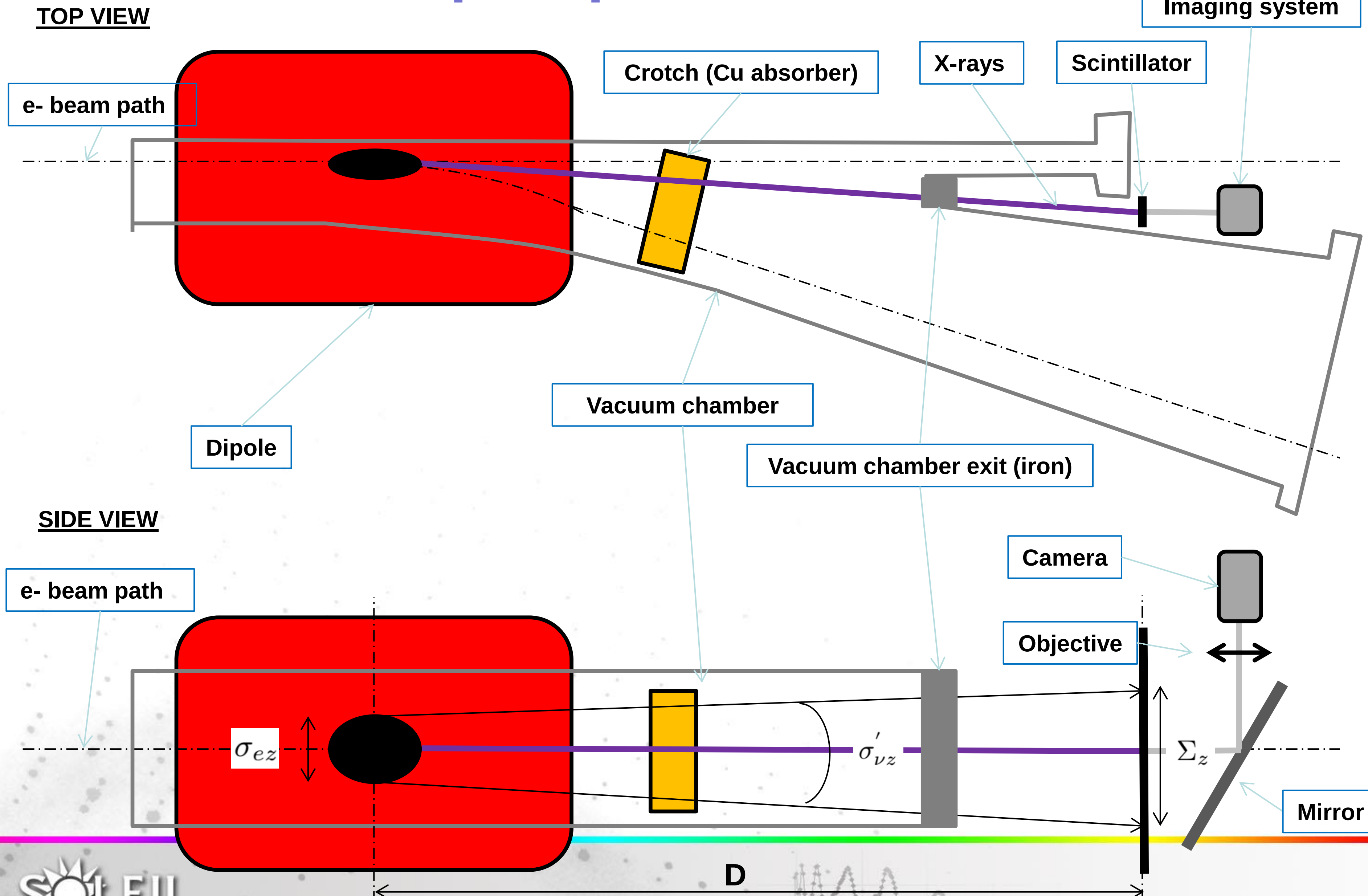
Commissioning of the AXD @ C12 (in-Air X-ray Detector)

Diagnostics and Synchronization Group
Accelerator and Engineering Division
Synchrotron SOLEIL

June 2017

AXD principle

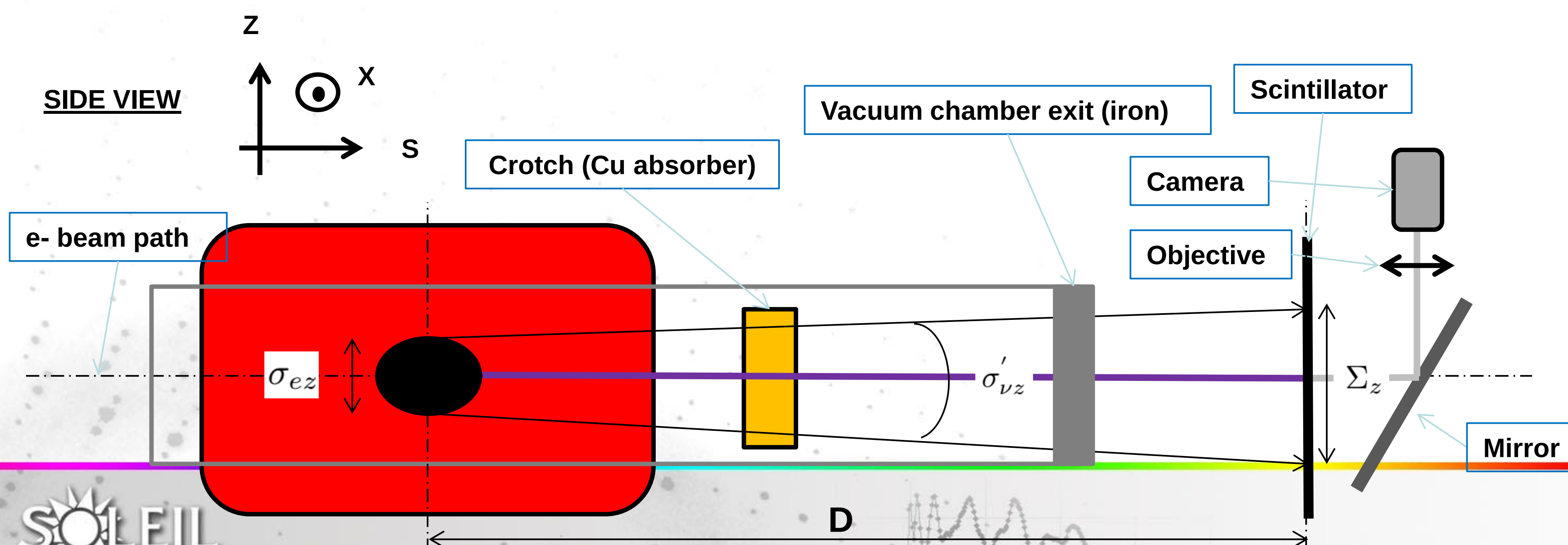
AXD principle



AXD principle

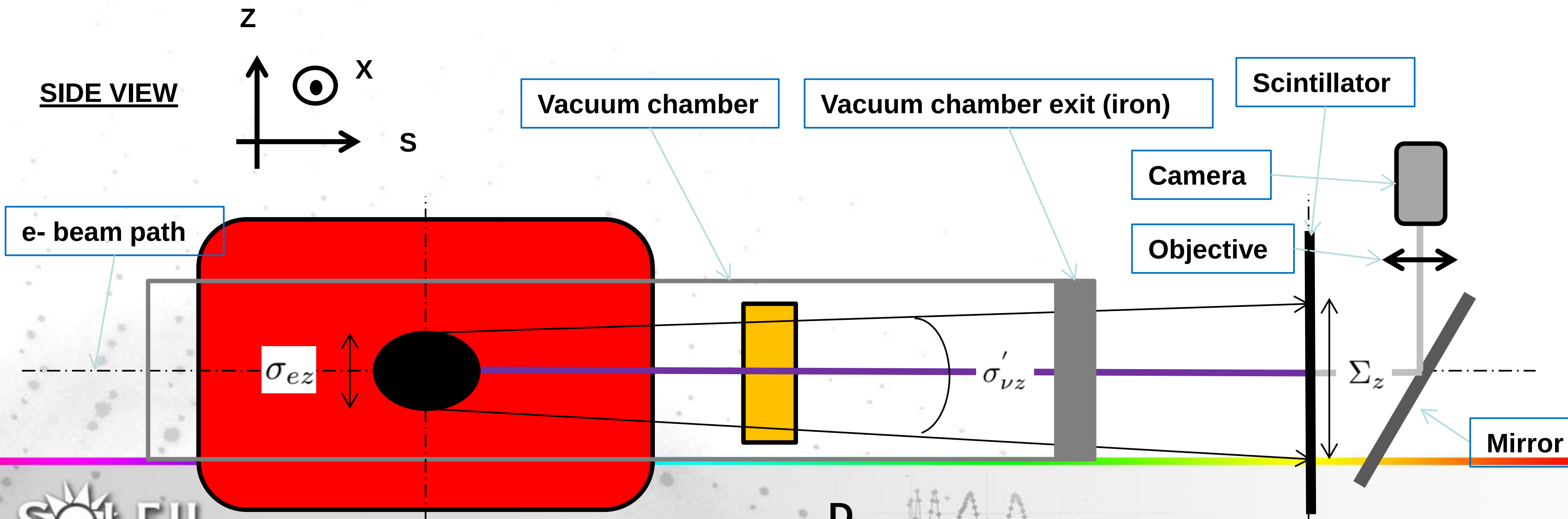
- SR passes through crotch absorber
- SR distribution on scintillator
- Retrieval of the vertical beam size:

$$\Sigma_z = \sqrt{\sigma_{ez}^2 + D^2 \times (\sigma_{\nu z}'^2 + \sigma_{ez}'^2)}$$



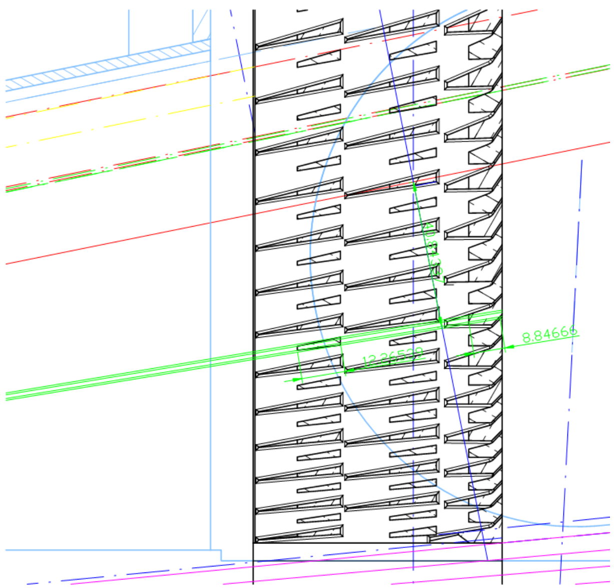
AXD principle

- Design by ESRF (6 GeV)
  - *B.K. Scheidt, Proceedings of DIPAC 2005, Lyon, France, 238-240 (2005).*
  - *B.K. Scheidt, Proceedings of DIPAC 2007, Venice, Italy, 72-74 (2007).*
  - *A. Franchi et al., Phys. Rev. ST Accel. And Beams 14, 034002 (2011).*
- Applied at ANKA (2.5 GeV) and ALBA (3 GeV)
  - *A. A. Nosych, U. Iriso, Proceedings of IBIC 2014 (2014).*
  - *A.-S. Muller et al., Proceedings of EPAC 2006, Edinburgh, Scotland, 1073-1075 (2006).*

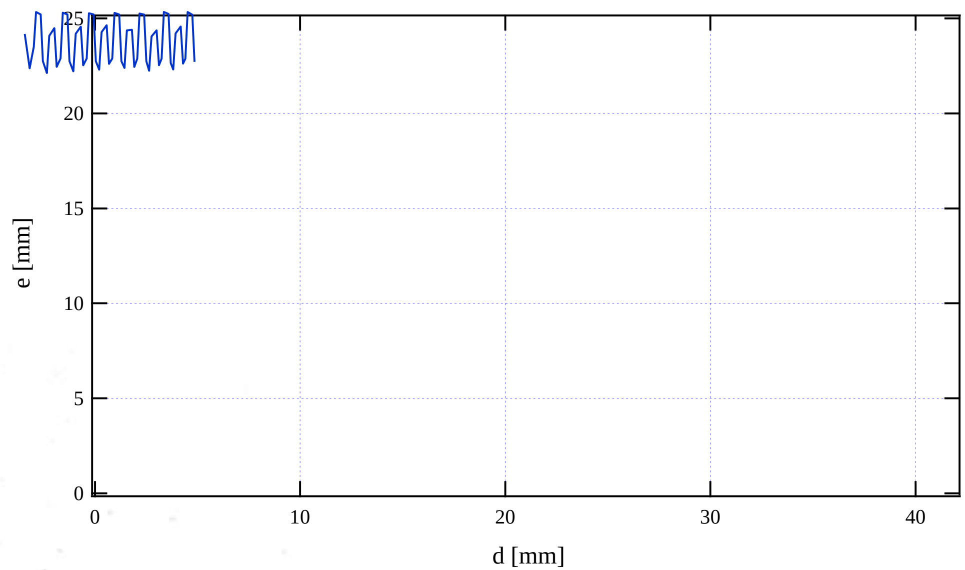


Crotch design

- Crotch absorber teeth design:
  - Maximize the surface of illuminated copper to optimize cooling.



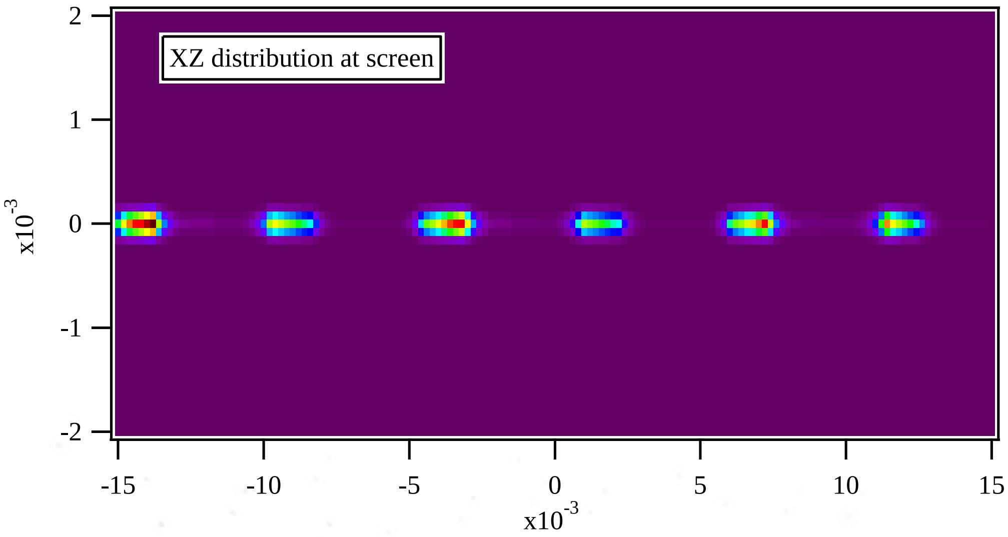
Crotch absorber



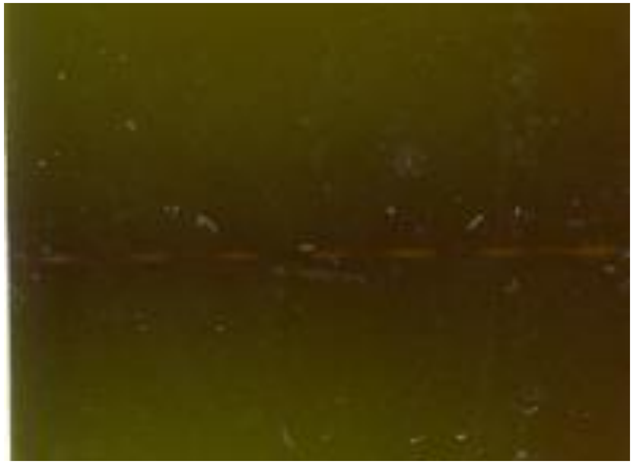
Copper thickness seen by photons depending on beam position with respect to 0° axis.
Thickness varies from 6 to 22 mm

SR after crotch

- Effect of the teeth:



SRW simulation of the XZ intensity distribution at the screen location



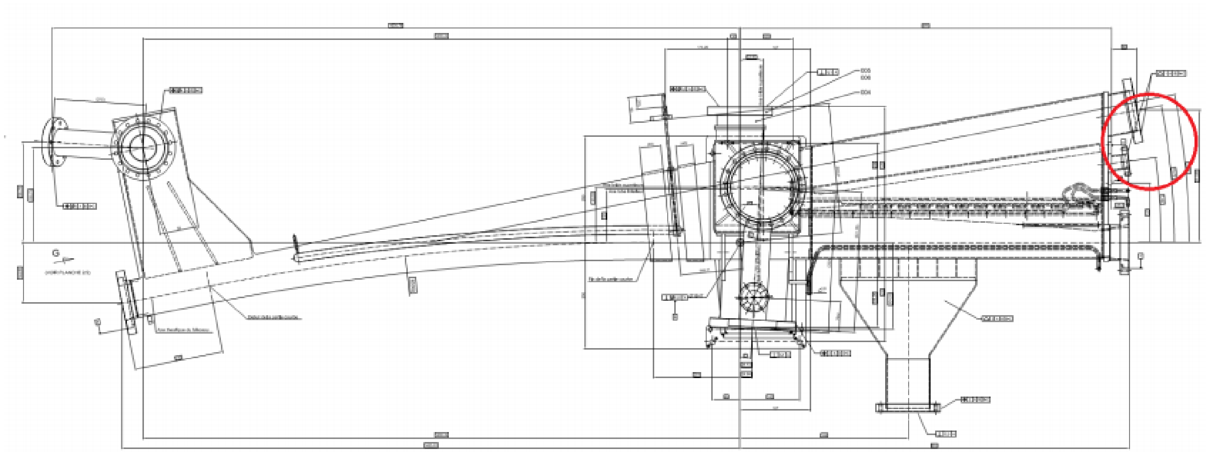
Dose footprint recorded on a Gafchromic film

->> Profile to be performed on less than 0.2 mm to measure photon beam size with less than 1% energy spread
->> Horizontal alignment of the screen and optical system to be done carefully

AXD possible locations

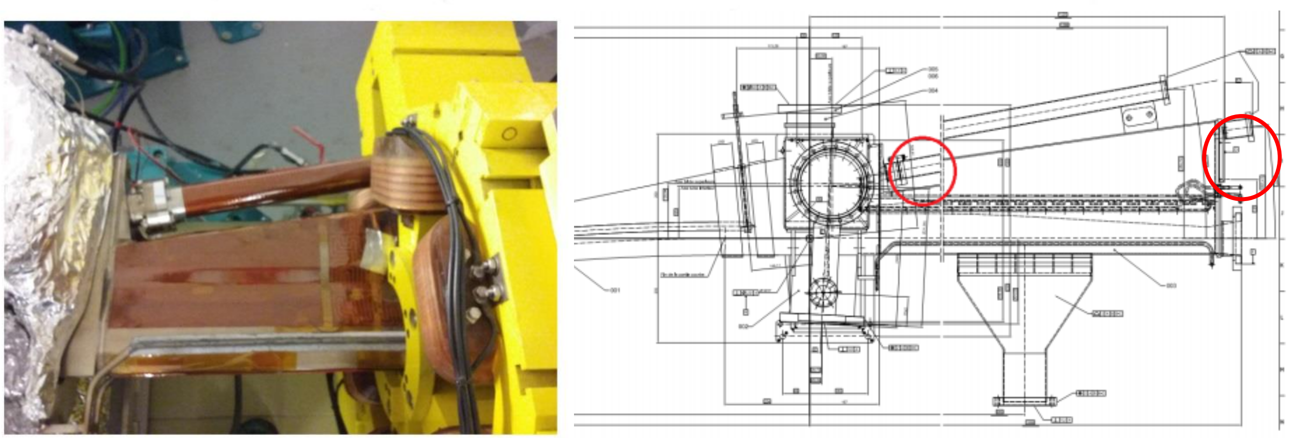
$$\Sigma_z = \sqrt{\sigma_{ez}^2 + D^2 \times (\sigma_{\nu z}'^2 + \sigma_{ez}'^2)}$$

- Different location have been considered:



(a) Dipole vacuum chamber : type 1.

1.7 m behind the source

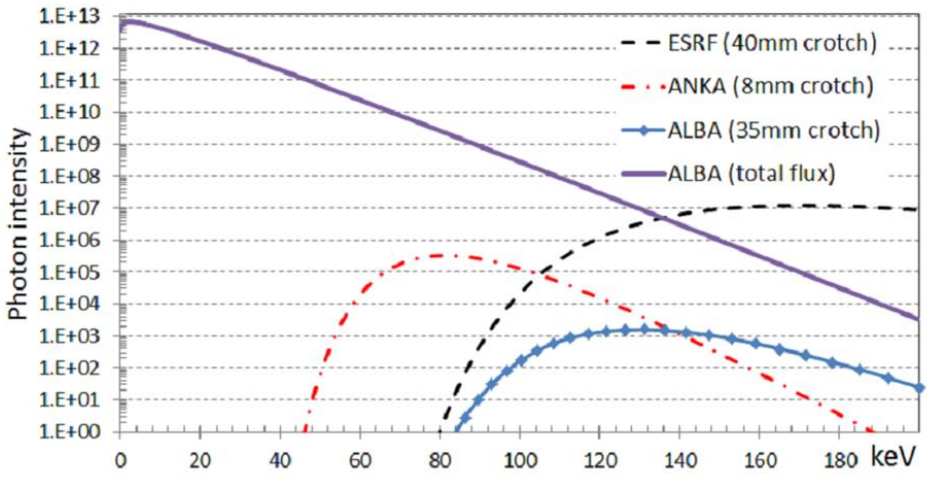


(b) Dipole vacuum chamber : type 2.

2 m or 1.3 m behind the source

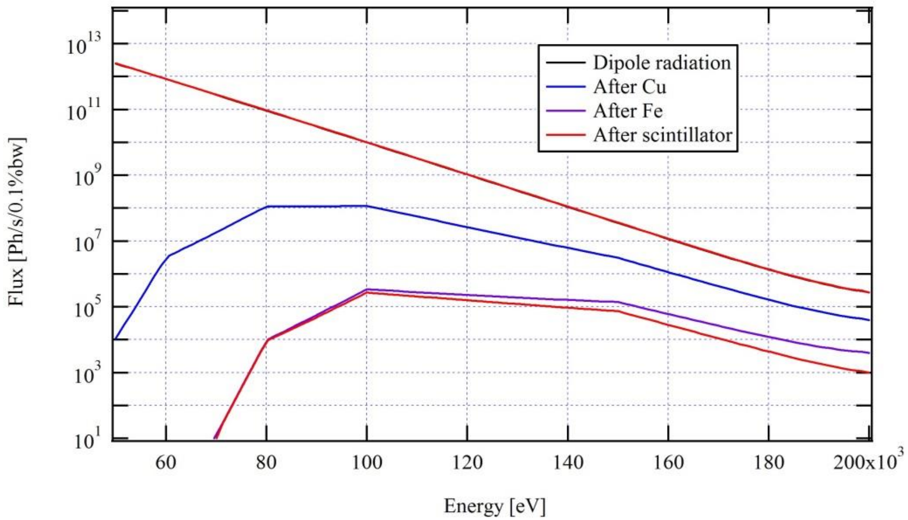
AXD: expected flux

- Photon distribution before and after the crotch and the vacuum chamber:



ALBA simulation

A. A. Nosych, U. Iriso: "A compact X-ray Detector for Vertical Beam Size Measurement at ALBA", IBIC2014

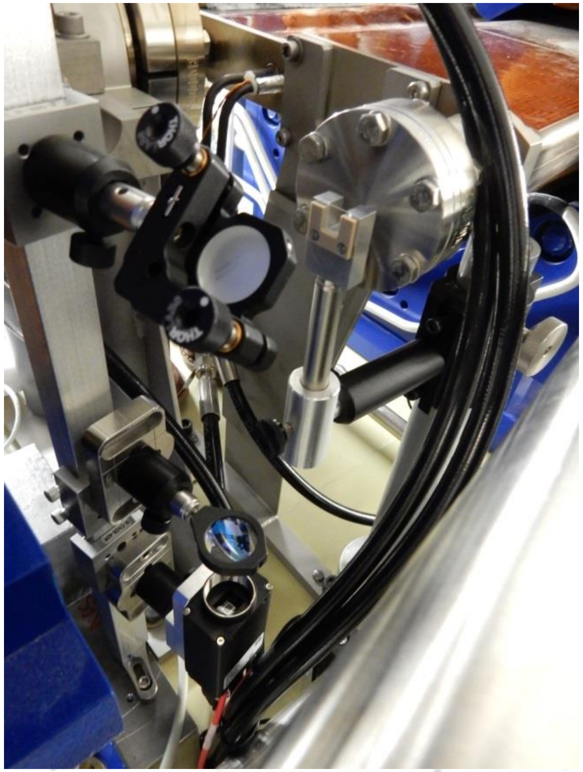


SOLEIL simulated flux integrated over a 10 x 10 mm window, with crotch + 20 mm of stainless steel
Distribution is peaked at 100 keV

->> CdW04 screen should be sensitive enough.

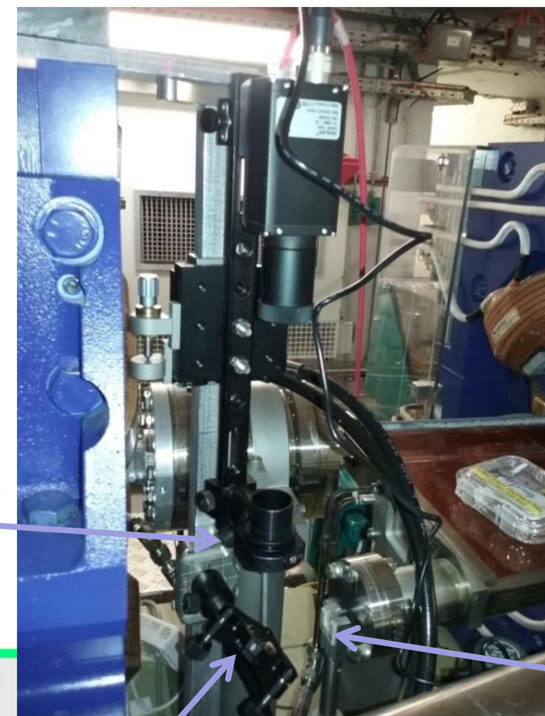
AXD first prototype: « AXD v0 »

- First prototype installed in August 2015 (2 meter from source):



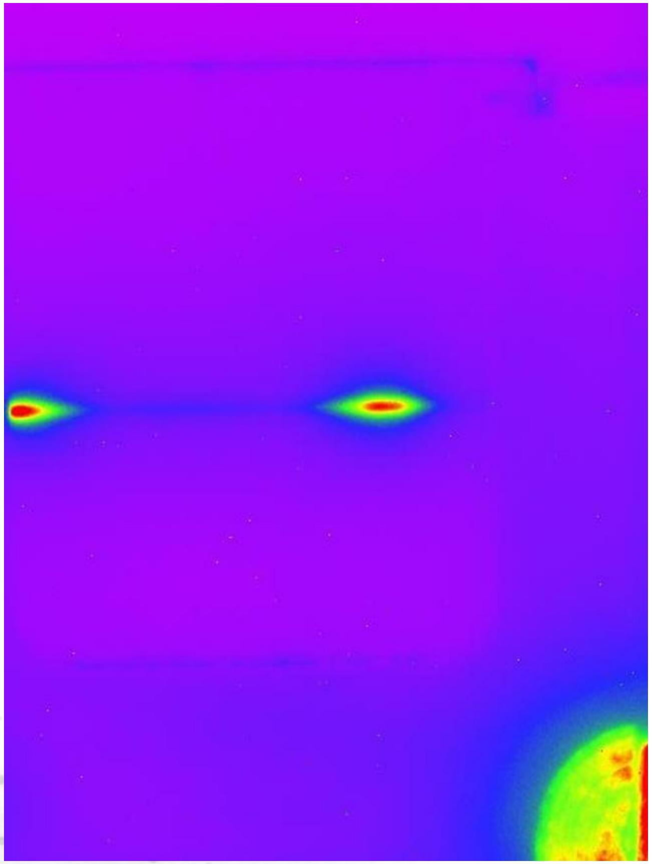
- Space is very limited
- Imaging system hanged on the quadrupole

->> Very difficult to align properly



« AXD v0 » preliminar measurements

- First prototype installed in August 2015 (2 meter from source):



- 2 teeth visible on the screen
- Some reflections on screws(visible light entering under the black sheet…)
- Enough flux!
- Zoom needed

« AXD v0 » preliminar measurements

- First images:

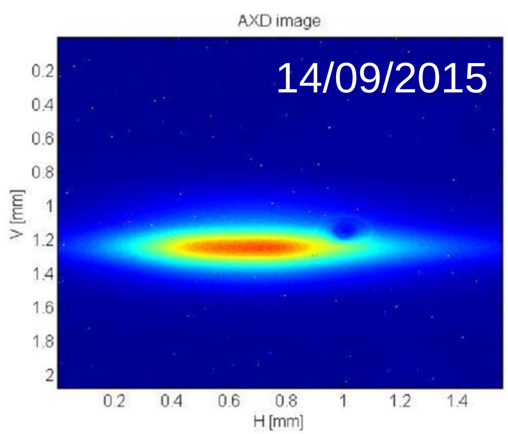
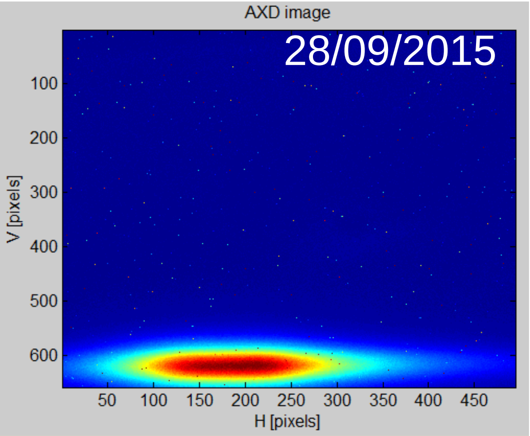
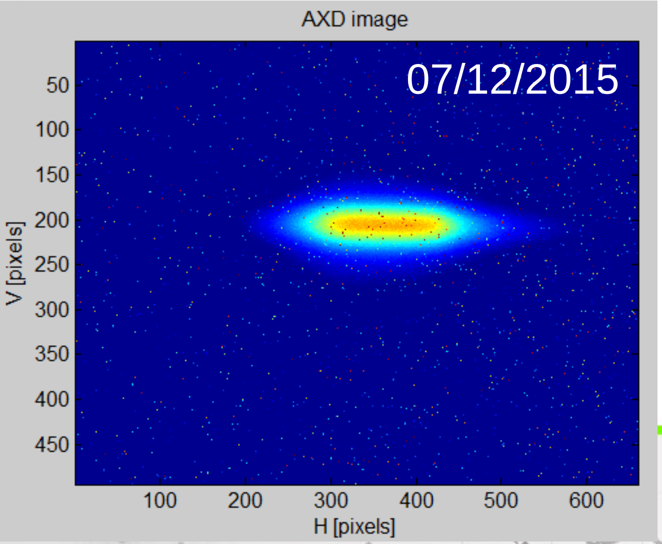


FIGURE 2 – AXD image with 450 mA. Scaling at the scintillator, assuming M=2.3. 14/09/2015.

C12-D2 at 2 m from the source

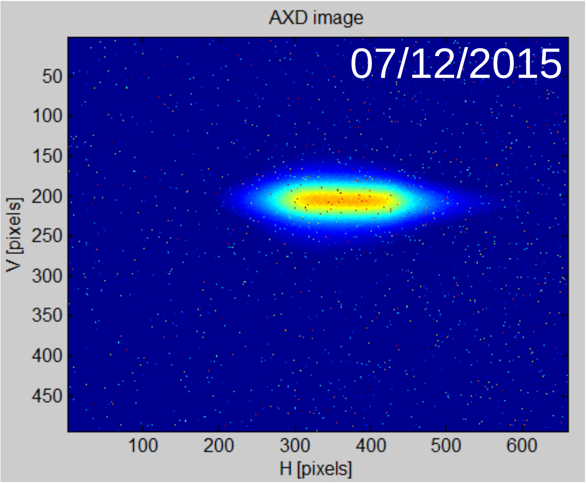


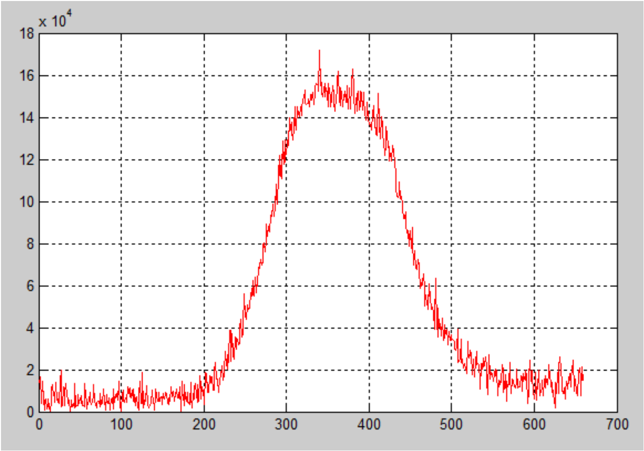
C12-D1 at 1.7 m from the source



« AXD v0 » preliminar measurements

- Horizontal profile:





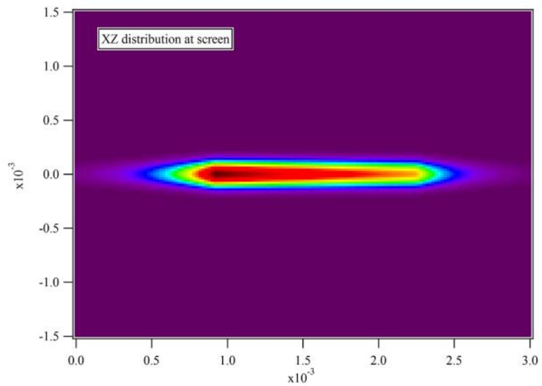
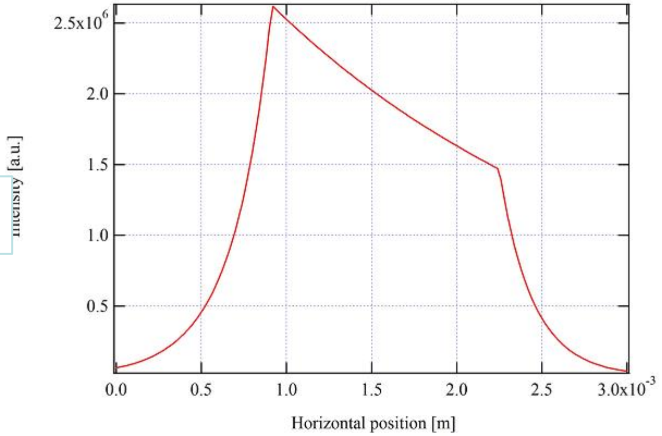


FIGURE 3 – AXD image simulated with SRW. Scaling at the scintillator.

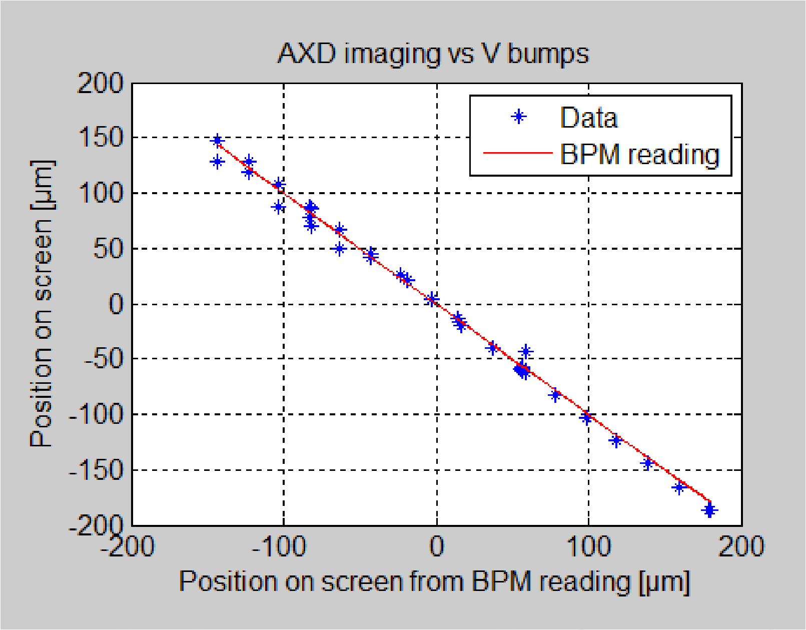
SRW simulation

Simulation

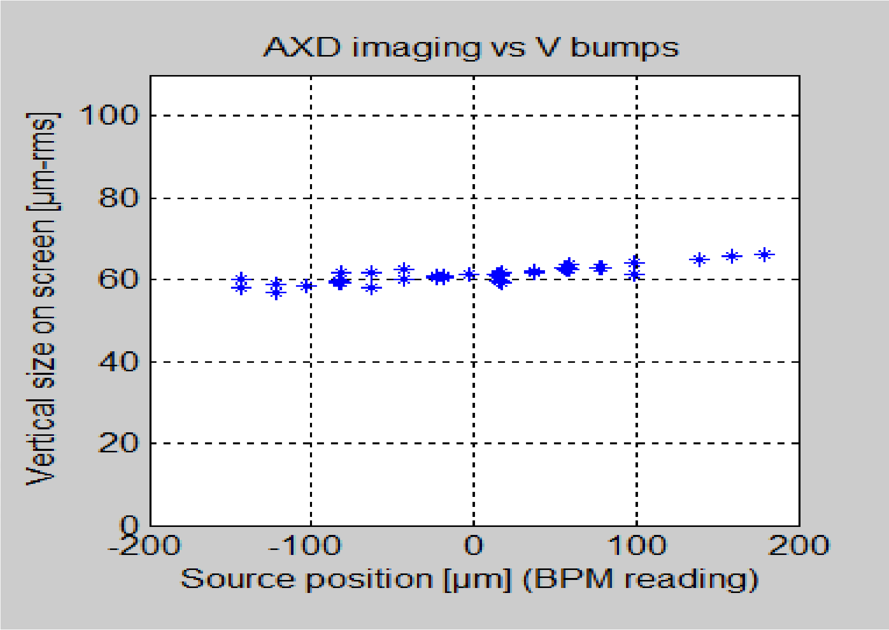


« AXD v0 » preliminar measurements

- Response to vertical bumps:



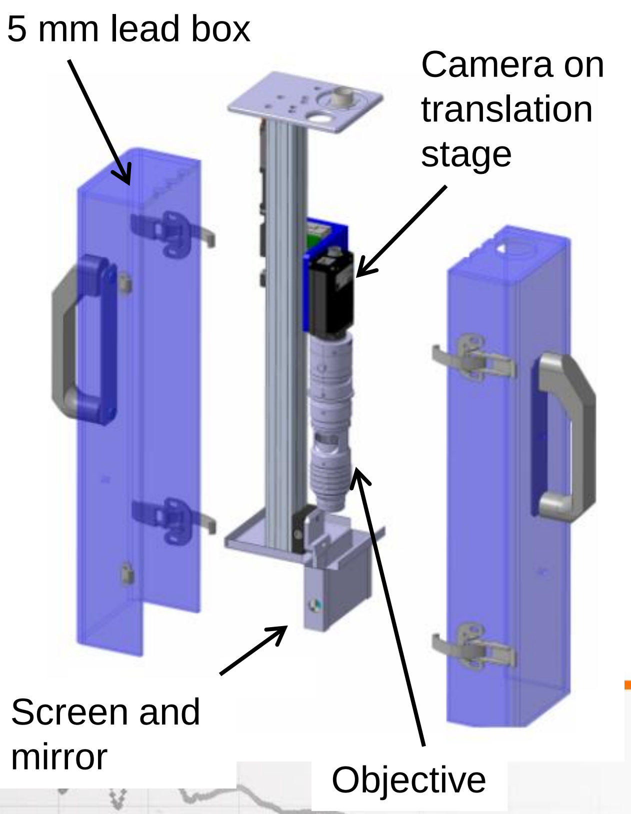
Vertical position on screen vs BPM position
->> Linear response



Vertical beam size on screen vs vertical beam position
->> a dependence is observed due to the change in Cu thickness

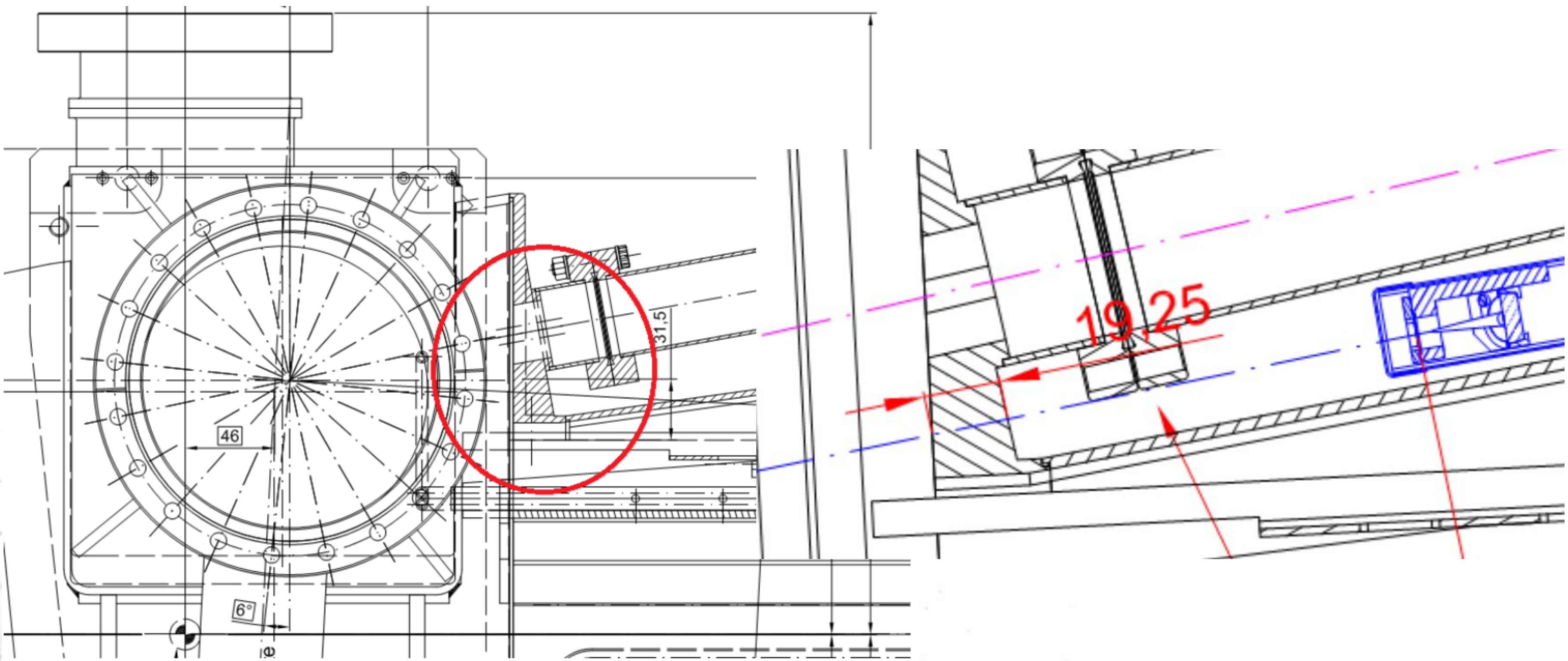
AXD new design: « AXD v1 »

- New design main improvements:
  - Scintillator inserted at 1.3 m from the source
  - Imaging system hold by real mechanics ->> no more instable setup
  - Use of a commercial zoom to ease change of magnification up to M>1
  - Lead protection of the imaging system to avoid killing one camera per month…
  - Motorized focusing system to enable focusing on-line with the SR



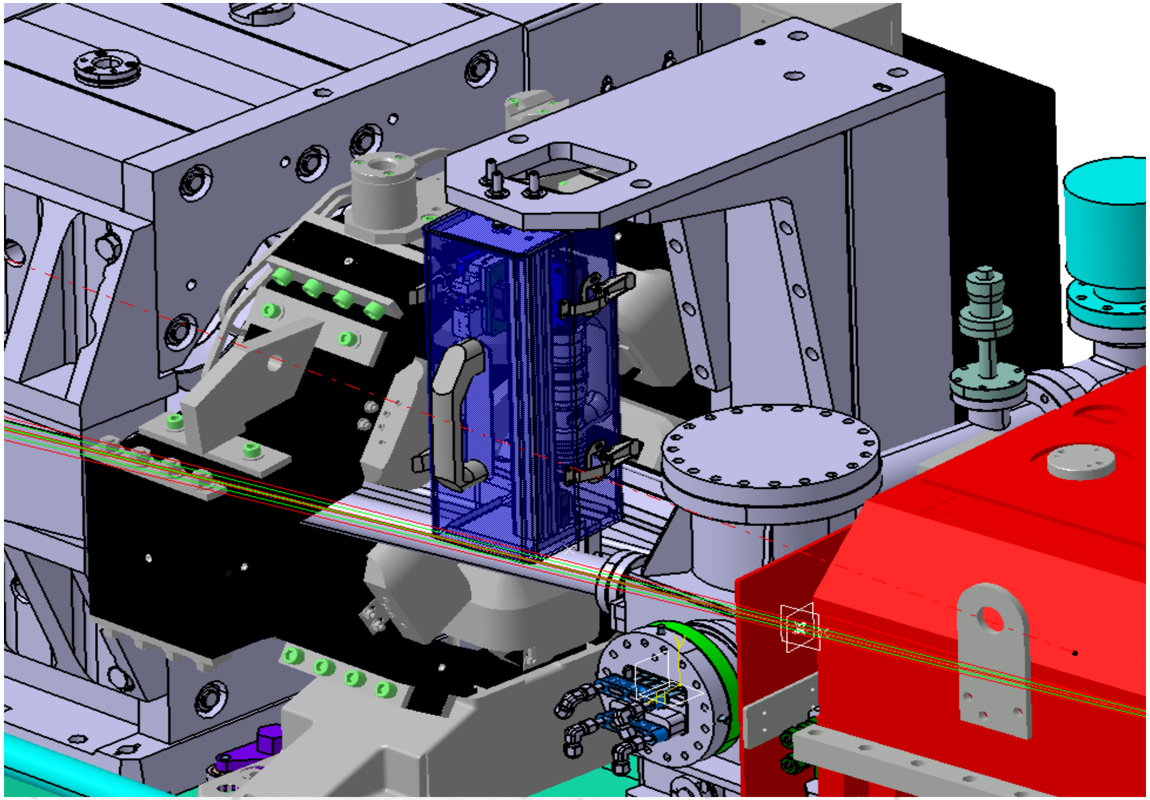
« AXD v1 »: design

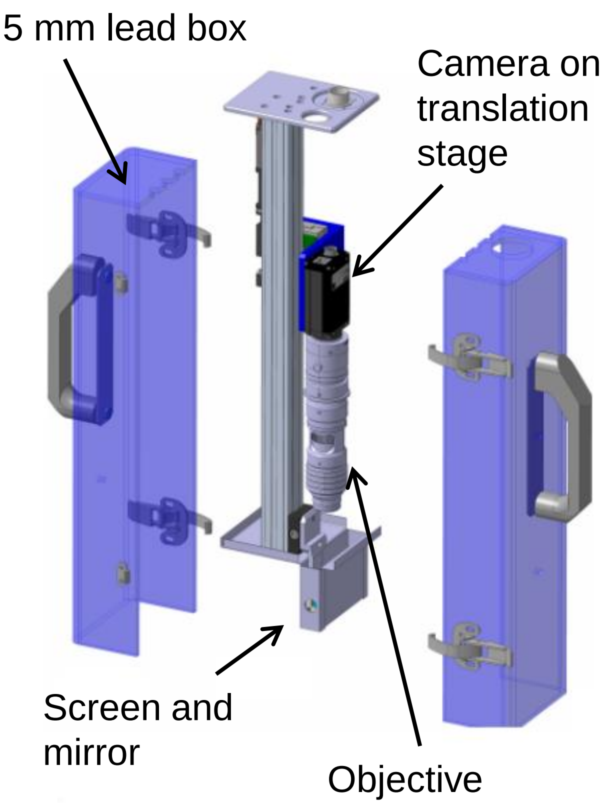
- New design main improvements:
  - Scintillator inserted at 1.3 m from the source



« AXD v1 »: design

- New design installed in august 2016



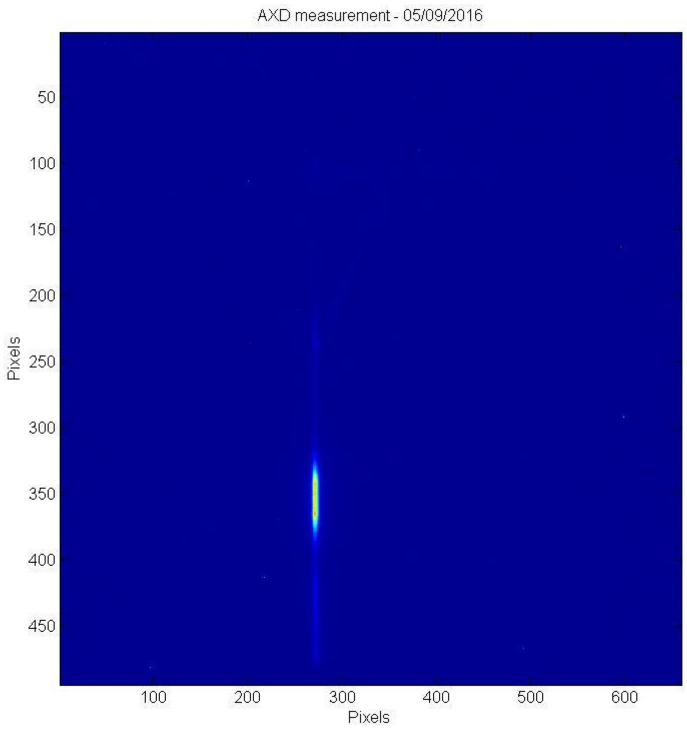


« AXD v1 »: design

- Installation in august 2016

« AXD v1 »: Preliminar measurements

- Preliminar measurements in “large field” mode

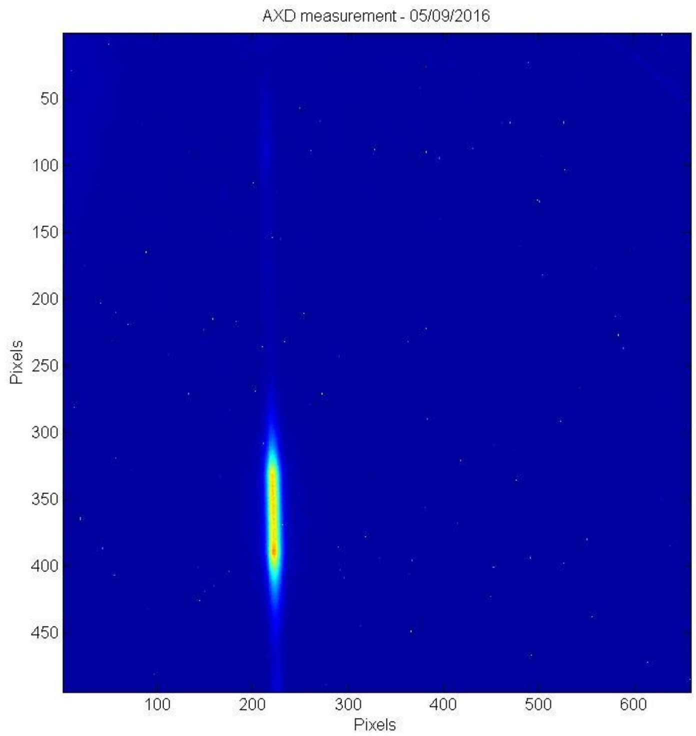


- G=0.35
- Σ = 55 µm-rms for 35.7 µm-rms @ PHC1
- Exp. Time = 2 s

G=0.35

« AXD v1 »: Preliminar measurements

- Preliminar measurements in “large field” mode

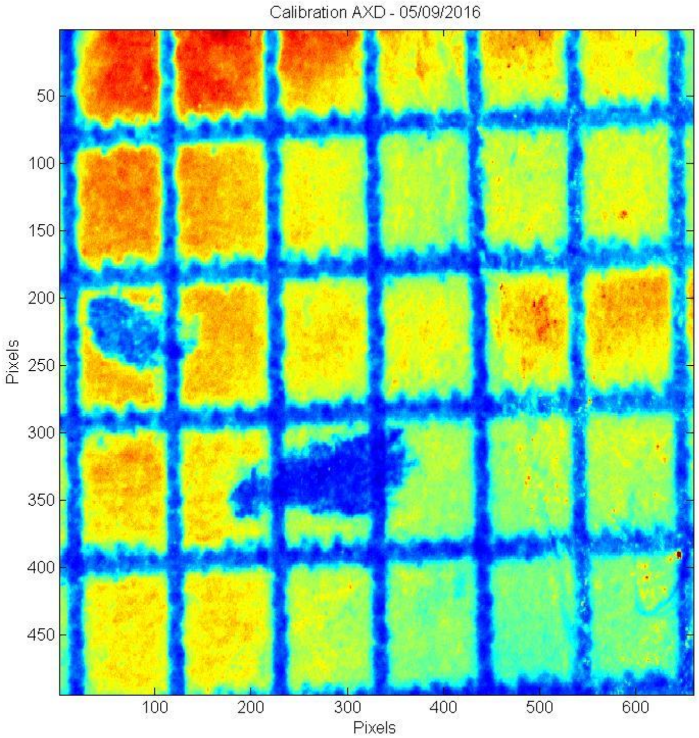


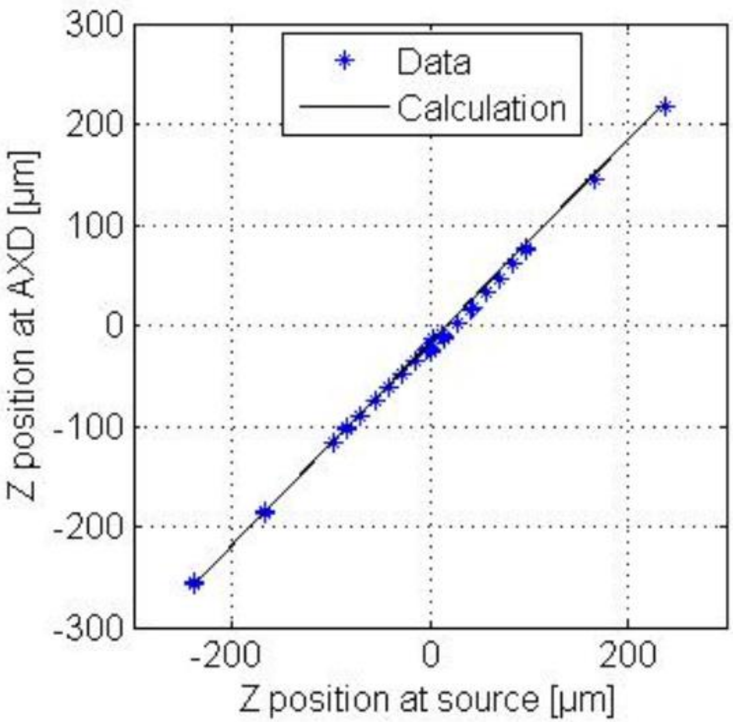
G=0.78

- G=0.78
- Σ = 49 µm-rms for 37.7 µm-rms @ PHC1
- Exp. Time = 5 s

« AXD v1 »: Preliminar measurements

- Calibration procedure:





- Record of a 0.5 mm grid
- Beam position measurement versus bumps

(using a device to calculate the exact source point position using BPM readings)

->> Cross-check = OK

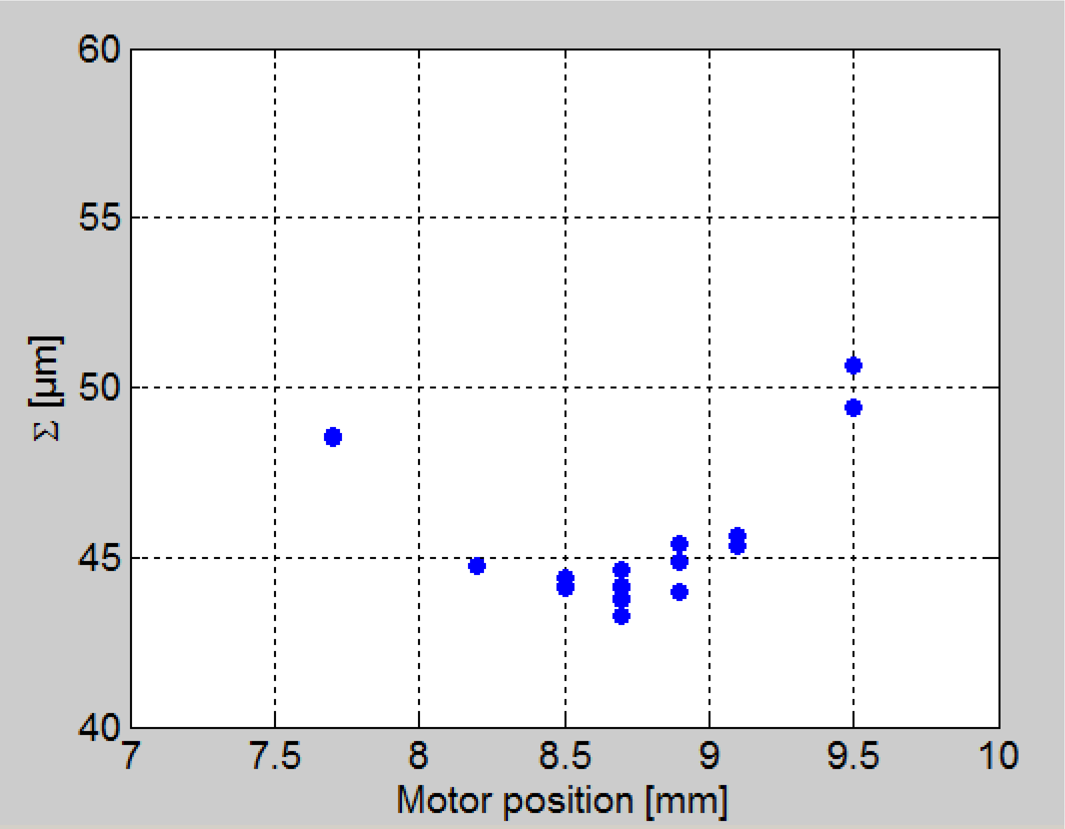
« AXD v1 »: design modifications

- The initial design did not enable to increase the zoom !!

- Mechanical modifications of September 2016:
  - Increase the size of the three holes on the horizontal arm on top of the post. This was to enable a larger range of adjustment of the rotation in Z and of the position in X of the whole imager assembly.
  - Increase the size of the hole to pass the camera connectors. The initial hole limited the range of translation in Z of the camera.
  - Make a plate of 5 mm thickness to elevate the camera and therefore displace it in the x direction towards the inside of the ring. The range of translation in X of the camera was not enough to center the tooth image on the CCD.

« AXD v1 »: focussing adjsutement

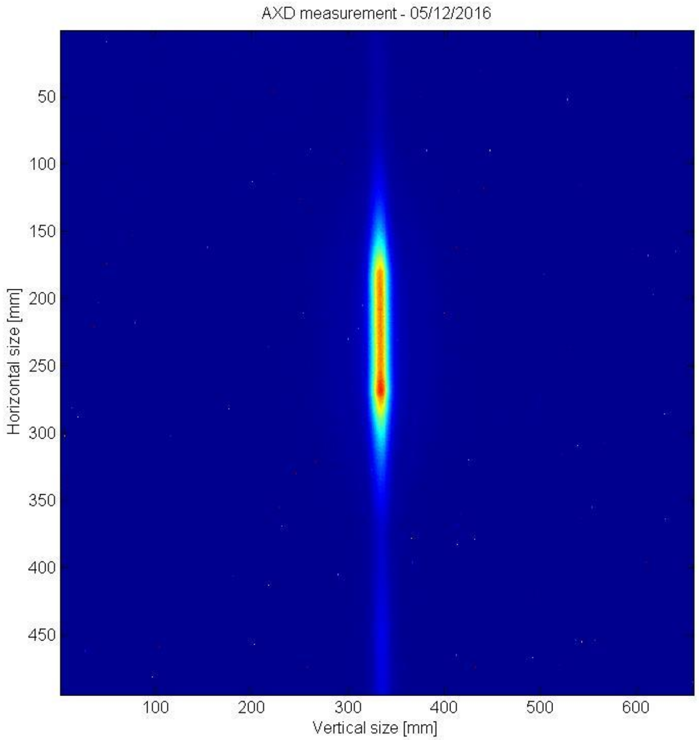
- On-line focussing adjustment minimizing the SR layer vertical size:



M ~ 1.16

« AXD v1 »: measurements

- Recent measurements in "small field" mode

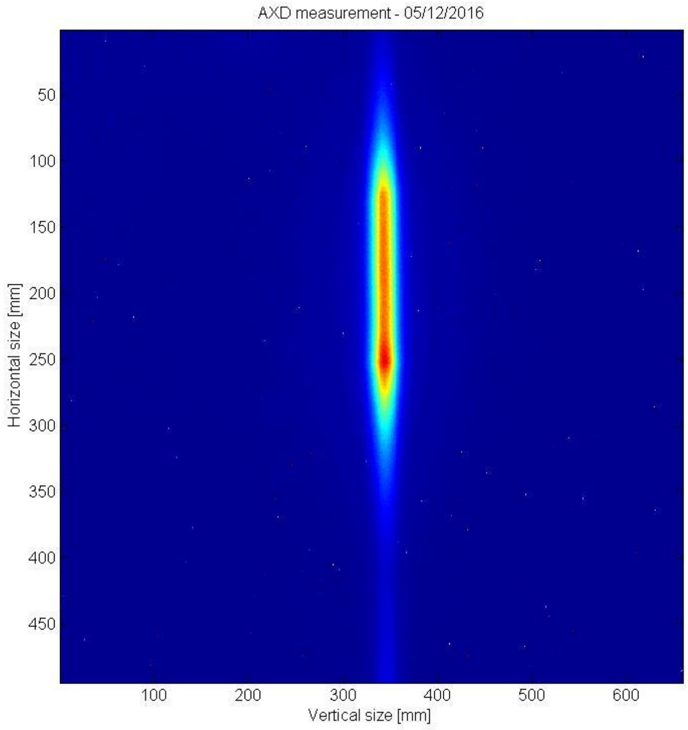


G=1.16

- M = 1.16
- Σ = 45 µm-rms for 15 µm-rms @ PHC1
- Σ = 48 µm-rms for 37 µm-rms @ PHC1
- Exp. Time = 6 s

« AXD v1 »: measurements

- Recent measurements in “smalest field” mode ->> zoom max

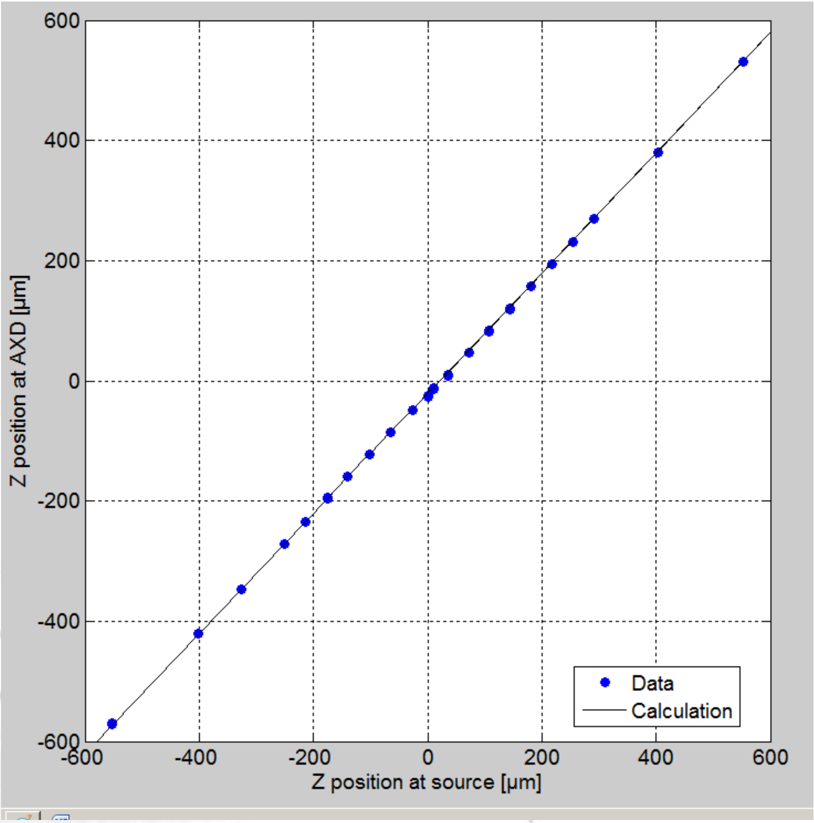


G=1.65

- M = 1.65
- Σ = 45 µm-rms for 15 µm-rms @ PHC1
- Σ = 48 µm-rms for 37 µm-rms @ PHC1
- Exp. Time = **10 s**

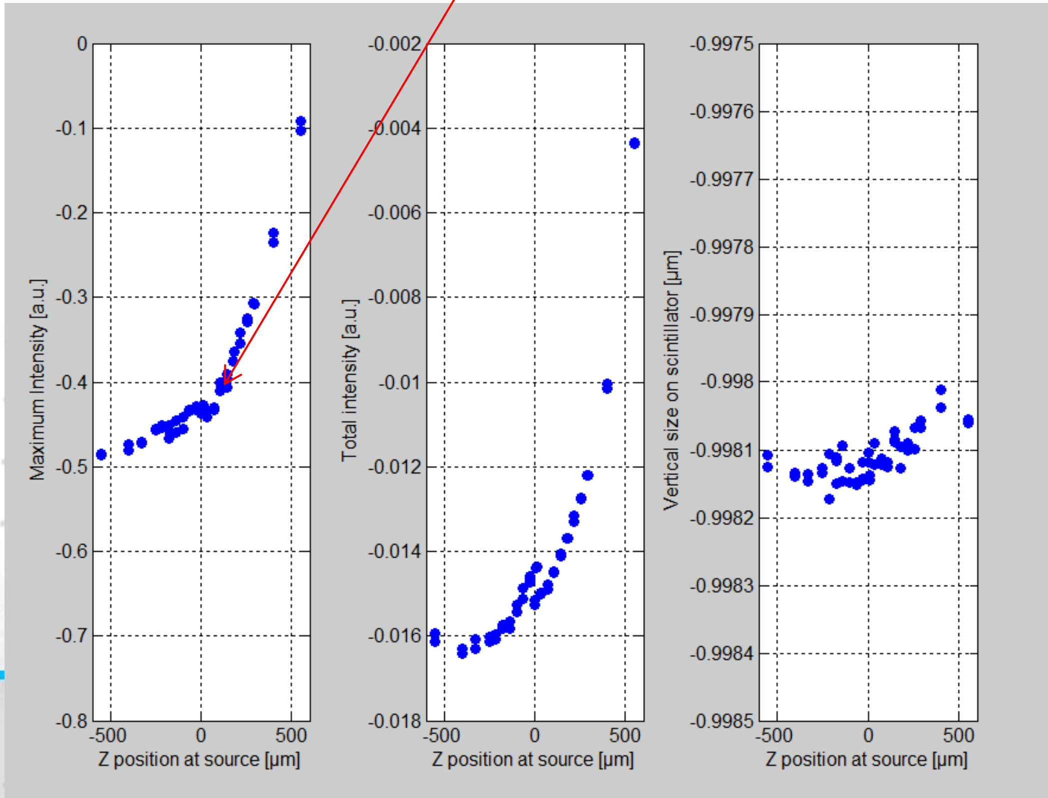
SR layer versus vertical bumps ->> calibration

- “Clean” procedure computing the expected position at the AXD location.
- But…

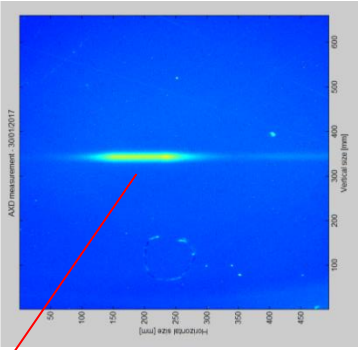


SR layer versus vertical bumps ->> calibration

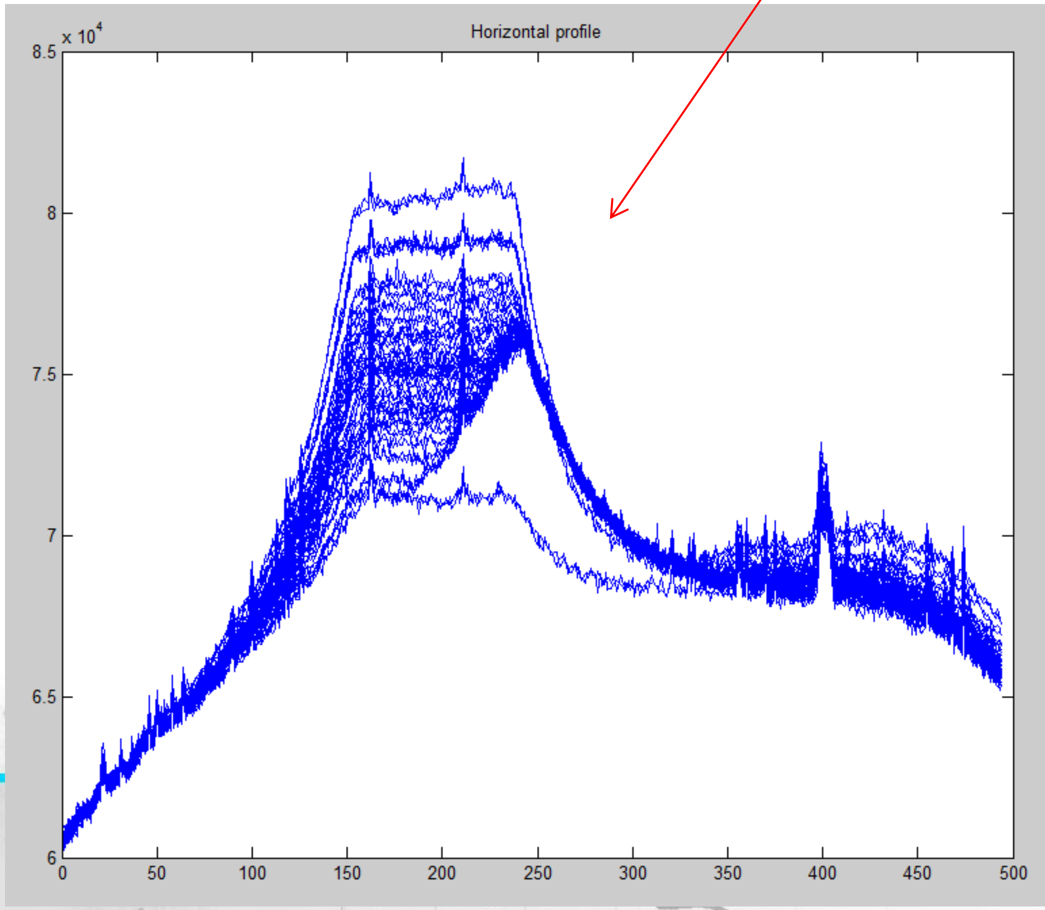
- But…
- Strange observations:
  - Intensity increases when beam goes up
  - No symetry up / down ???
  - Break in the intensity increase slope above the orbit plane ???
  - Slight increase of the vertical beam size ???



SR layer versus vertical bumps ->> calibration

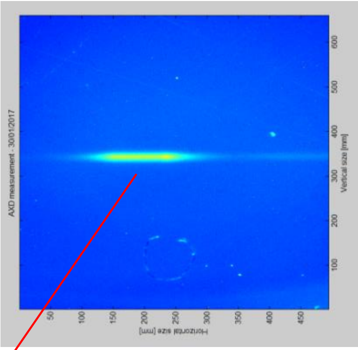


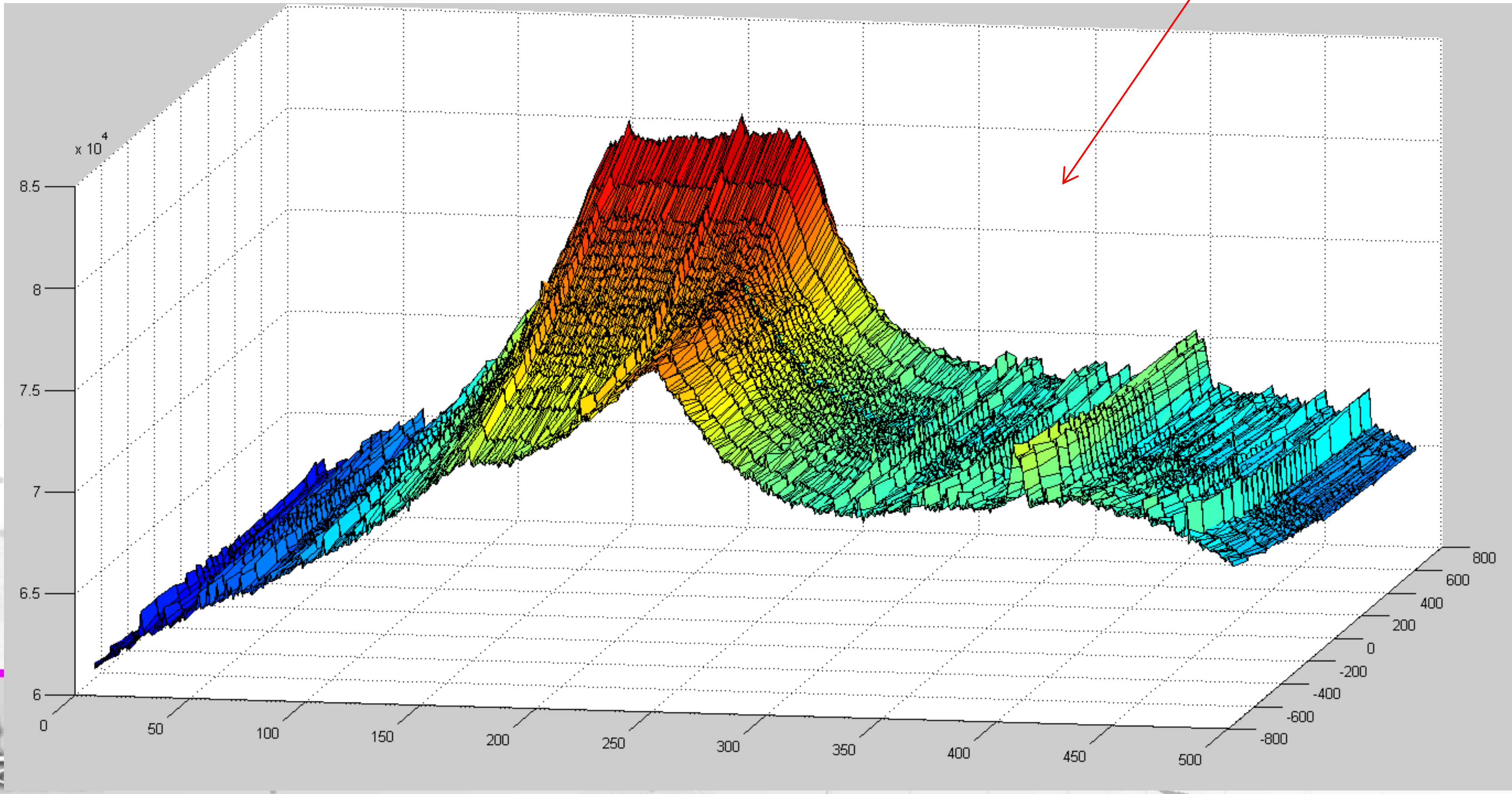
- But…
- Strange observations:
  - A « triangle » appears in the H distribution when beam goes down ???



SR layer versus vertical bumps ->> calibration

- But…
- Strange observations:
  - A « triangle » appears in the H distribution when beam goes down ???



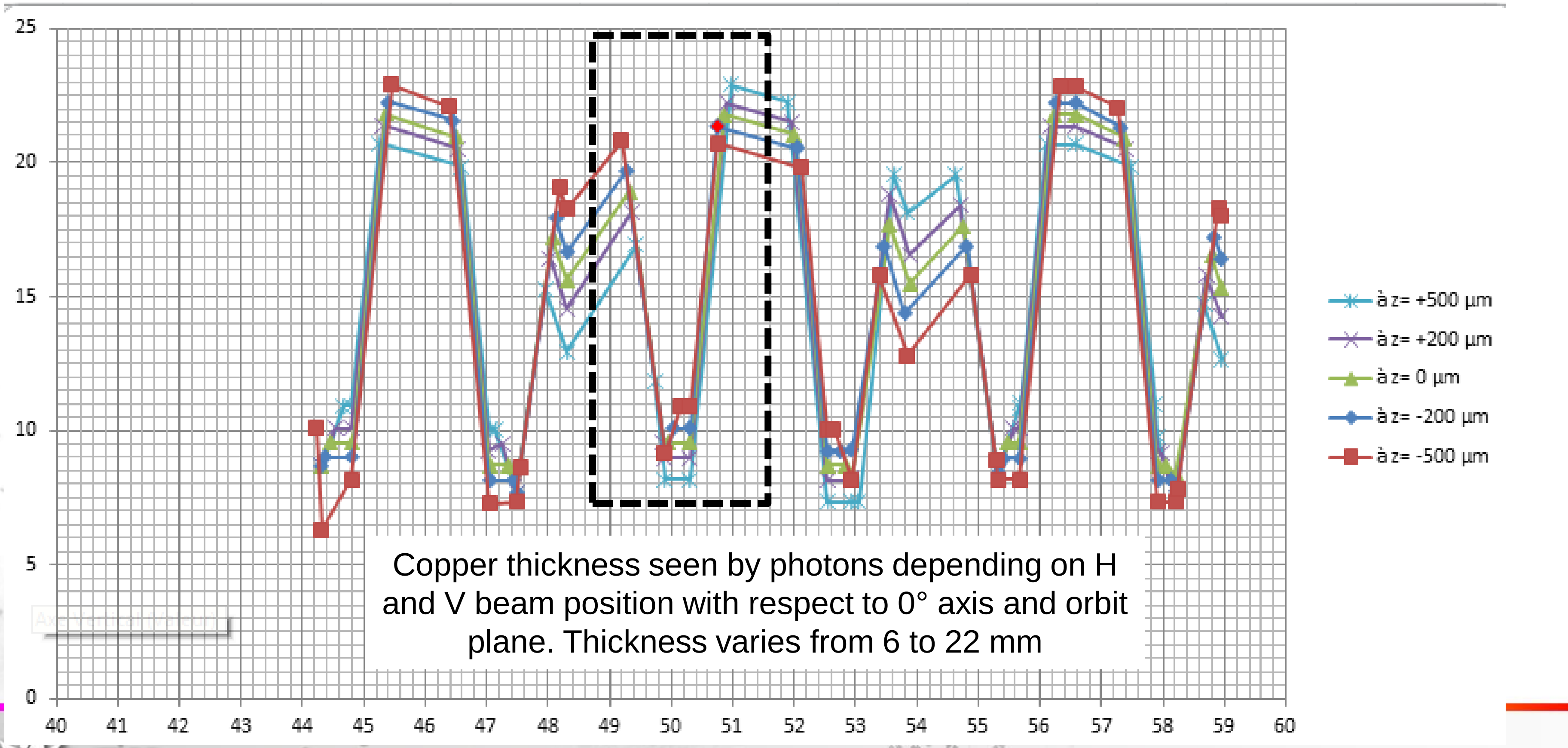


SR layer versus vertical bumps ->> calibration

- Strange observations:
  - ->> Back to crotch design…
  - ->> Refined calculation of crotch thickness versus Z axis…

SR layer versus vertical bumps ->> calibration

- Strange observations:
  - ->> Back to crotch design…
  - ->> Refined calculation of crotch thickness versus Z axis…



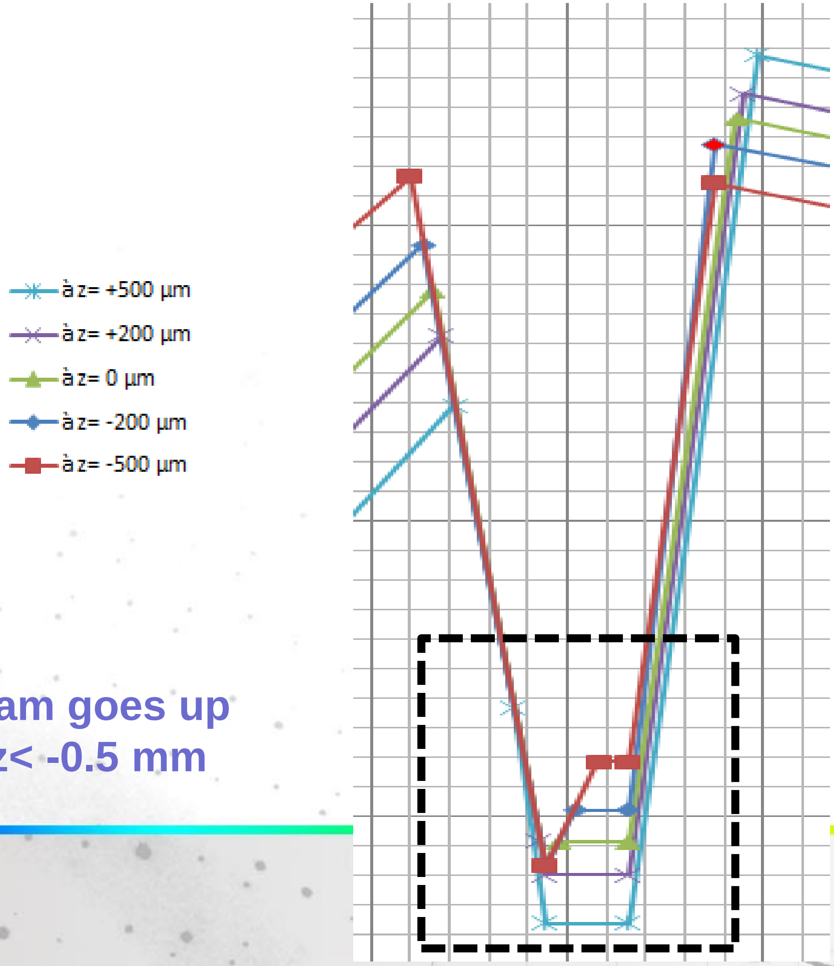
SOLEIL SYNCHROTRON

SR layer versus vertical bumps ->> calibration

- Strange observations:

  ->> Back to crotch design…

  ->> Refined calculation of crotch thickness versus Z axis…



- **Thickness reduces when beam goes up**
- **« Hole » in the thickness at z< -0.5 mm**

SR layer versus vertical bumps ->> calibration

- **Thickness reduces when beam goes up:**

  ->> Intensity increases when beam goes up ☺

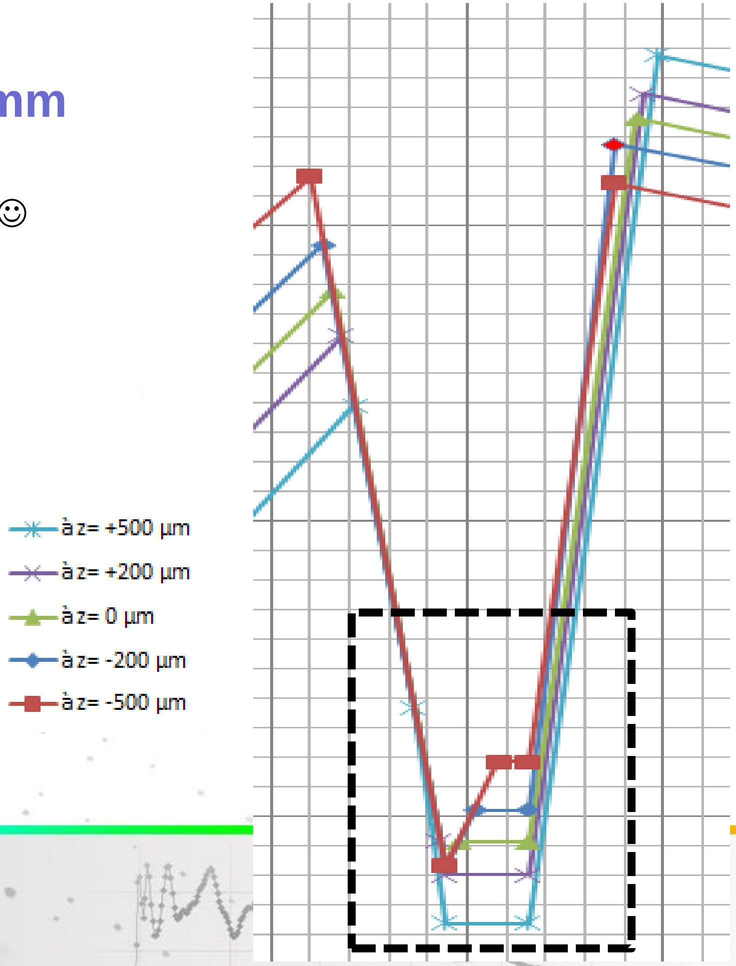
  ->> No symetry up / down ☺

  ->> Slight increase of the vertical beam size ☺

- **« Hole » in the thickness at z< -0.5 mm**

  ->> Break in the intensity increase slope ☺

  ->> A « triangle » appears in the H distribution ☺



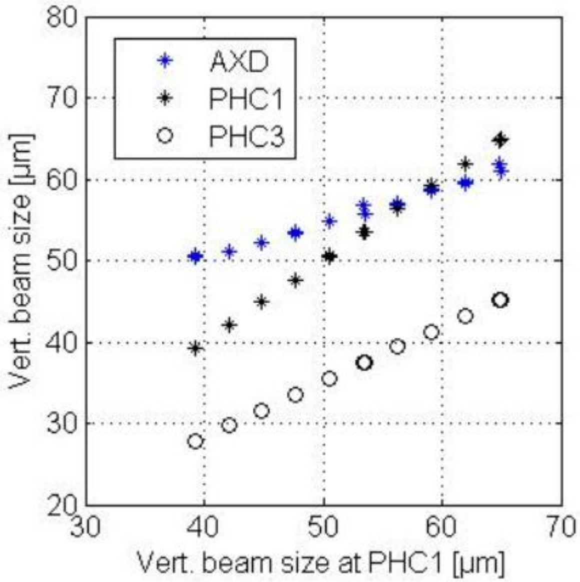
SOLEIL SYNCHROTRON

Beam size versus tunette @ PHC1

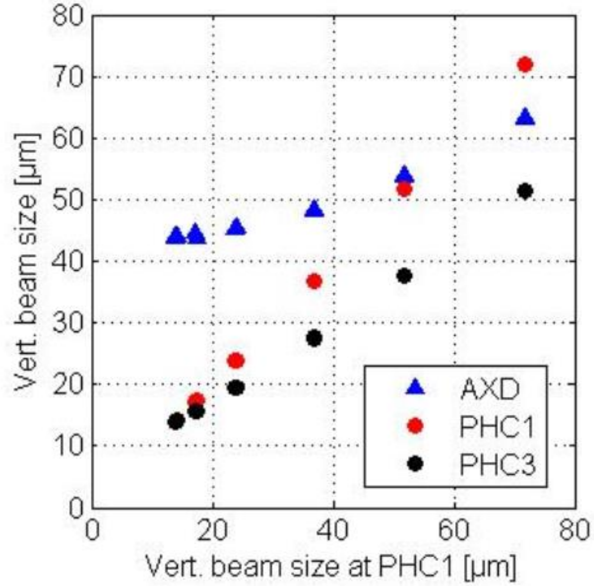
- Beam size tunette
  = vary the coupling, i.e. vertical beam size

- Tunette @ PHC1
  = use PHC1 measurement to control the vertical beam size increase

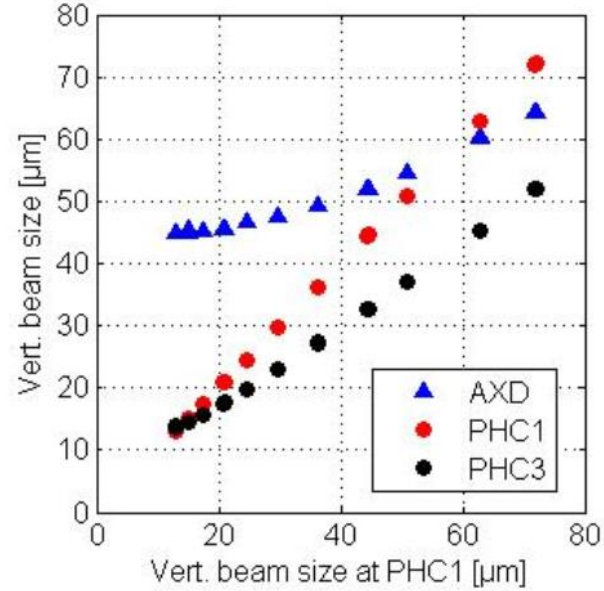
Beam size versus tunette @ PHC1



G=0.78



G=1.16



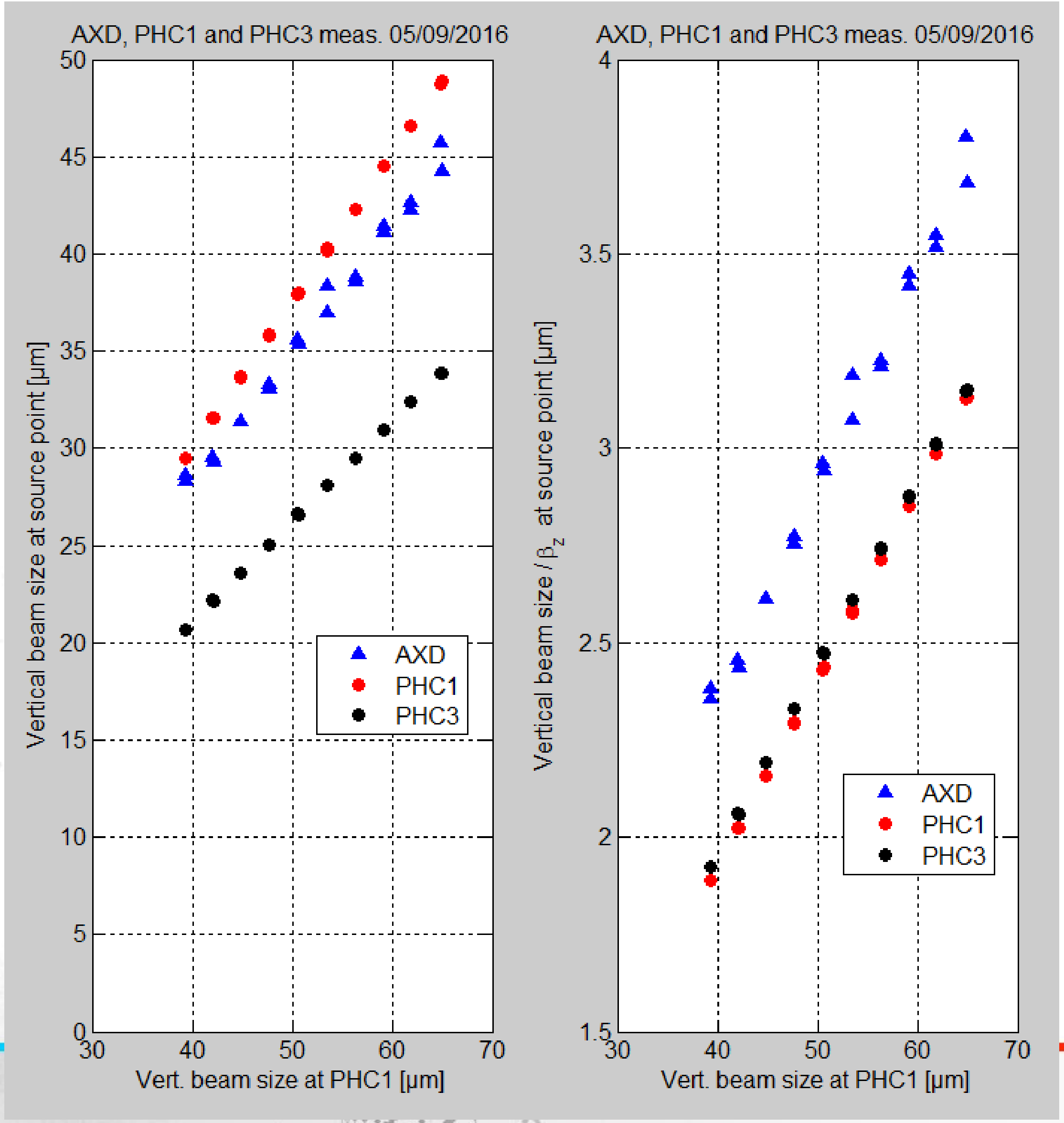
G=1.65

- Resolution improves with M up to 1.16
- No more improvment from 1.16 to 1.65

SOLEIL SYNCHROTRON

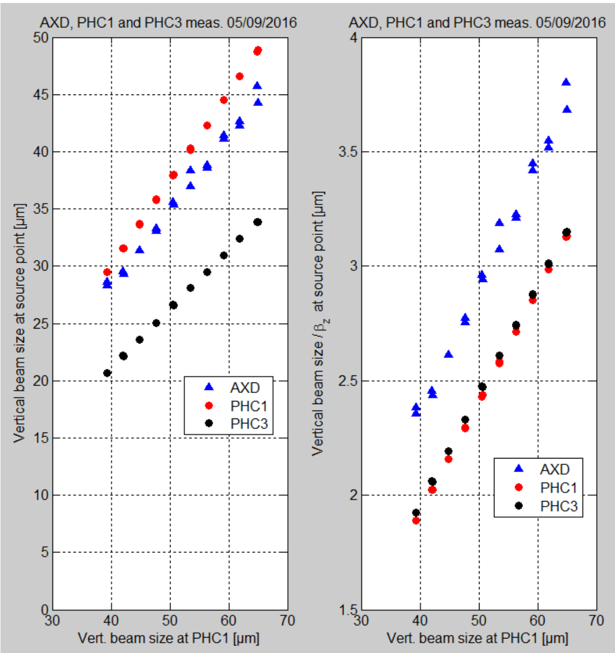
Beam size versus tunette @ PHC1

G=0.78

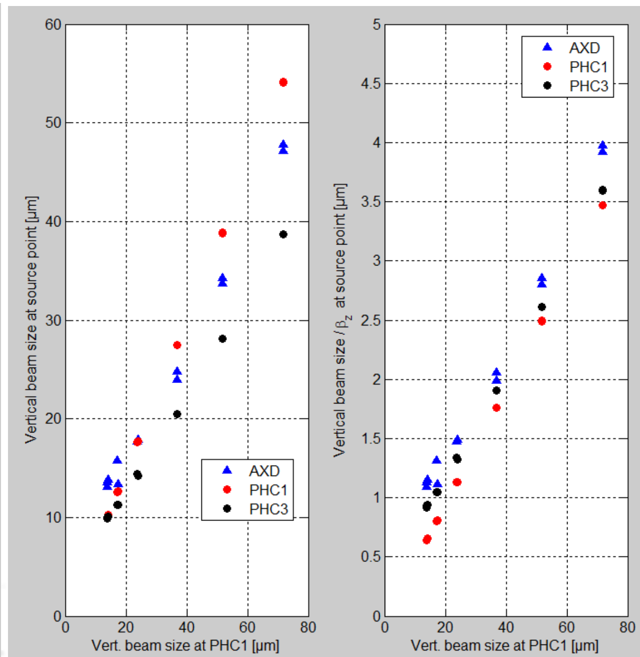


- E=100 keV i.e. 31.53 µrad-rms
- Resolution AXD = 0 pixels.
- Resolution PHC = 4.55 µm-rms

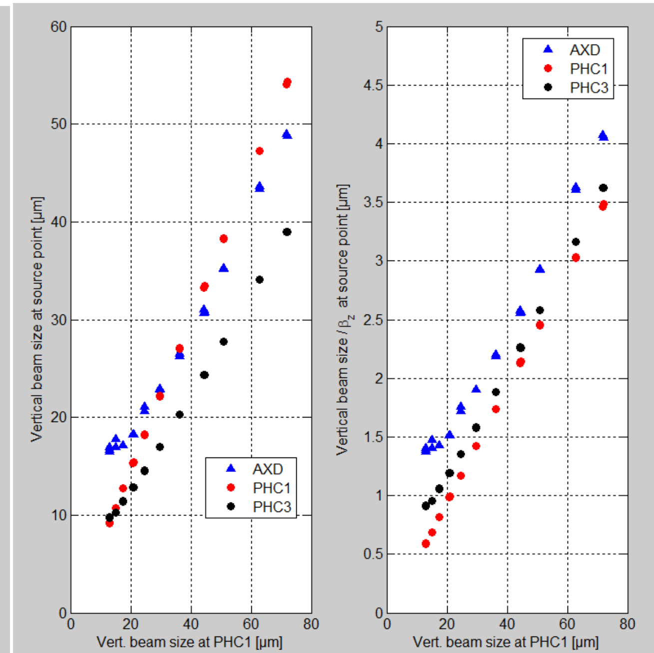
Beam size versus tunette @ PHC1



G=0.78



G=1.16



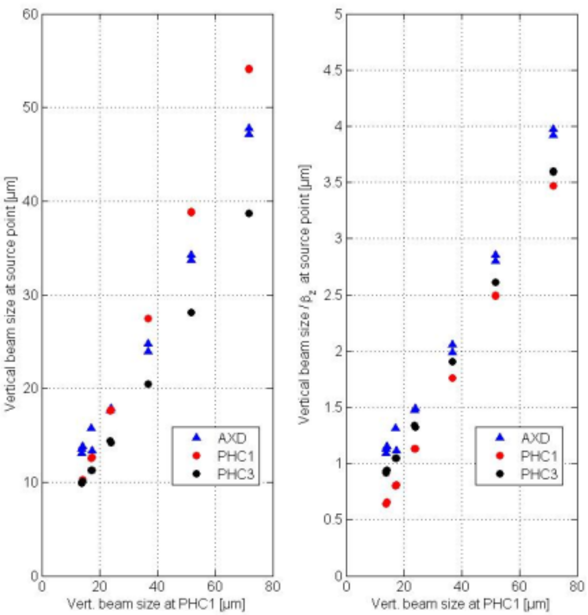
G=1.65

- E=100 keV i.e. 31.53 µrad-rms
- Resolution AXD = 0 pixels.
- Resolution PHC = 4.55 µm-rms

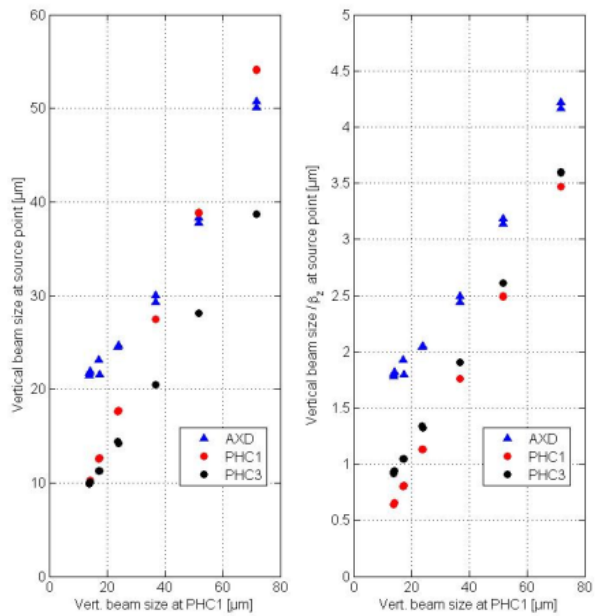
Beam size versus tunette @ PHC1

Experiment vs analytical model:

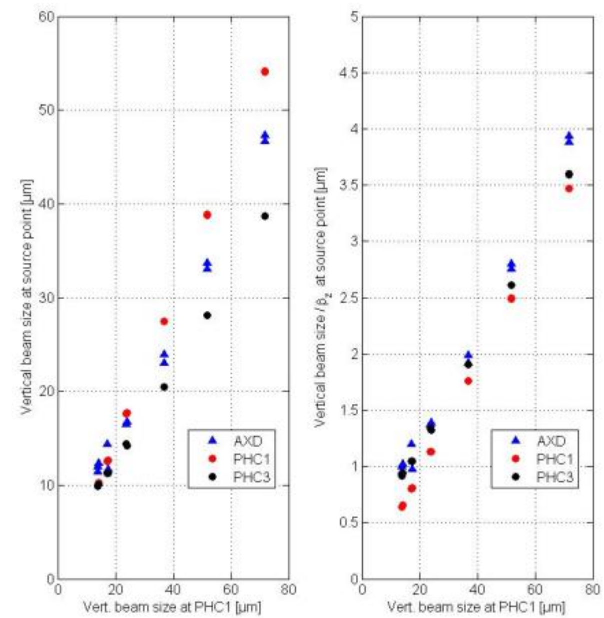
G=1.16



- E=100 keV i.e. 31.53 µrad-rms
- Resolution AXD = 0 pixels.
- Resolution PHC = 4.55 µm-rms



- E=120 keV i.e. 28.8µrad-rms
- Resolution AXD = 0 pixels.
- Resolution PHC = 4.55 µm-rms

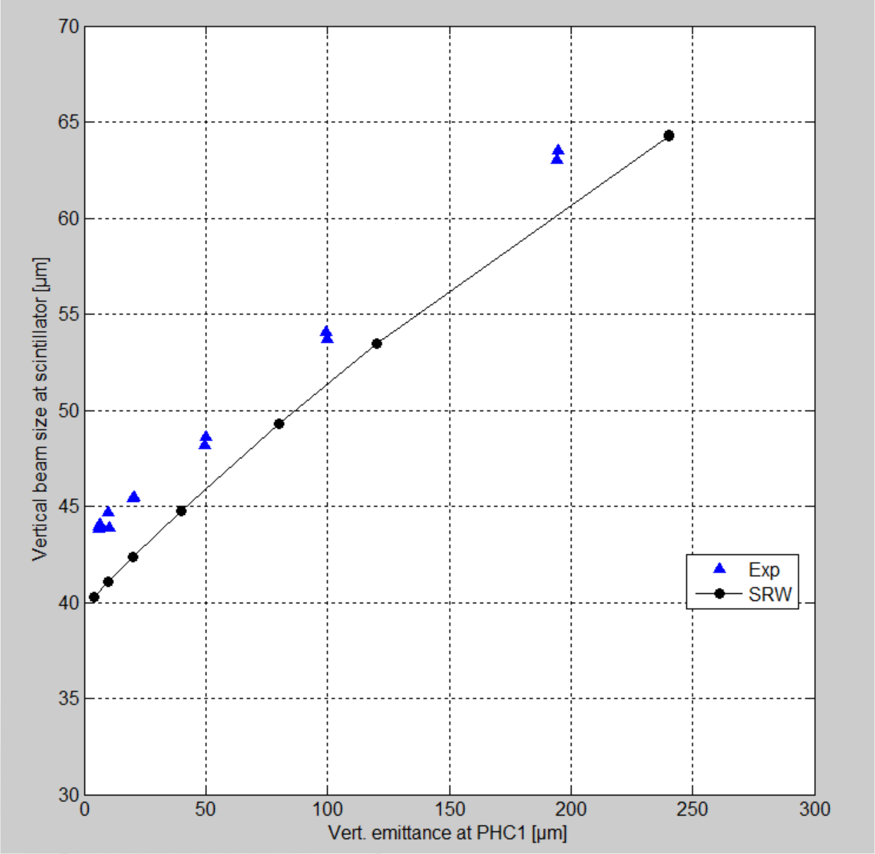


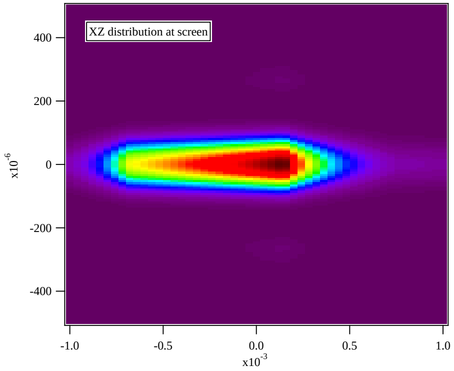
- E=100 keV i.e. 31.53 µrad-rms
- Resolution AXD = 1 pixels.
- Resolution PHC = 4.55 µm-rms

Beam size versus tunette @ PHC1

Experiment vs SRW simulation:

G=1.16



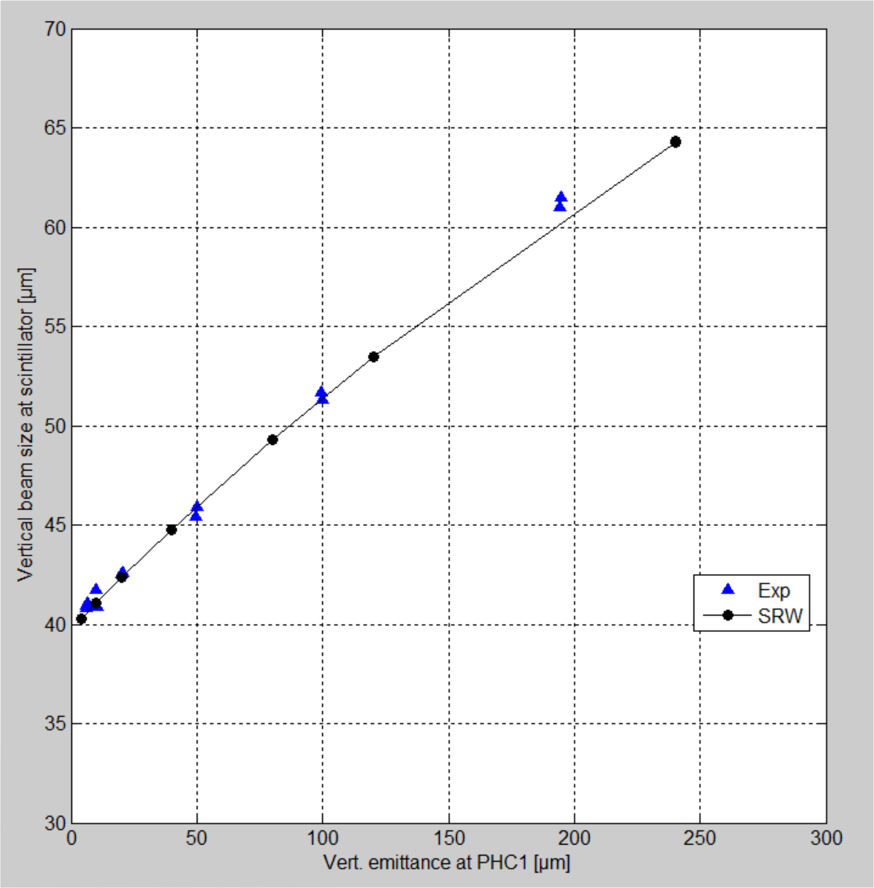


- Res. AXD = 0 pixels
- Crotch: 8.94 g/cm3
- CaV: 8.00 g/cm3
- CaV thickness: 20 mm

Beam size versus tunette @ PHC1

Experiment vs SRW simulation:

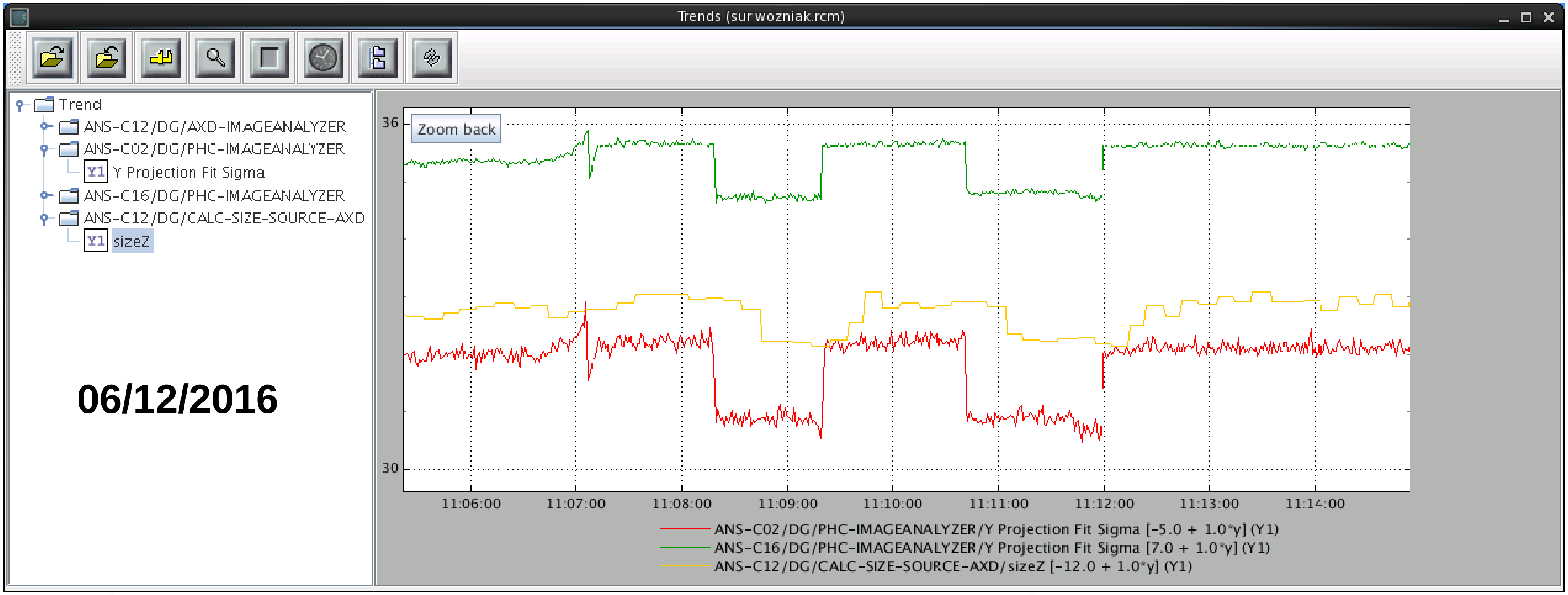
G=1.16



- Res. AXD = 2.5 pixels
- Crotch: 8.94 g/cm3
- CaV: 8.00 g/cm3
- CaV thickness: 20 mm

« AXD v1 » operation

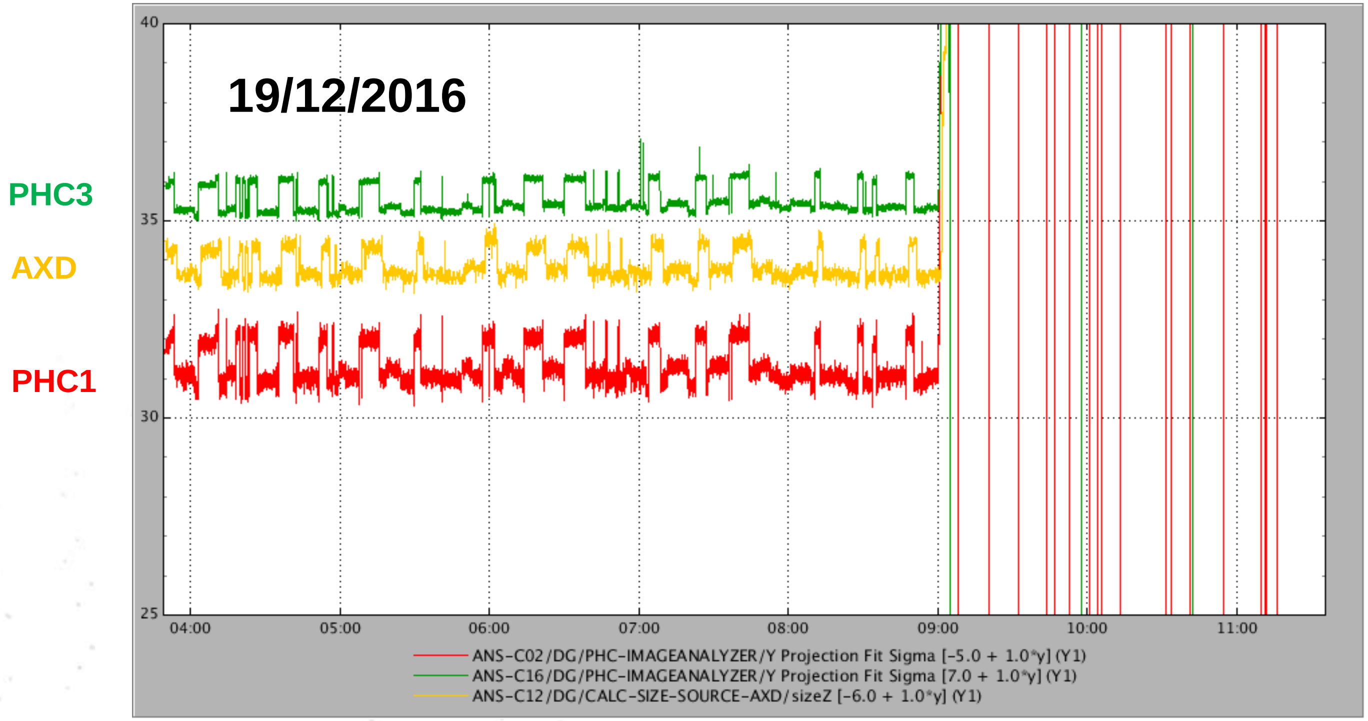
- With the maximum zoom of M = 1.65



- **10 s exposure time ->> hudge smoothing**
- Very low sensitivity to vertical beam size variations

« AXD v1 » operation

- On the 12th of December: back to M = 1.17

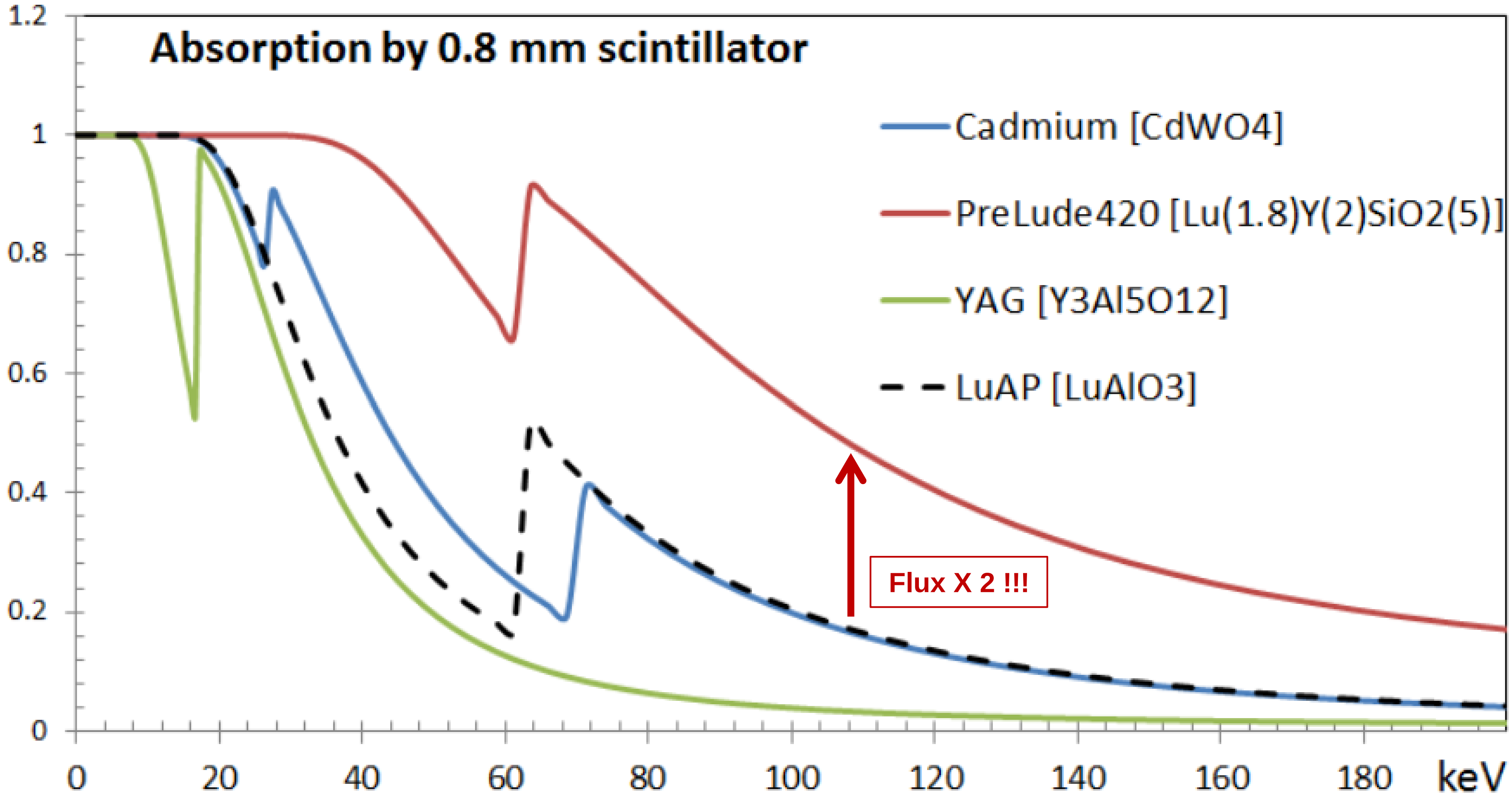


- Recover a 6 or 7 s exposure time
- Recover higher sensitivity in vertical size variation measurements

« AXD v1 » : scintillator comparisons

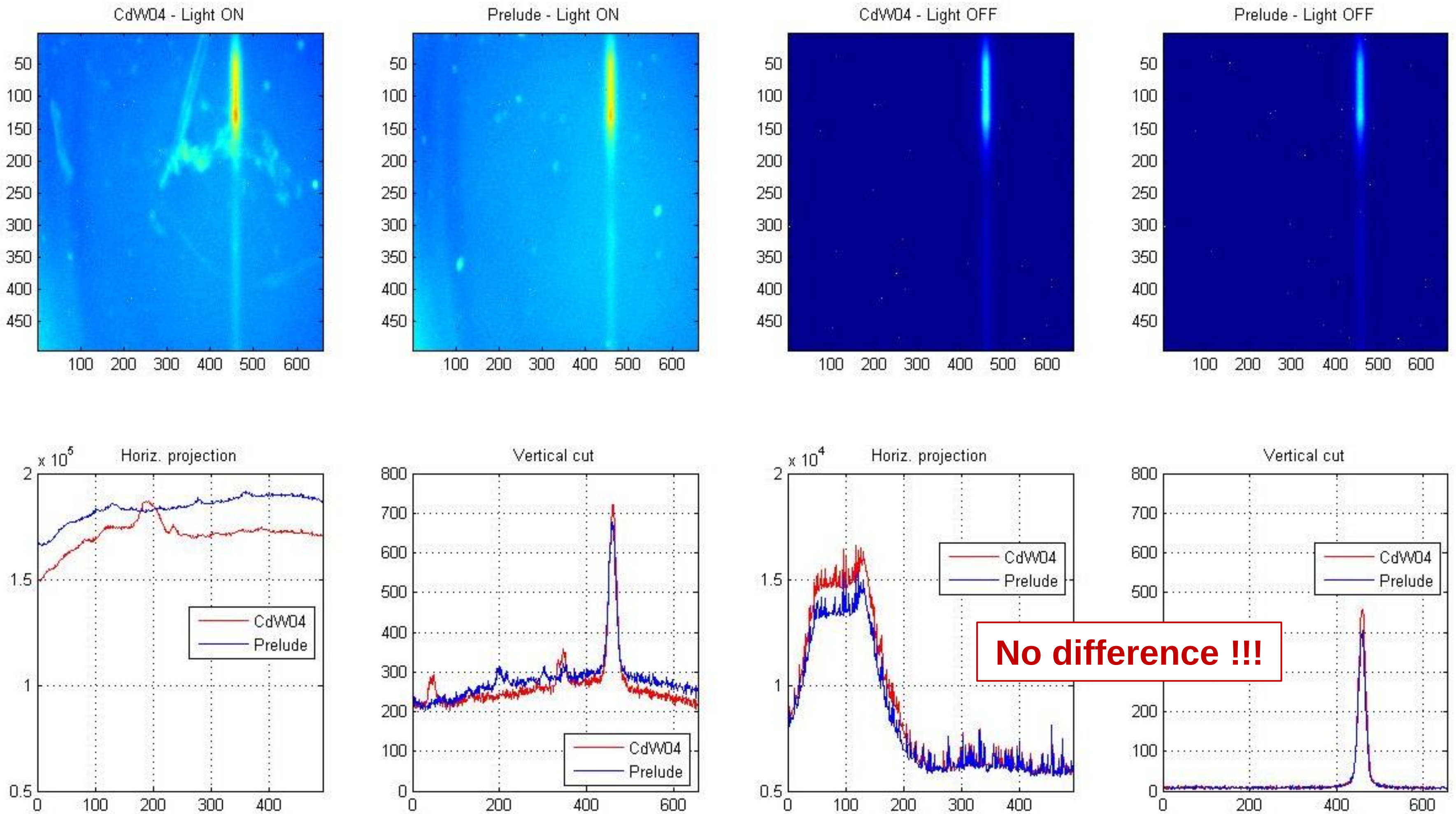
- Scintillator absorption:

Nosych et al., IBIC 2014.



« AXD v1 » : scintillator comparisons

- Comparison of 0.5 mm thick CdW04 and PreLude…



Next steps

- Understand scintillator PreLude non-improvement…
- Improve simulation / experiment to understand size at source point
- Include AXD measurement as input for vertical beam size feedback
- Develop other AXD systems to multiply vertical size measurements
  - ->> refine vertical size correction