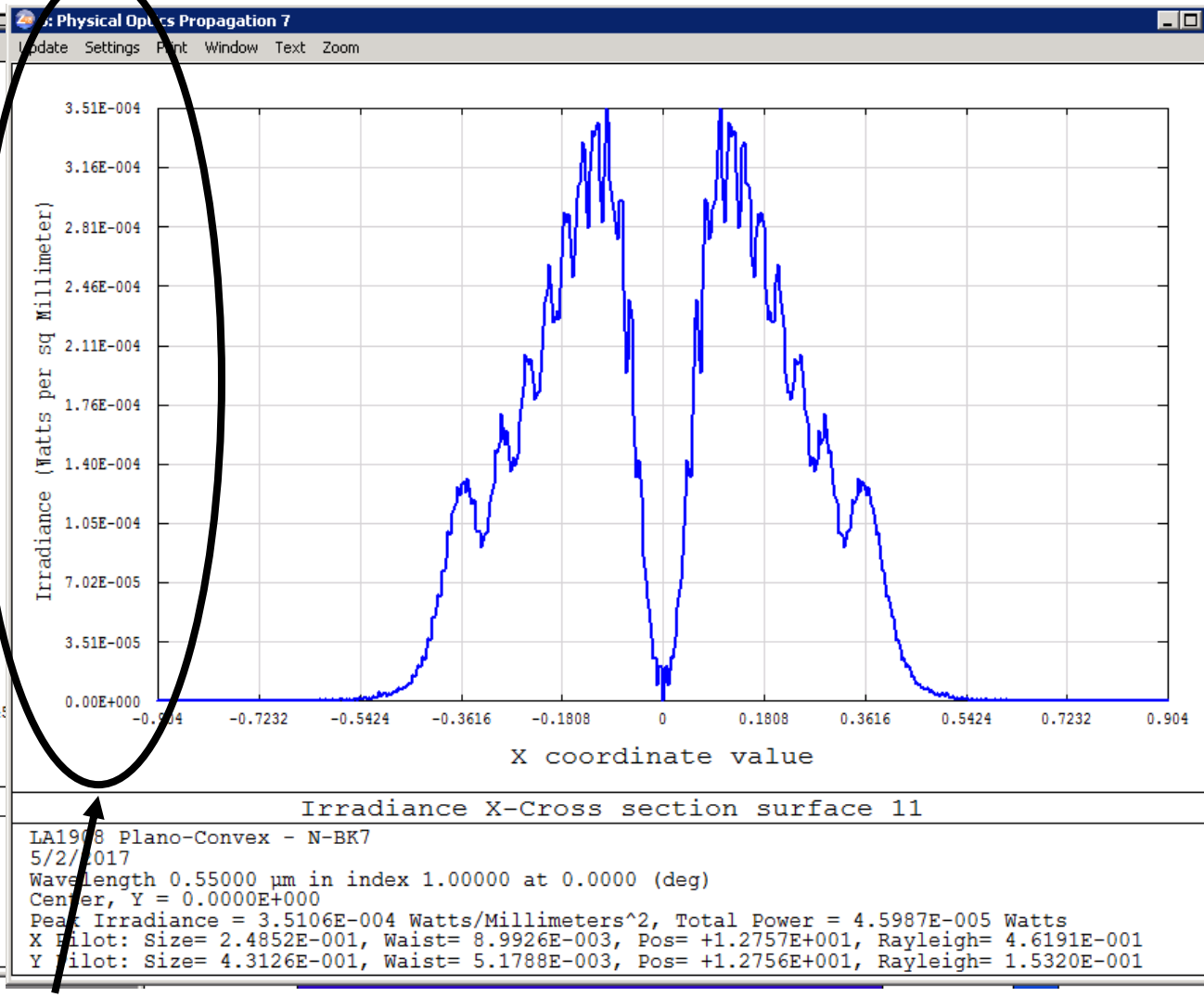


Different spatial size: focused is more concentrated

On Focus

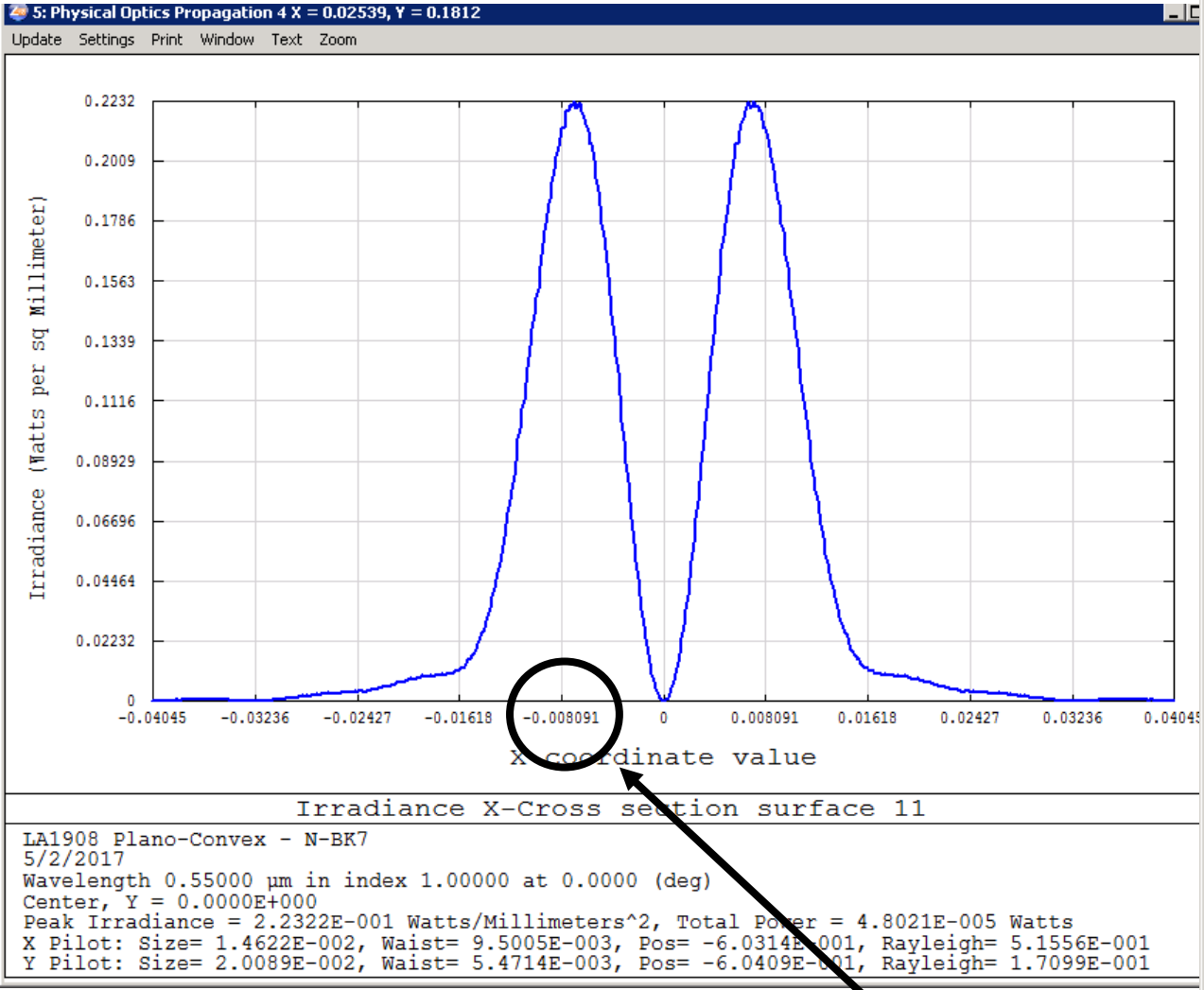


Off Focus

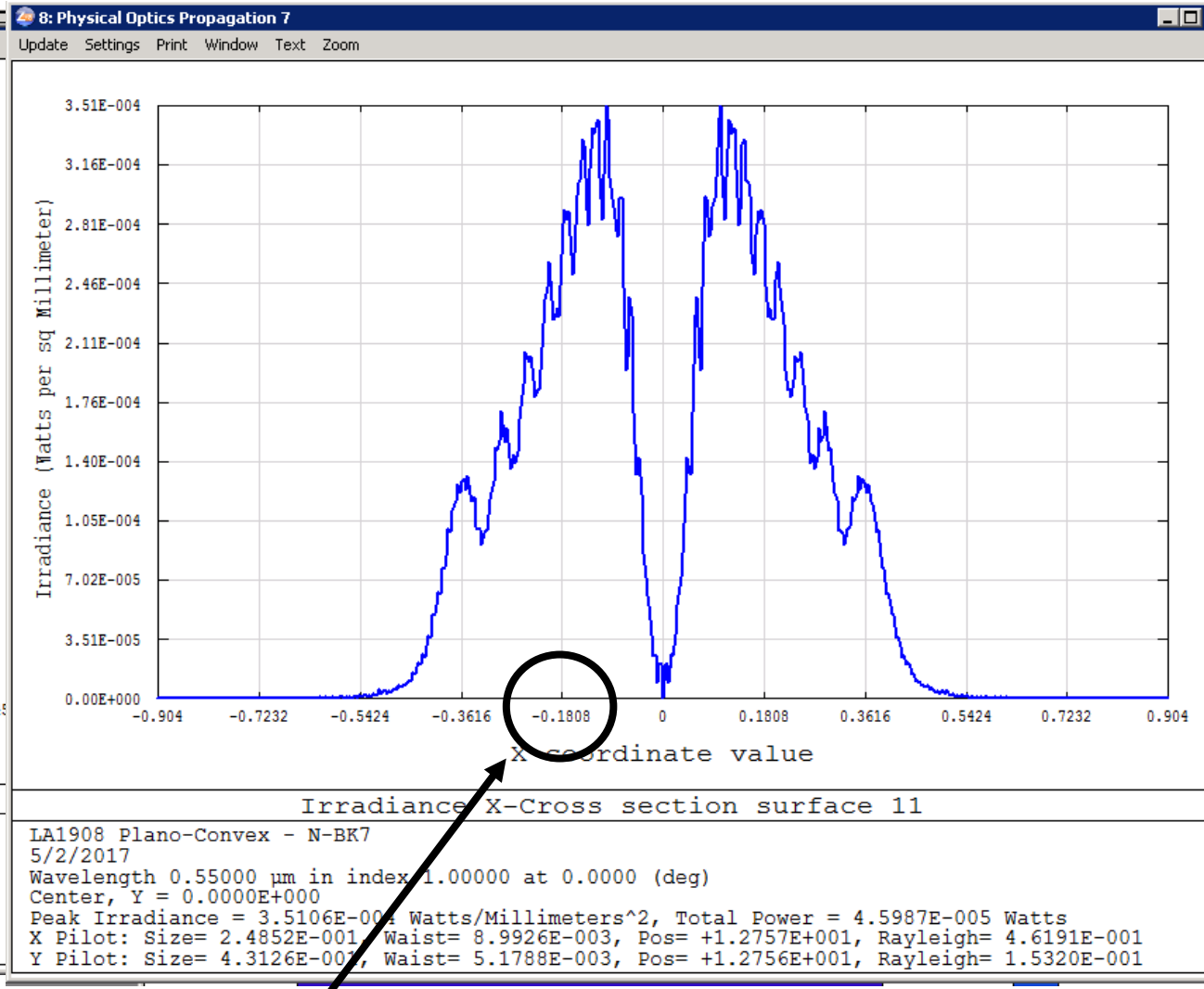


Different Scale from same initial intensity,
Peak ratio between on focus/off focus ≈ 636

On Focus



Off Focus



Different size from same initial intensity,
peak position on focus ≈ 0.007 mm, position on focus ≈ 0.10 mm