Development of diagnostics Based on Scintillating Screens for Ion Beam Characterization

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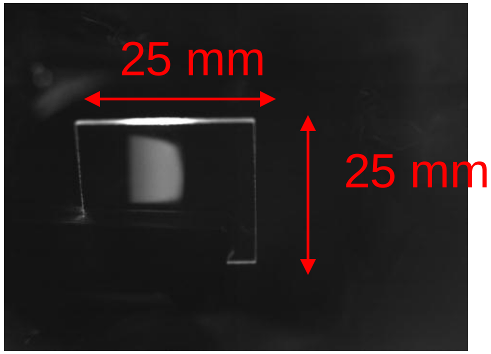
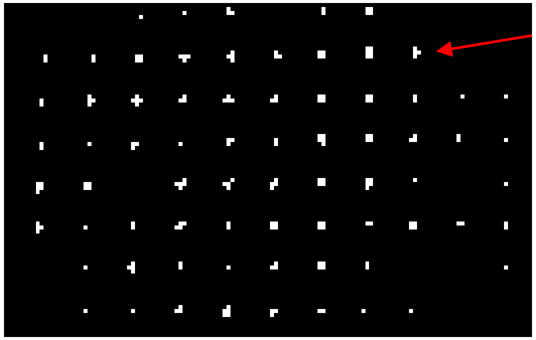
Objectives : “ideal“ scintillator

- **Beam profiler**



- **Pepper-pot device**



Ø pepper-pot holes
50 um
Drift distance:
60 mm

Limiting factor for measuring small beams:

Spatial resolution of the material

In general, Limits from individual grain size; (um scale)

Crystals - uniform at molecular level → high resolution !

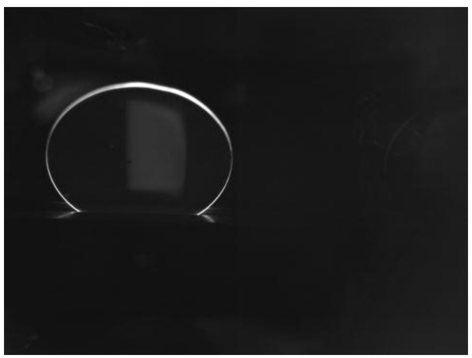
Resolution of CCD camera

High resolution CCD camera with a varifocal lens to adjust the field of view

Experiment 1: Beam Profile Monitor

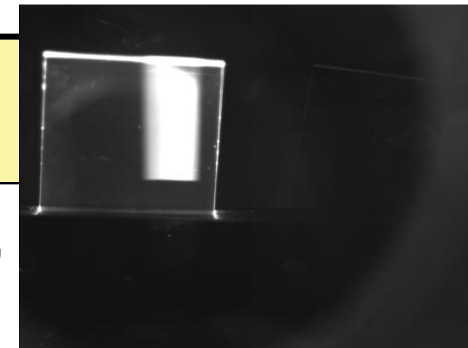
Investigation of the time dependence of Light output at MPI – K (Heidelberg) for low energy high intensity beam

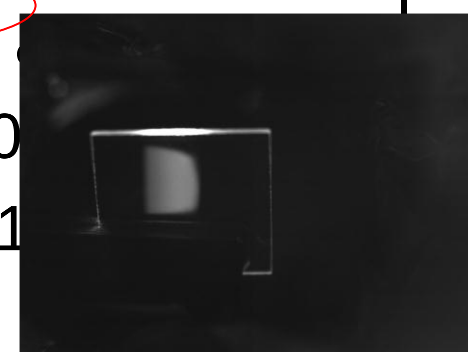
List of materials



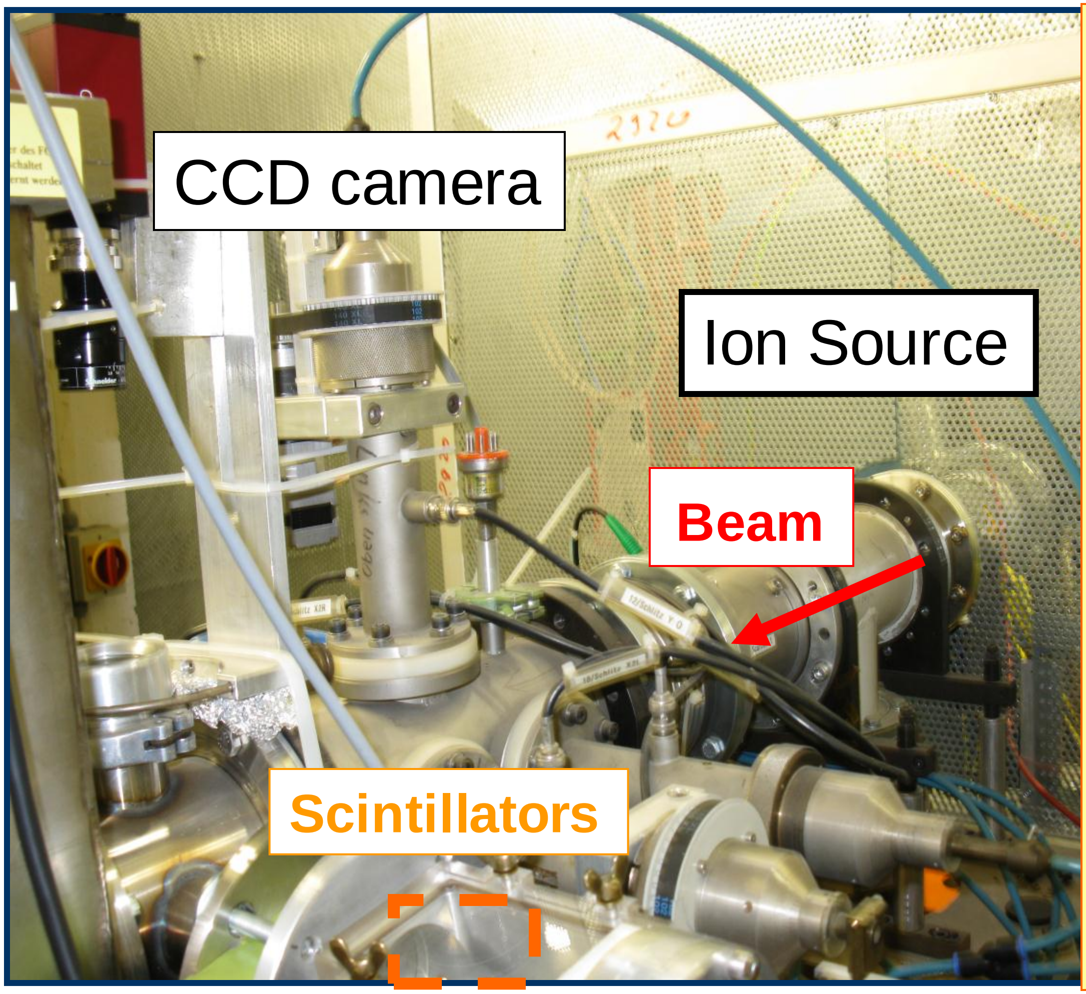
A total irradiation time of 1.5 sec to 2 sec have been applied to each material

Type	Material
Inorganic Doped	YAG:Ce, YAP:Ce
Inorganic Undoped	Sapphire, YAG
Quartz	Herasil 3 Infrasil 30 Suprasil 1
Glass	D 263 T





Experiment 1: Ion beam irradiation Test Setup at MPI-K



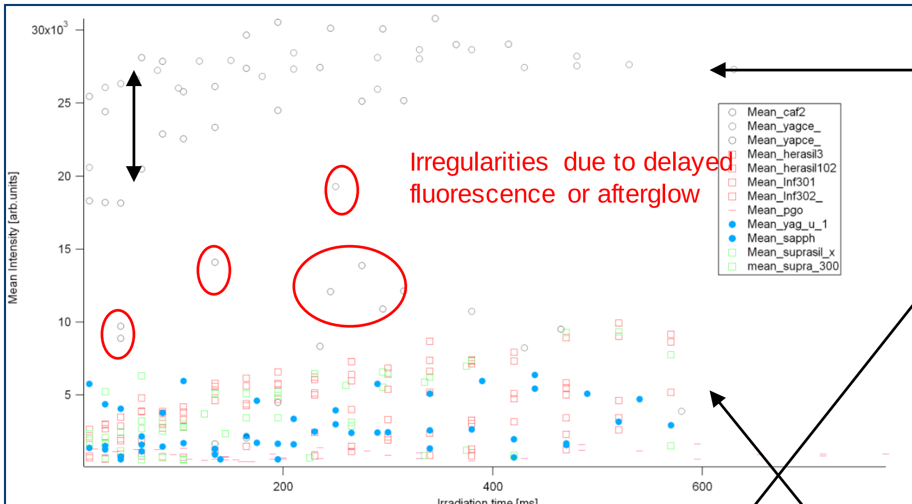
Ion Beam (proton) Characteristics :

- ✓ **Energy** 8 KeV/u
- ✓ **Beam Current** 10 μA
- ✓ **Particles per pulse** : 9.4*10^11– 3*10^13
- ✓ **Variable Pulse Length** 15 ms - 500 ms
- ✓ **Frequency** : 1 Hz
- ✓ **3 Macro Pulses** of each beam pulse

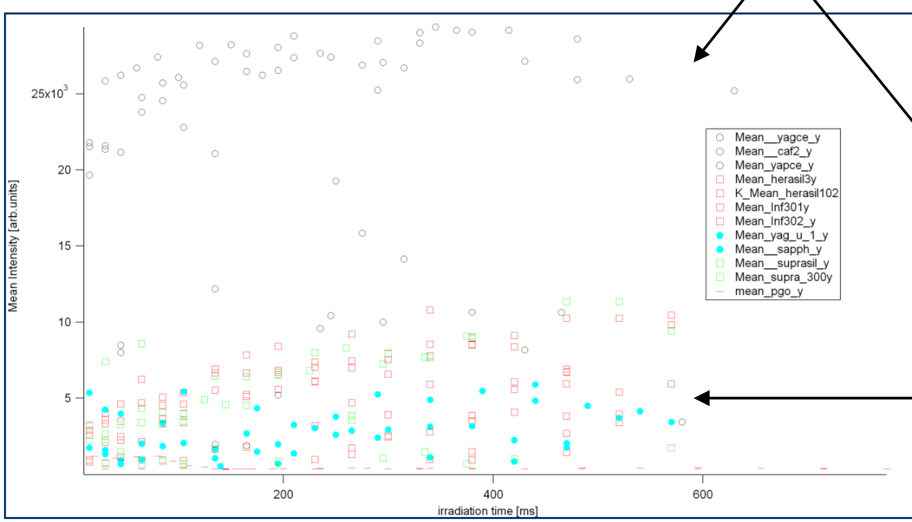
Main results for all scintillators:

Mean Light Output for all materials [a.u] v.s Irradiation Time [ms]

Horizontal Prof.



Vertical Prof.



All doped inorganic materials: YAG:Ce, YAP:Ce, CaF2:Eu.

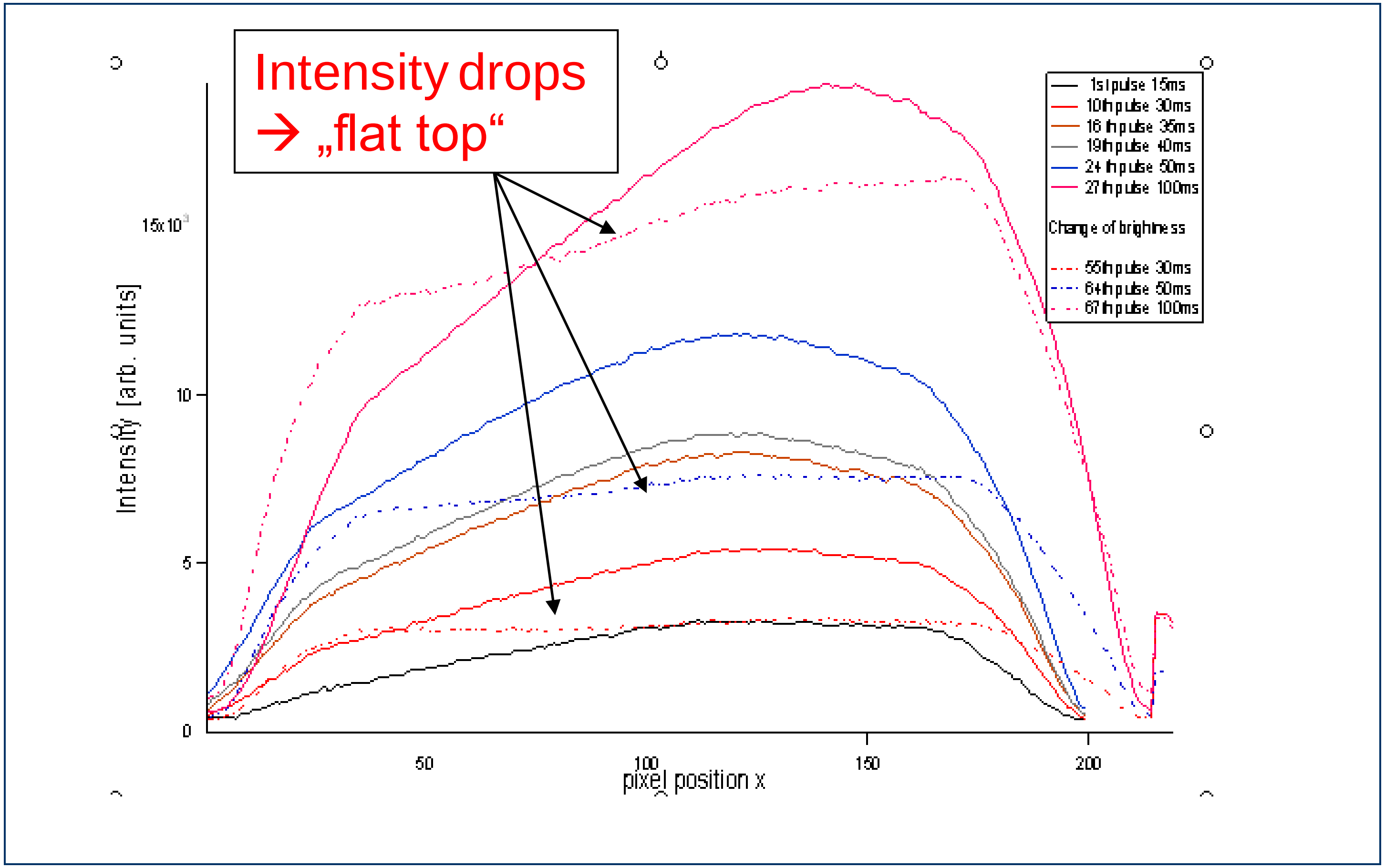
- Highest LO **but** highest fluctuations !

- Lowest LO but Lowest fluctuations !

All other materials: Unoped inorganic material + Quartz.

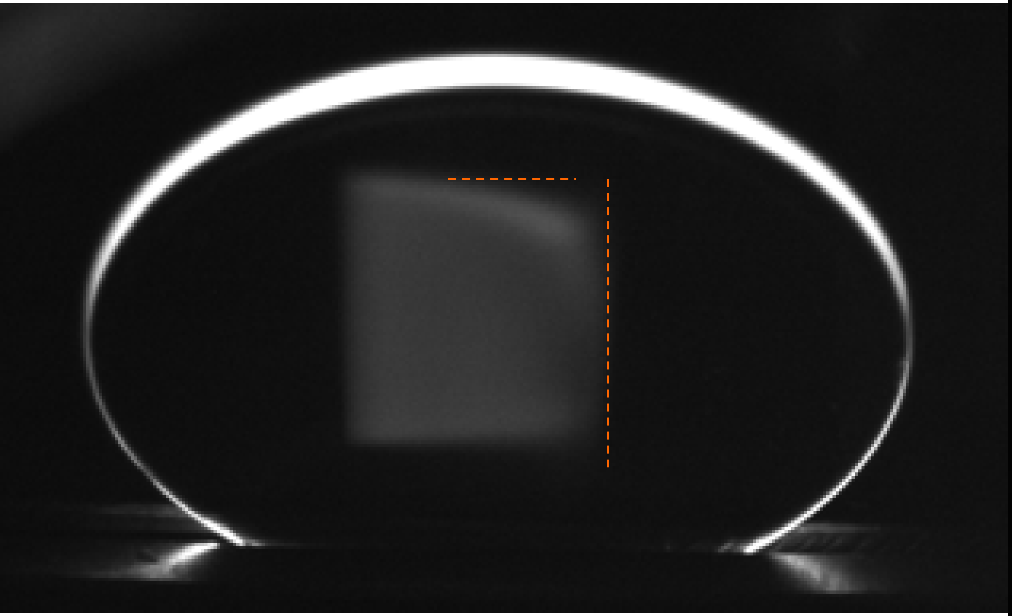
Reproducibility: “broken tooth“ shape

Example of Herasil 3 - Intensity [a.u] v.s Position [pixels] for 65 beam pulses (total integrated time: 2000ms)

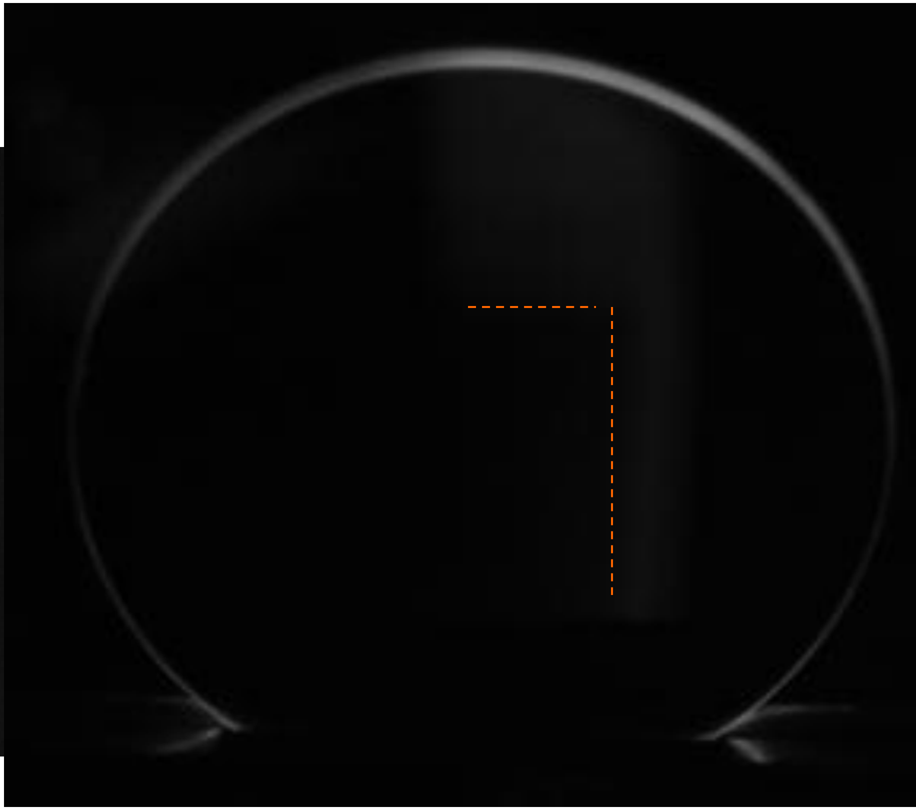


Degradation Effects : YAG Undoped within a irradiation time of 1.3 sec

2nd Macro pulse
of 50 ms pulse



One day later, 1st Macro pulse of
50 ms pulse



Results & Conclusion

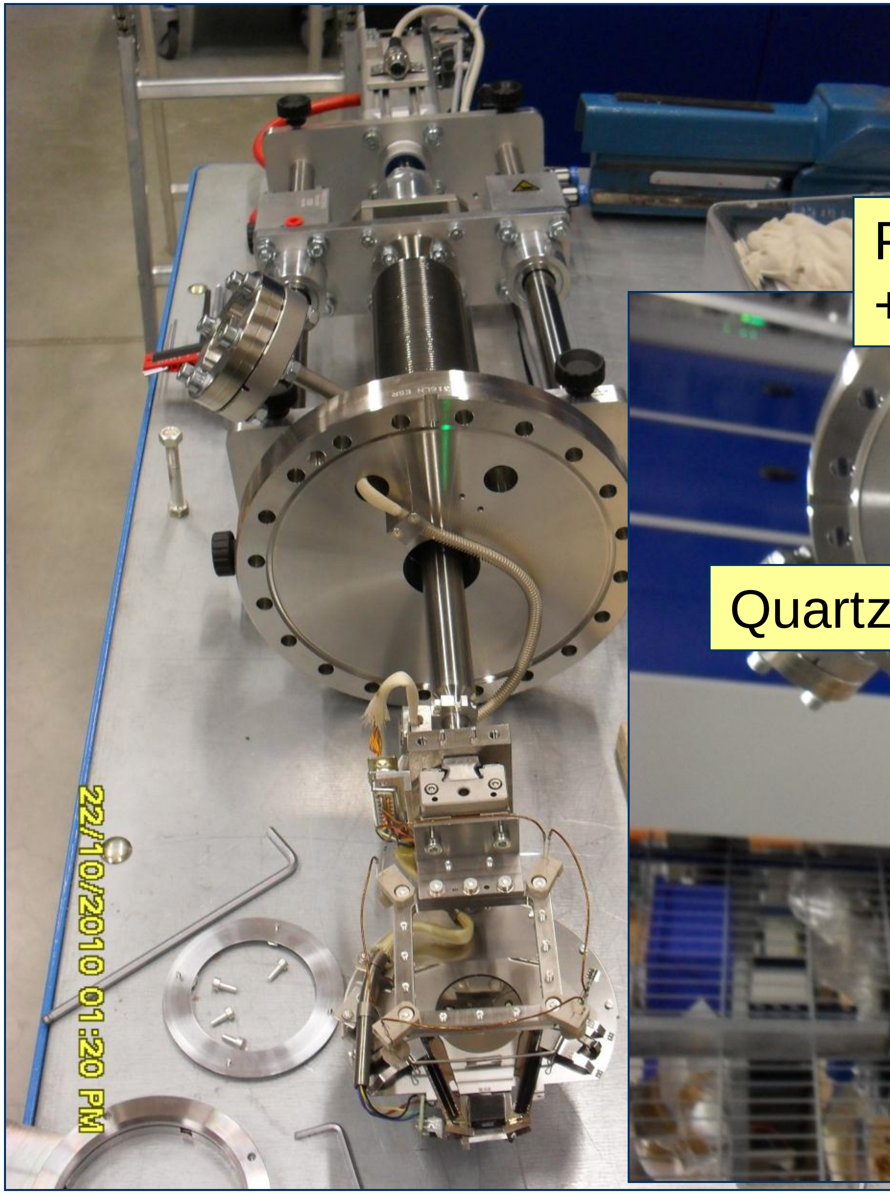
- A complete statistical analysis → No “**Ideal**“ Scintillator could be found !
- **Good candidate**: Quartz (Herasil 3 and Infrasil 3) and even better for lower current !
- **Potential candidate:** YAG:Ce, CaF2:Eu, Suprasil1, Infrasil 30.

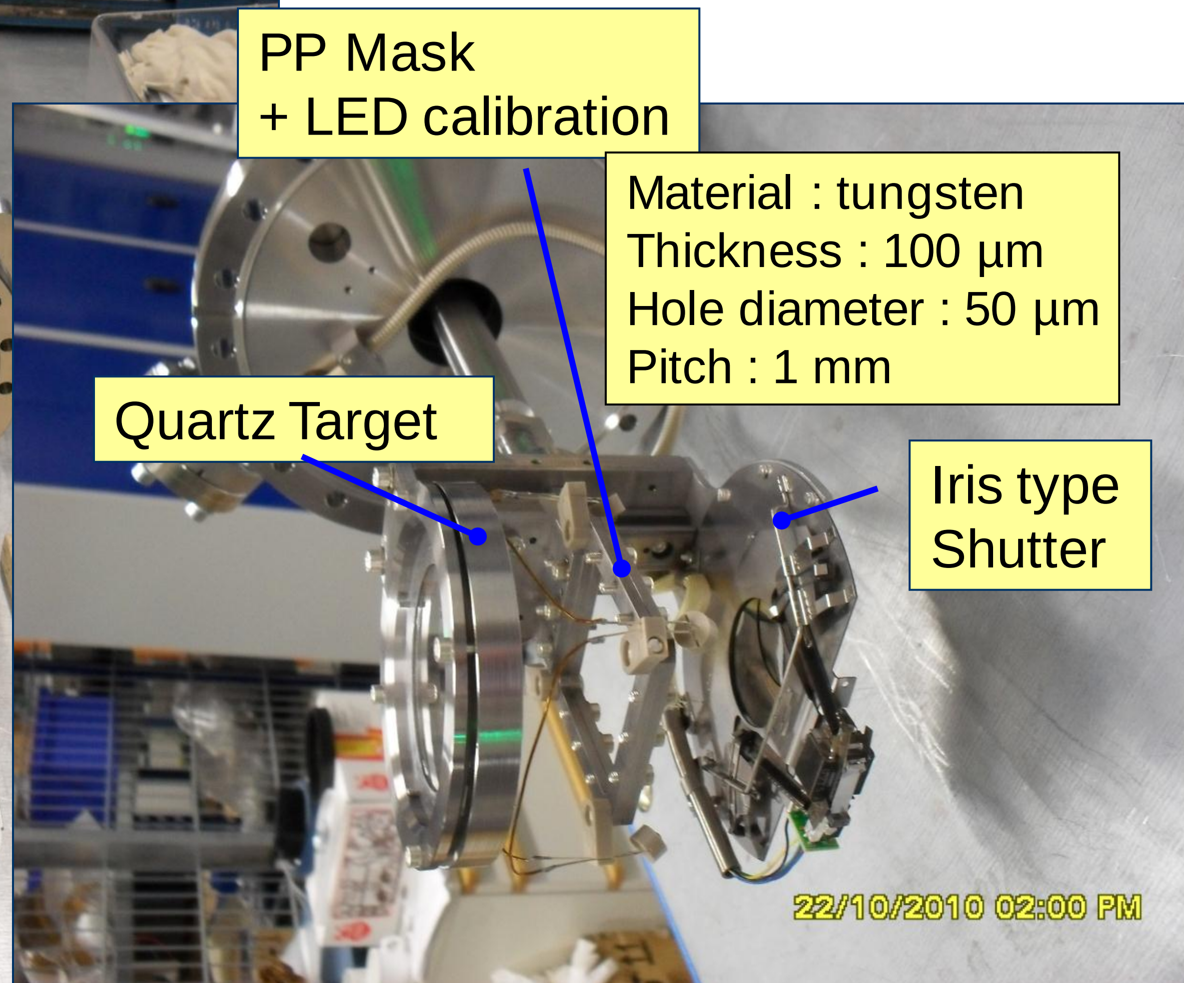
→ Need **further investigation to explain satisfactorily large fluctuations of LO and non-repeatability of measurements.**

- As a **target viewer**: add borosilicate glass (low LO but cheap!)
- As **part of the Pepper-pot**: Quartz are the most reliable one but only for a limited time (for low energy high intensity)!

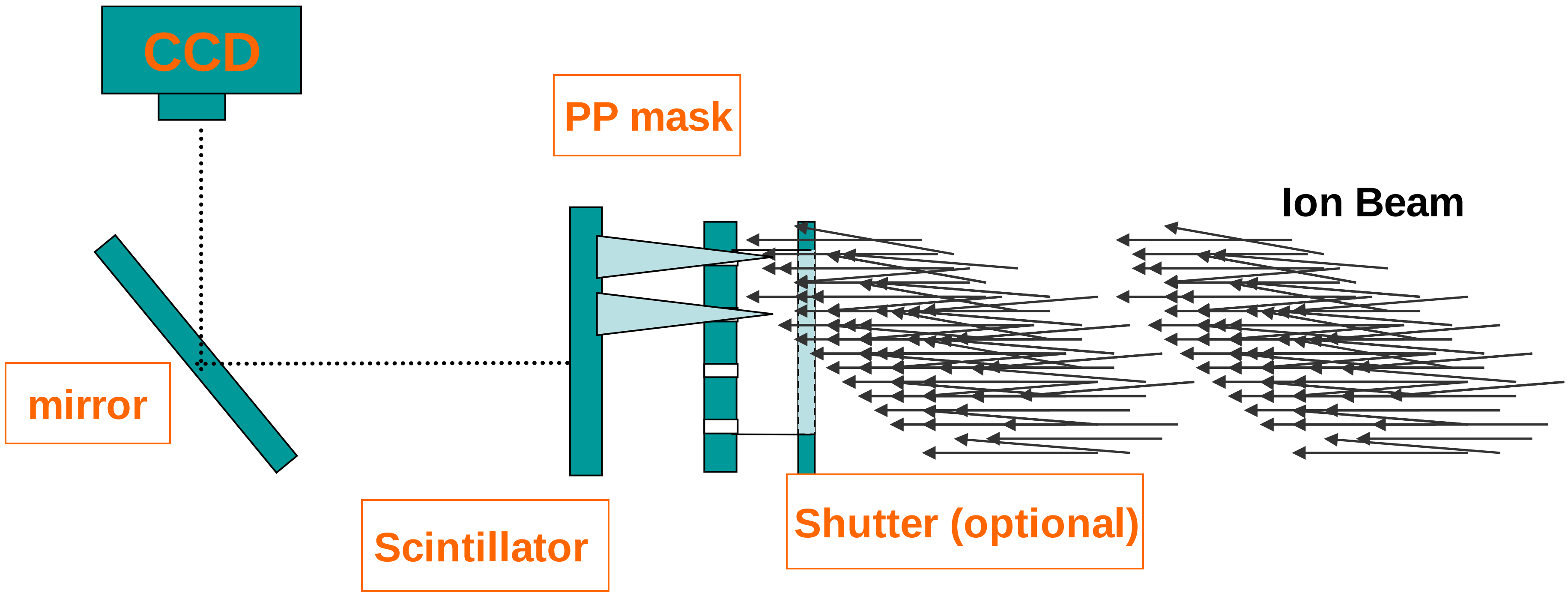
Experiment 2: Pepper-pot device at HIT

in collaboration with GSI (2009-2010)



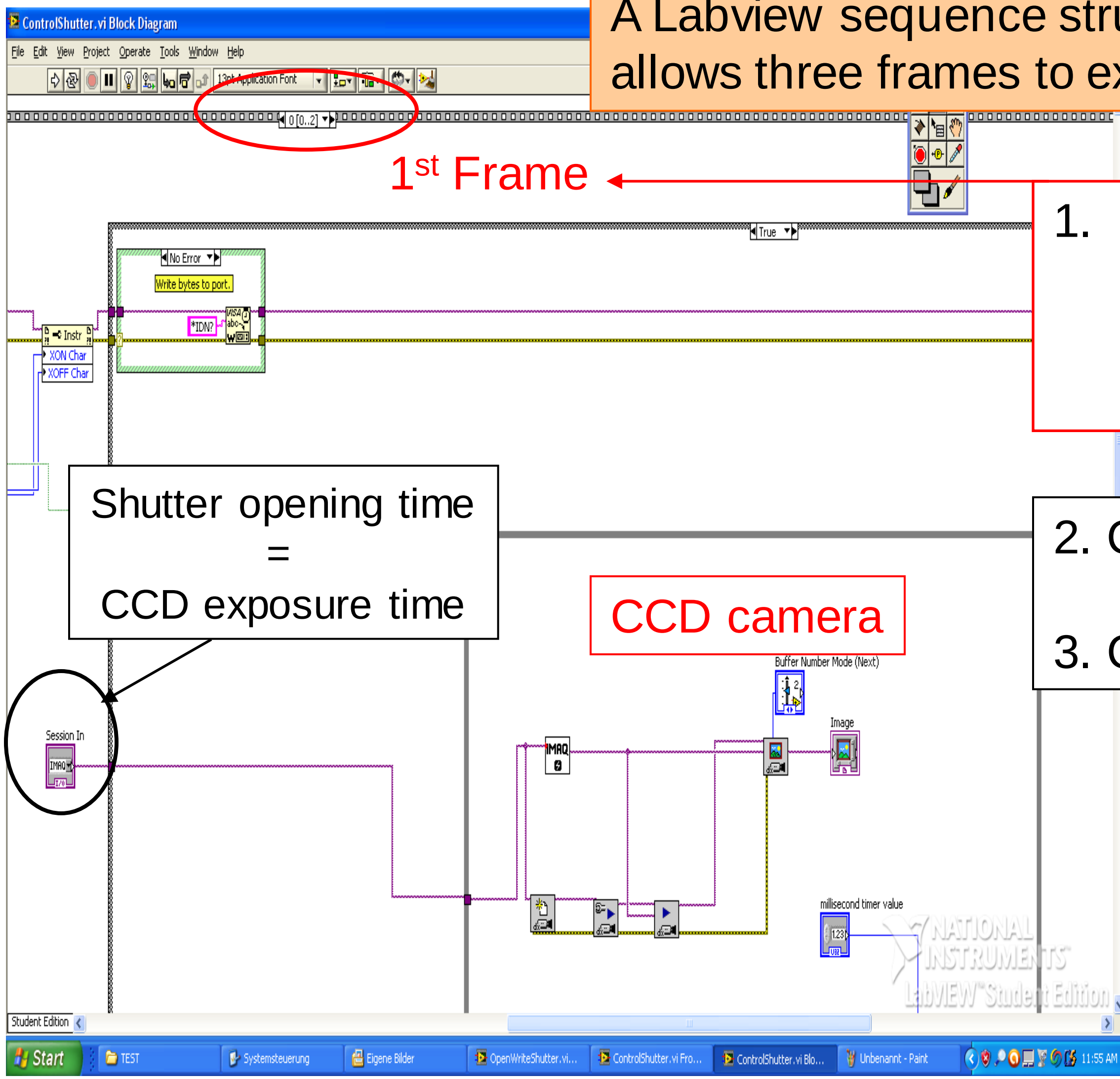


Pepper Pot Device – A Fast Imaging device



Allow to create an image that portrays the distribution of particles in the beam (“emittance“) in (x,x‘,y,y‘).

Main part of the Data Acquisition System



A Labview sequence structure opens which allows three frames to execute sequentially

1st Frame

1. Open the shutter for a period x (ms), trigger the CCD camera with an exposure time of x (ms)

Shutter opening time
=
CCD exposure time

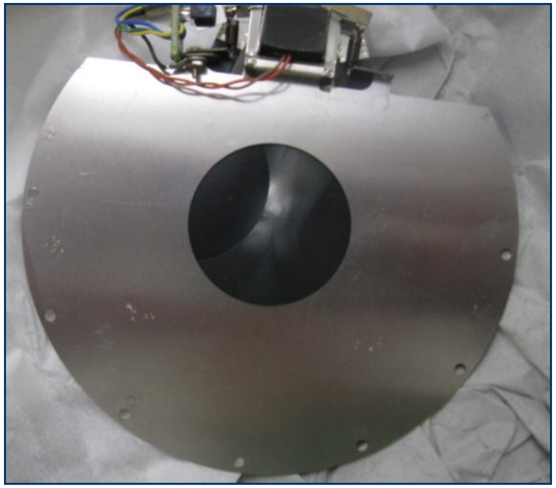
CCD camera

2. Close the shutter

3. Close the serial port

Experiment 2: Pepper-pot device with Quartz

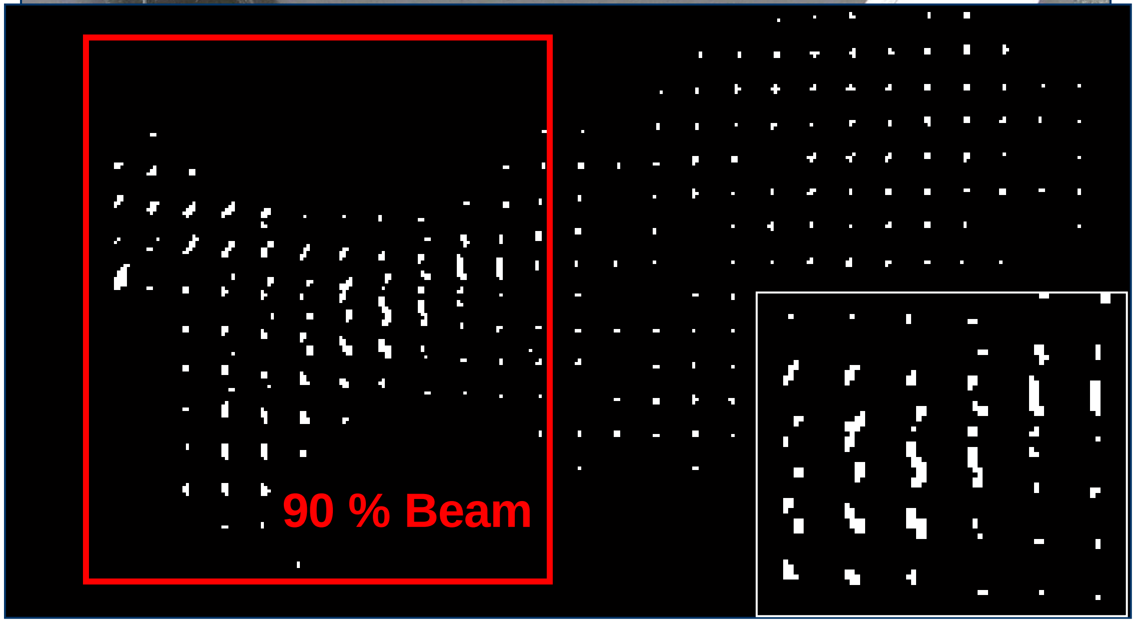
Secondment of Dr. Susanta DAS (E.R at Stockolm Univ.)



Algorithm:
“spots/holes“ matrix combination

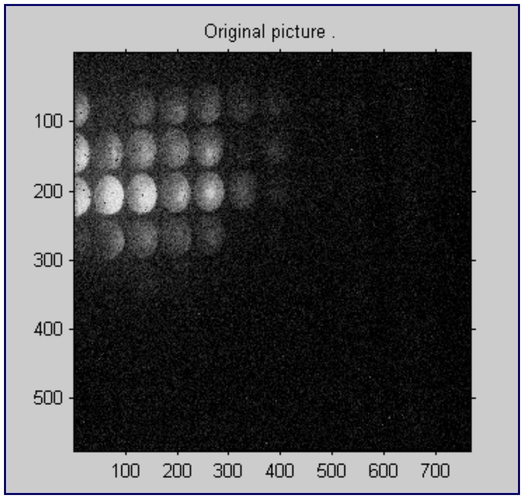
1 hole ≡ 1 beamlet ? No !

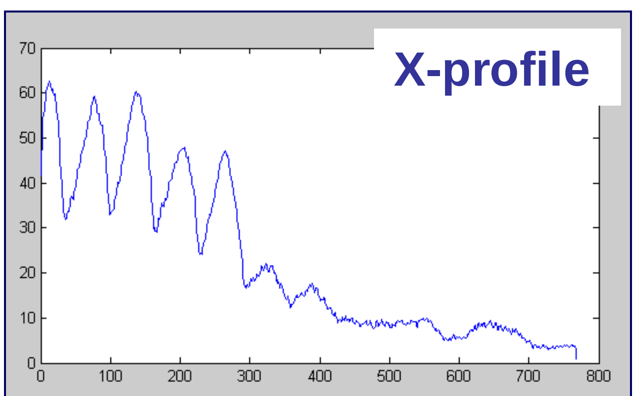
→ **Does this pepper-pot data can reflect the real emittance ?**



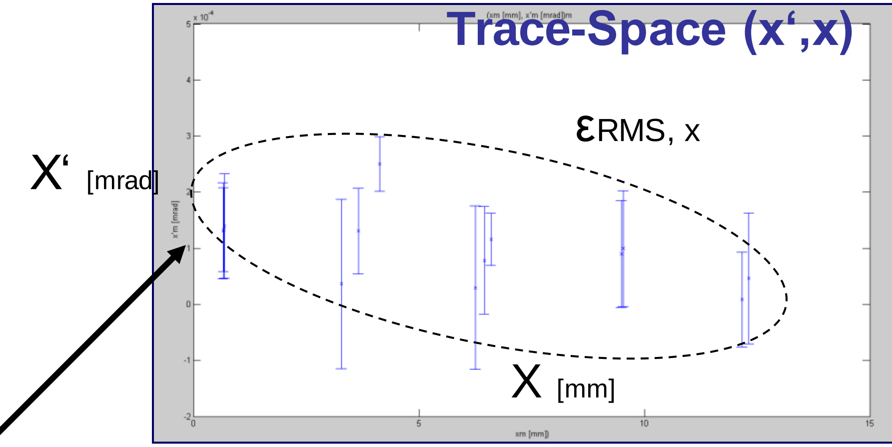
Another Pepper-Pot @ INFN-LNS

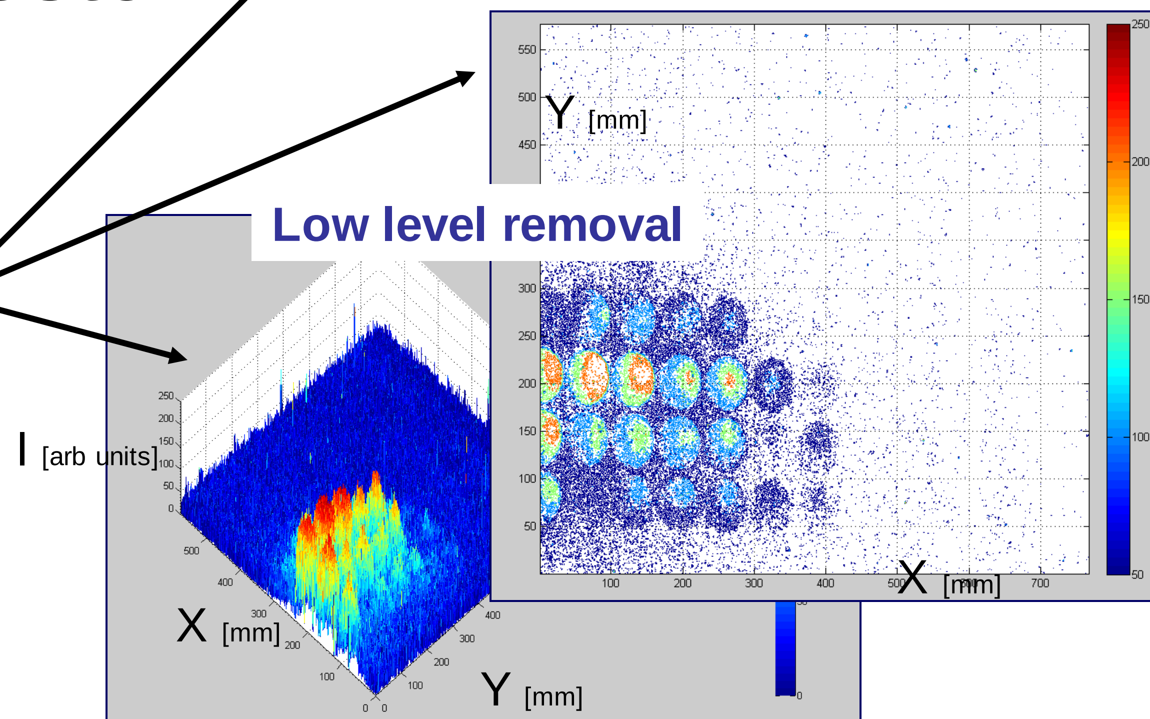
Image pre- and post- processing via Matlab and ImageJ





Visit my Poster !





Conclusion

- **<u>Experiment 1</u>:** Further experiment to better understand the occurence of fluctuations and radiation damage

→ spectroscopy (combination of color center with high flux rate)

- **<u>Experiment 2:</u>** Pepper pot mechanical device and DAQ completed.

- Visit my poster on **emittance method** and **algorithm** !

Acknowledgements

Berkeley University: Markus Stromeier

Diamond Light Source: Cyrille Thomas, Christopher Bloomer

Gesellschaft für SchwerIonenforschunh mbH:
Christoph Dorn, Peter Forck, Eiko Guetlich ,Rainer Haseitl, Beata Waselek

Imperial College: Simon Jolly

Thank you all !

INFN LNS: Luigi Cosentino, Paolo Finocchiaro, Alfio Pappalardo, GianFranco Vecchio

Max Planck Institute: Manfred König, Robert Von Hahn

Rutherford Appleton Laboratory: Dan Faircloth, Scott Lawrie, Alan Letchford

University of Oxford: Nicolas Delerue

Université de Lyon: Christophe Dujardin

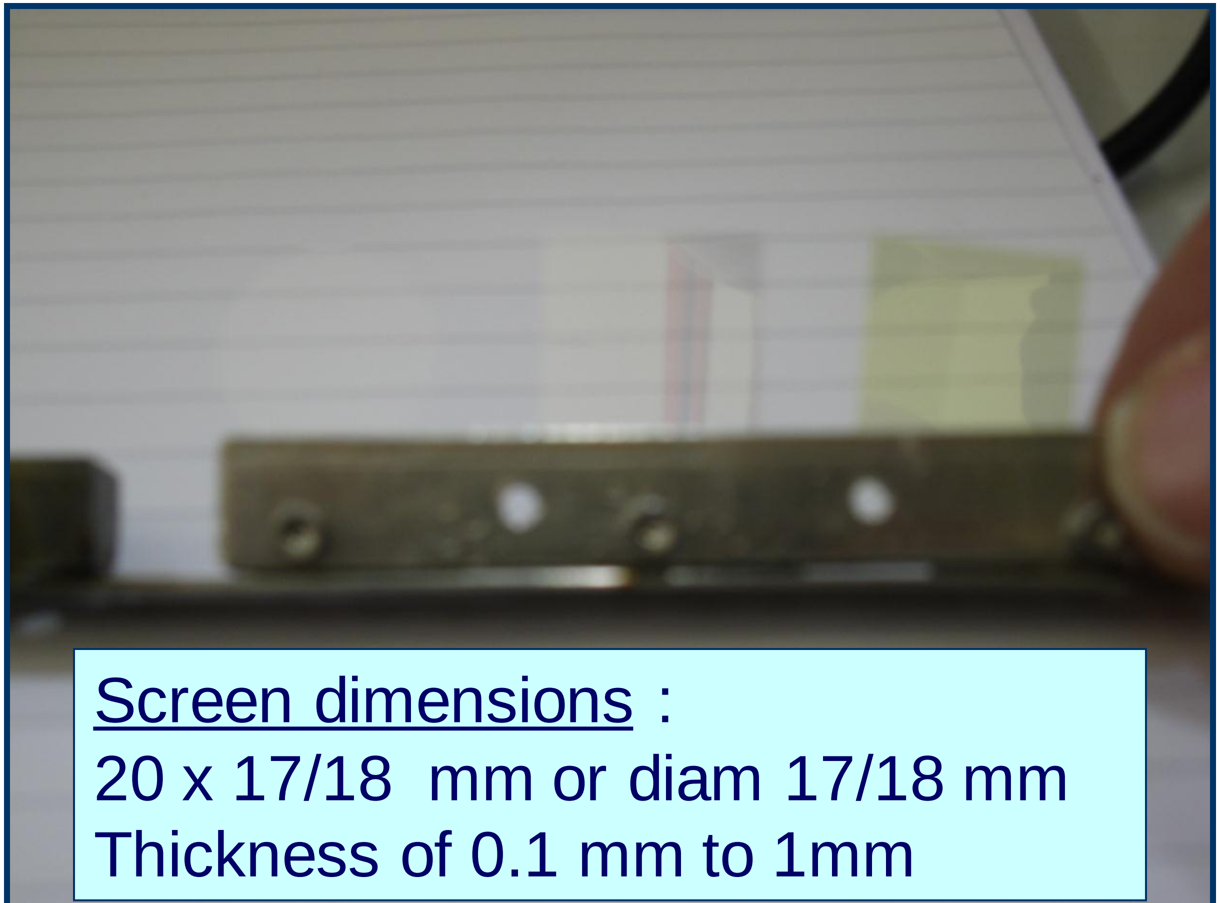
WZW Optics: Jens Borrmann

Prague TU: Tomas Cechak, Katerina Vavru

APPENDIX

Ion Beam-Material Irradiation Test @ Max Planck Institute (Heidelberg)

Investigate 3 scintillators materials in one machine run

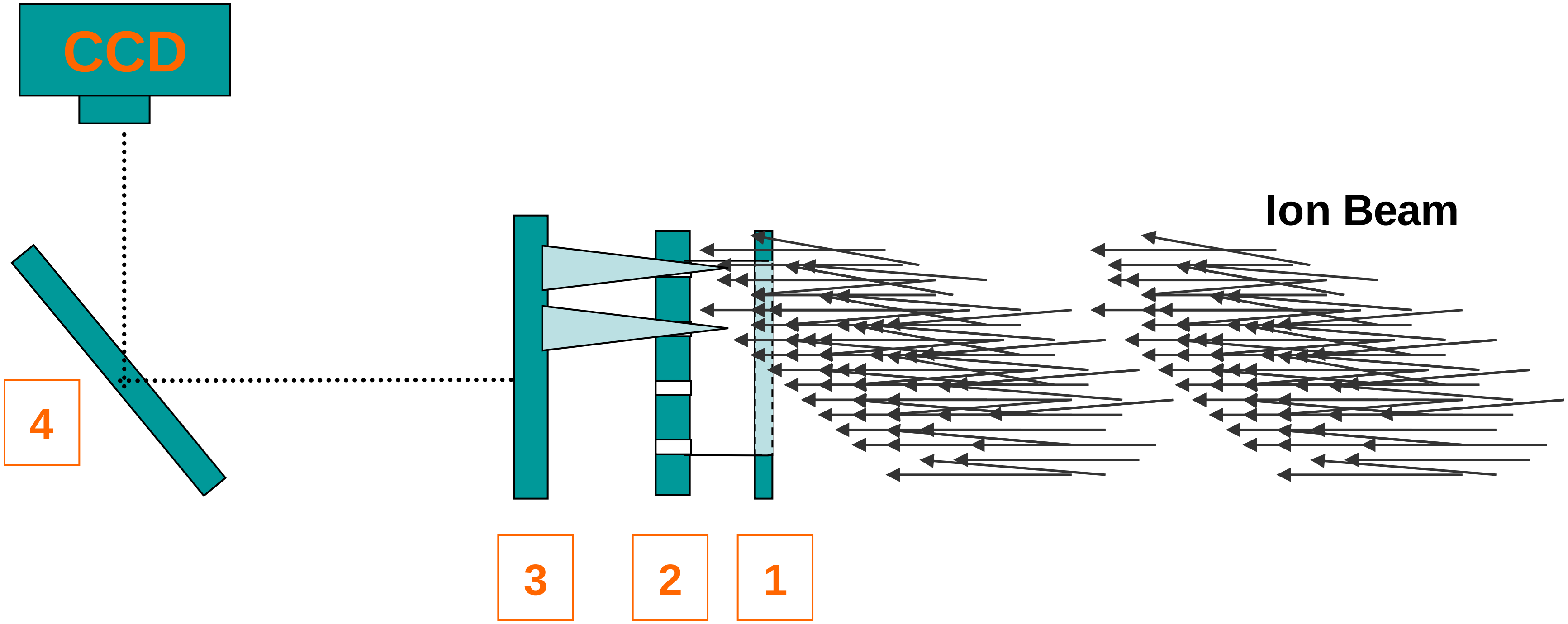


Screen dimensions :

20 x 17/18 mm or diam 17/18 mm

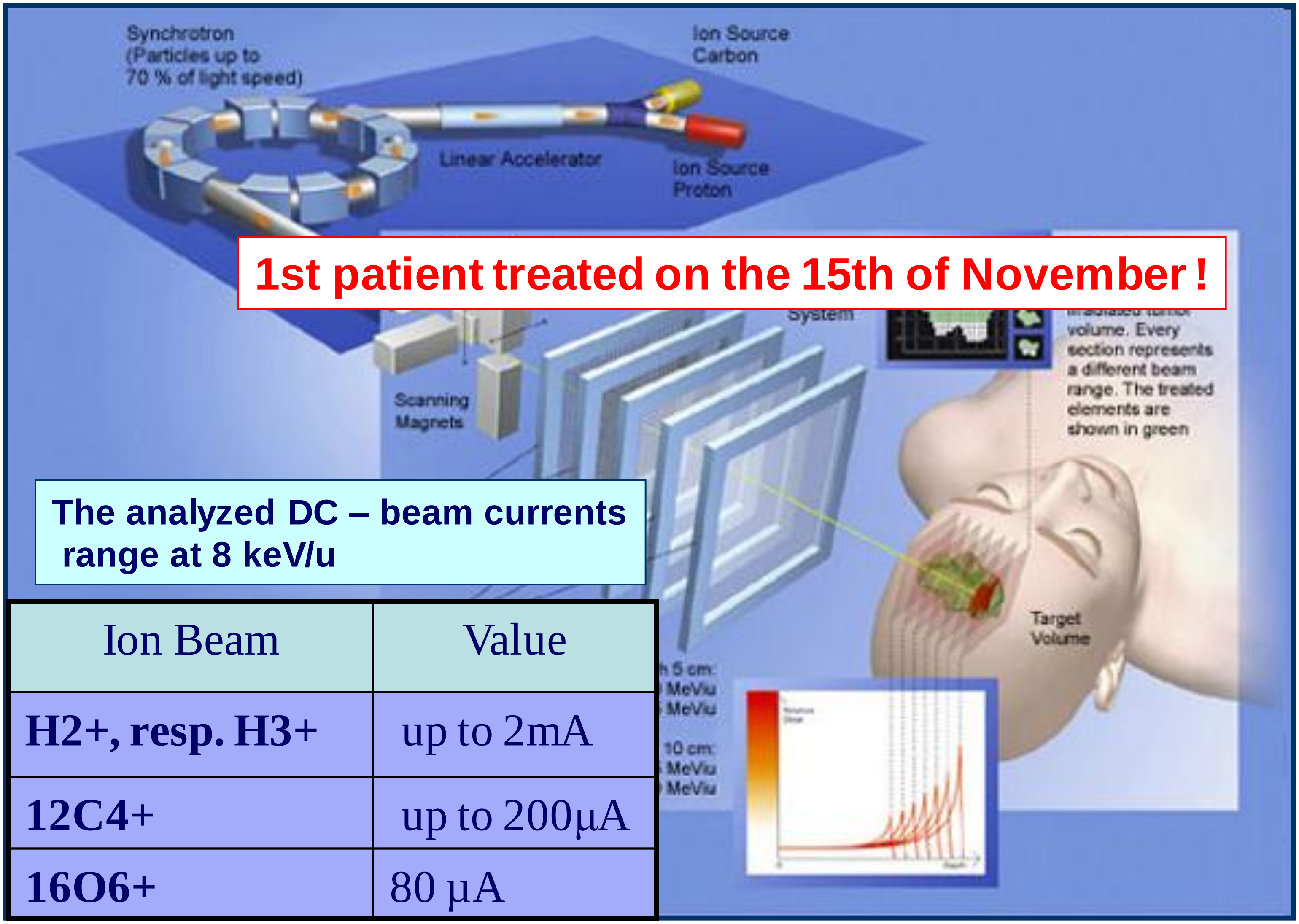
Thickness of 0.1 mm to 1mm

Pepper Pot Device – A Fast Imaging device



Allow to create an image that portrays the distribution of particles in the beam

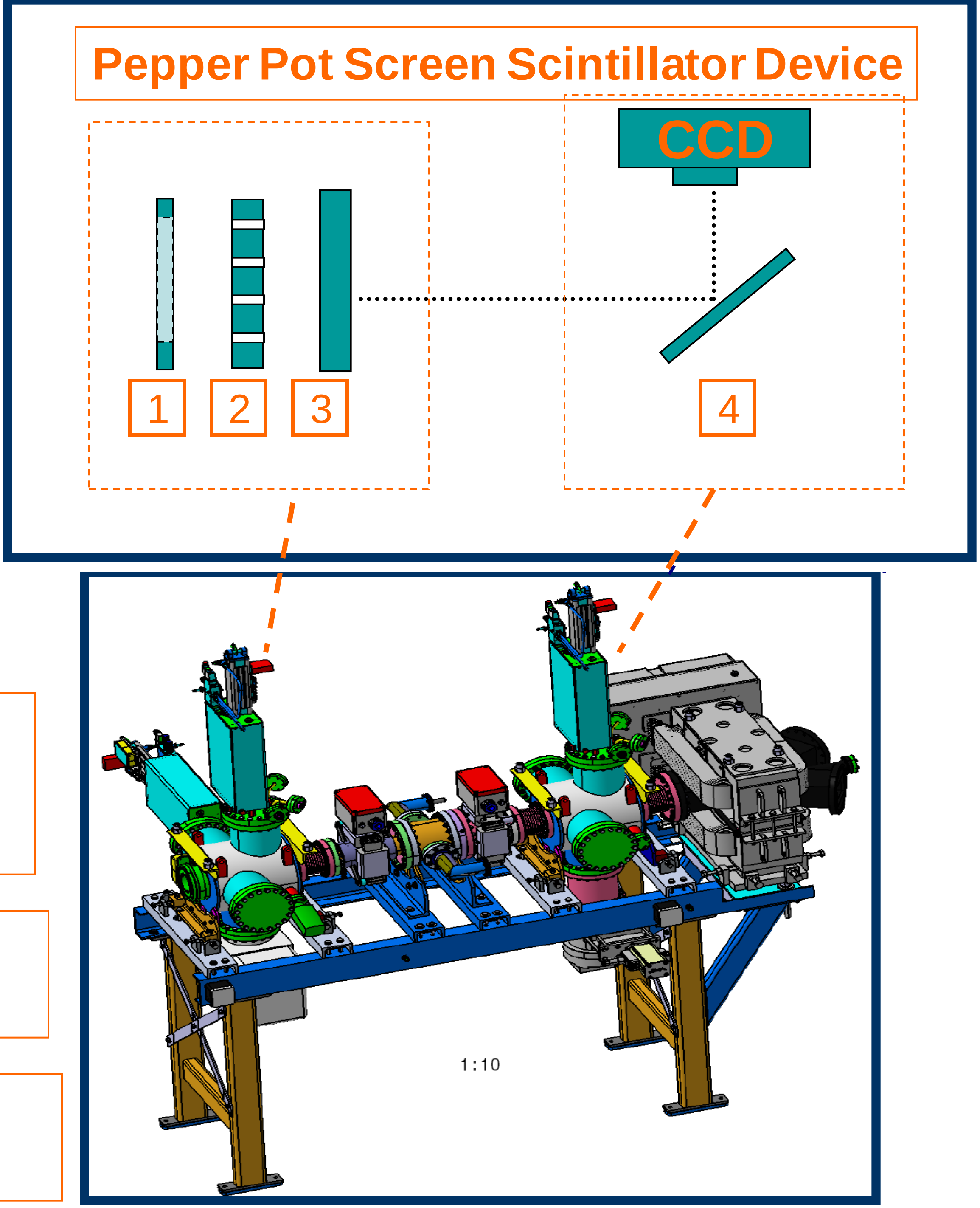
HIT facility



1st patient treated on the 15th of November !

The analyzed DC – beam currents range at 8 keV/u

Ion Beam	Value
H2+, resp. H3+	up to 2mA
12C4+	up to 200µA
16O6+	80 µA



1. Iris Shutter
2. Pepper-pot Mask (parallel collimator)
3. Scintillator Screen
4. Mirror + CCD camera

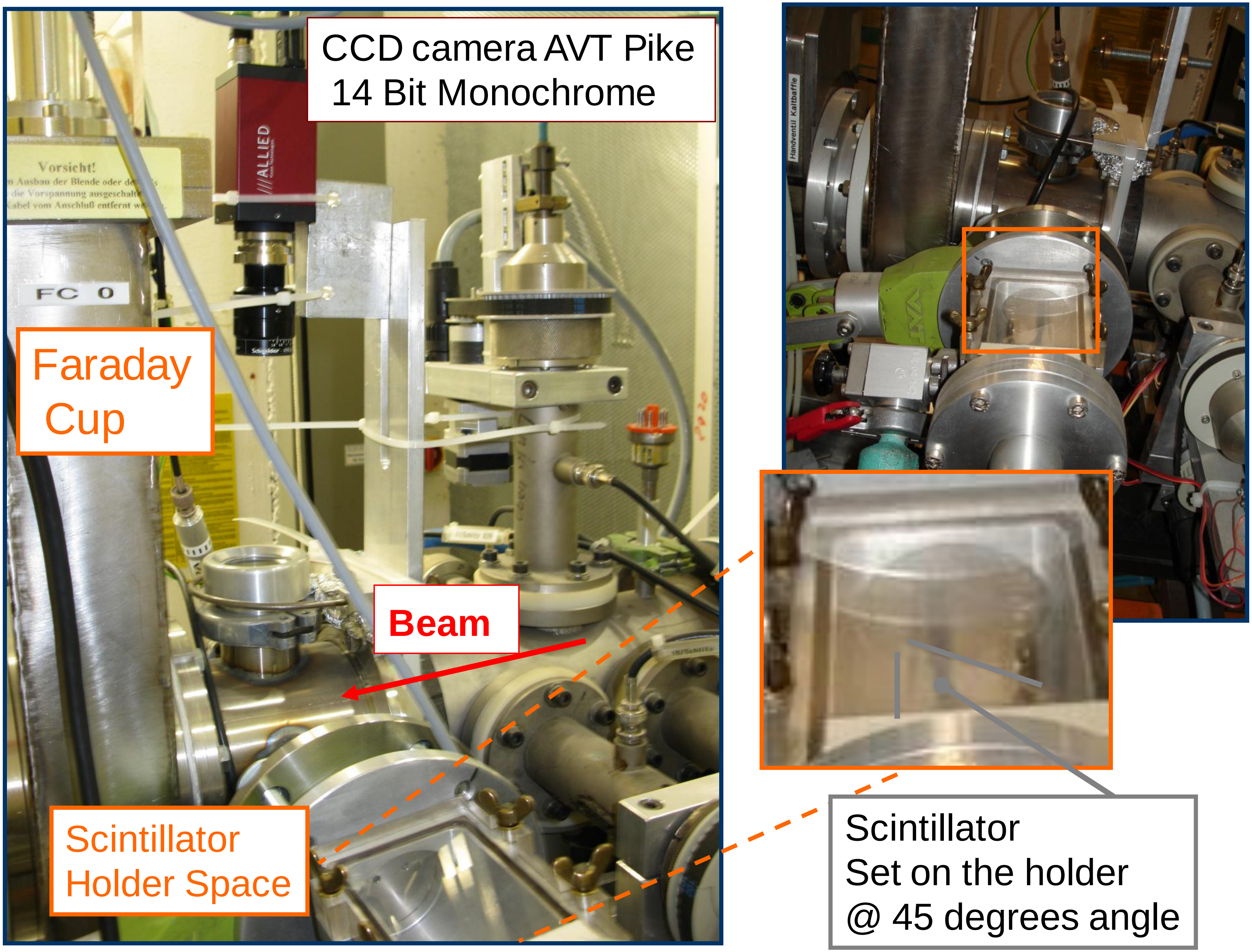
Why using a Pepper Pot Device ?

- **Replaced traditional wire /slit scanners (destruction due to thermal strain)**

- **Want to measure both x-y components of the beam emittance simultaneously <u>in one shot</u> and <u>data obtained in real time</u>**

→ **uses a slit to select a portion of the beam for analysis**

	Advantages / Disadvantages
Two-slit scanner :	slow
Multiwire collector :	Faster than two slits method but need amplifier for each wire
Allison-type scanner :	**slower than pepper pot**
Pepper- Pot :	**fast, need “adequate“ scintillator**



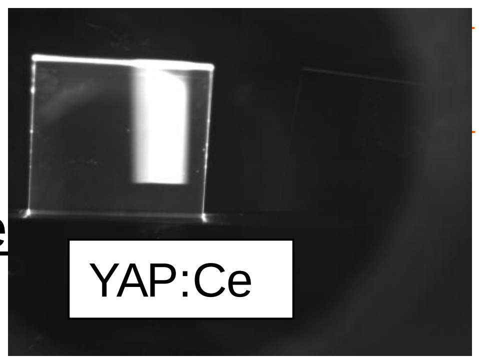
CCD camera AVT Pike
14 Bit Monochrome
Faraday Cup
Beam
Scintillator Holder Space
Scintillator
Set on the holder
@ 45 degrees angle

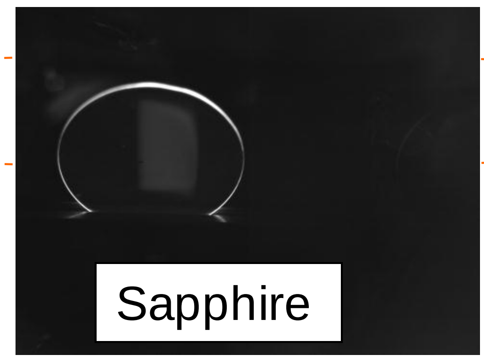
Summary : All Materials

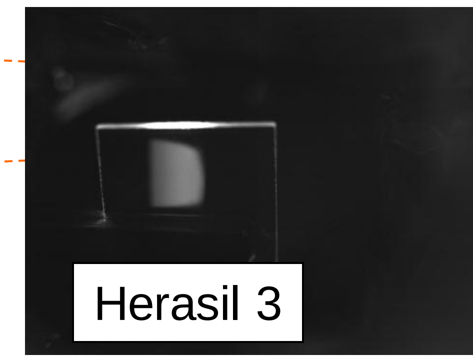
	Inorganic doped Crystals	Inorganic undoped Crystals	Quartz/Glass
Light Output :	+++ (high & ↑)	+ (moderate & →)	++ (moderate & ↑)

Damage :

Low Time De



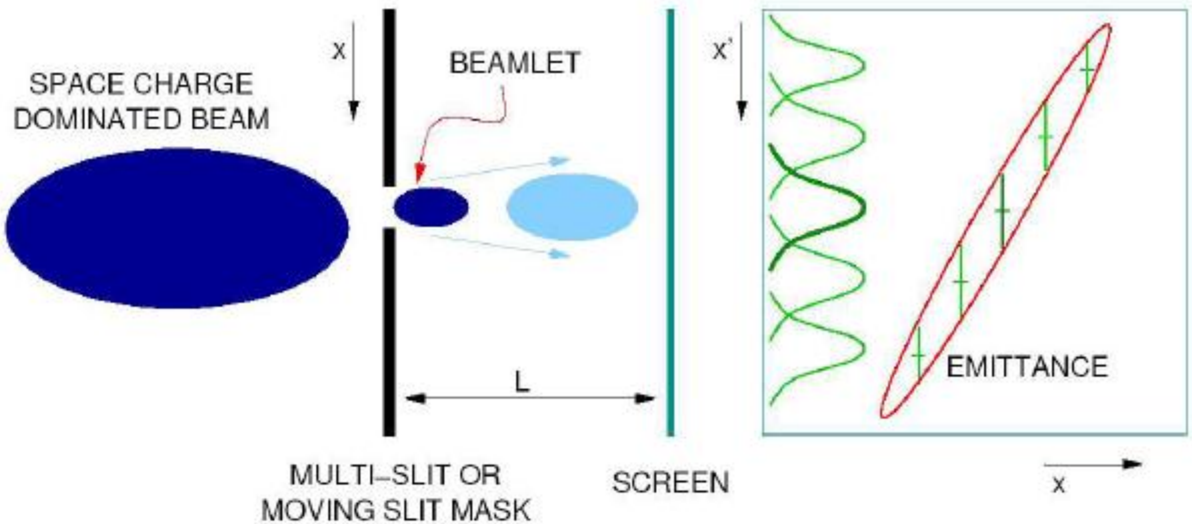


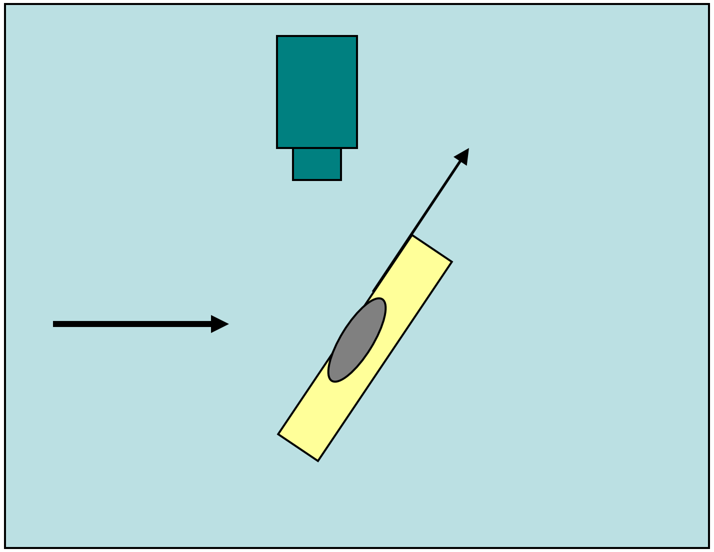


	Inorganic doped Crystals	Inorganic undoped Crystals	Quartz/Glass
Reproducibility :	+++	++	+++

Quantitative Analysis should be performed thin, emittance dominated beamlets

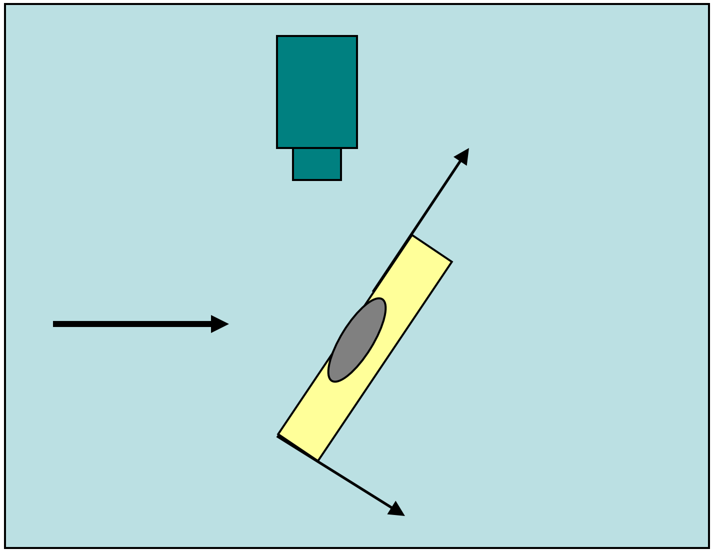
- After drift the width of expanded beamlet is measured with screen
- Beam trace space (average momentum and momentum spread) is reconstructed from position and width of beamlet images on screen -> Emittance is then fitted in phase space
- Need slit masks with actuators and screen station to measure emittance





Profile Monitor

Use a scintillator to produce an image of the transverse beam distribution



- **Crystal - Why ?**
- uniform individual grain scale **not a limiting factor** : inorganic (electronic band structure found in crystals), doped and undoped (light output vs stronger structure) inorganic, quartz crystal and borosilicate glass (advantages LO, grain size, cost, etc..)

- **CCD** camera FOV combined to focal lens have to be configured to obtain a adequate pixel resolution. The camera pixel size is 7.4 um sets the resolution limit.