2010, a scintillating year

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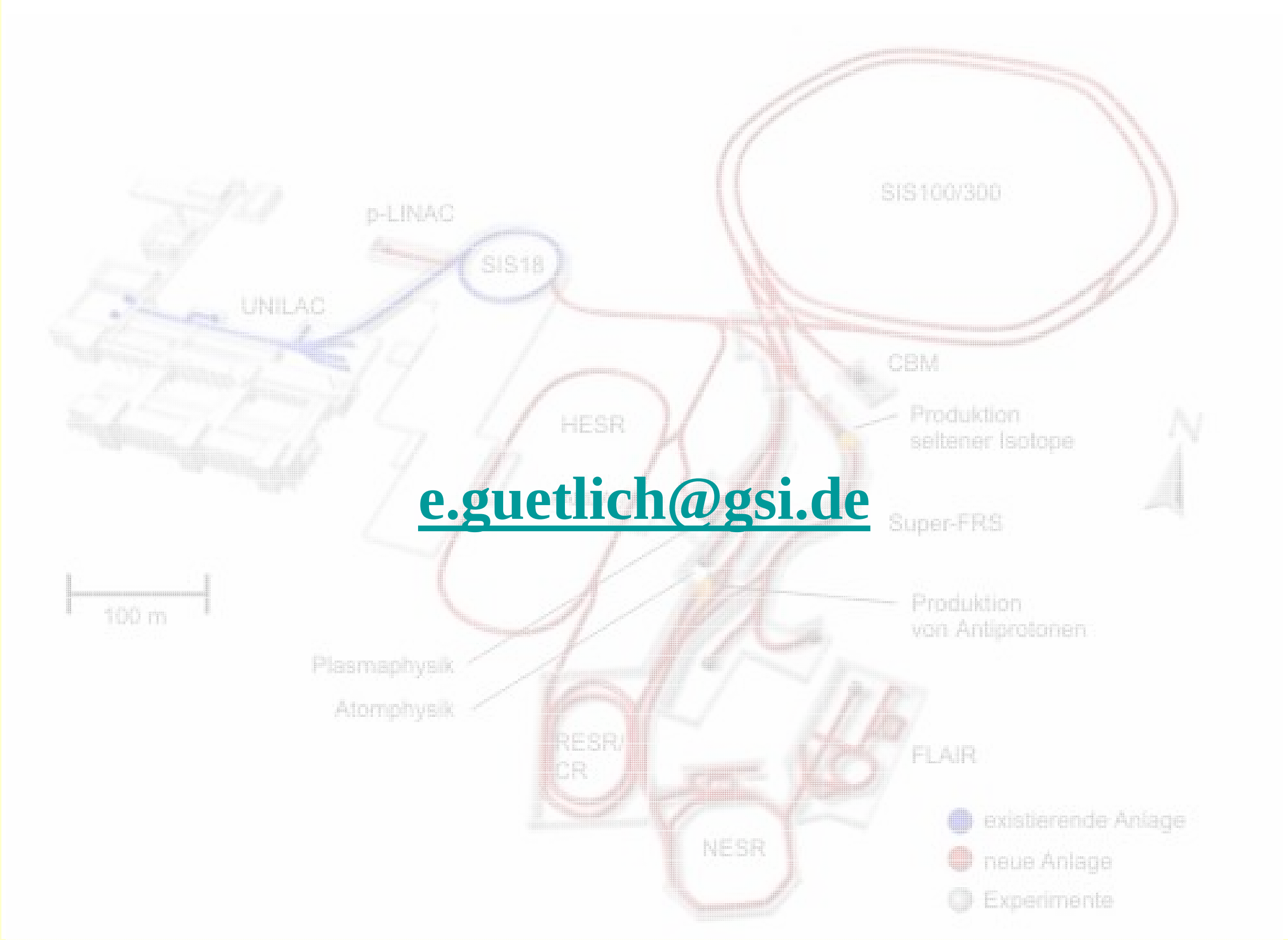

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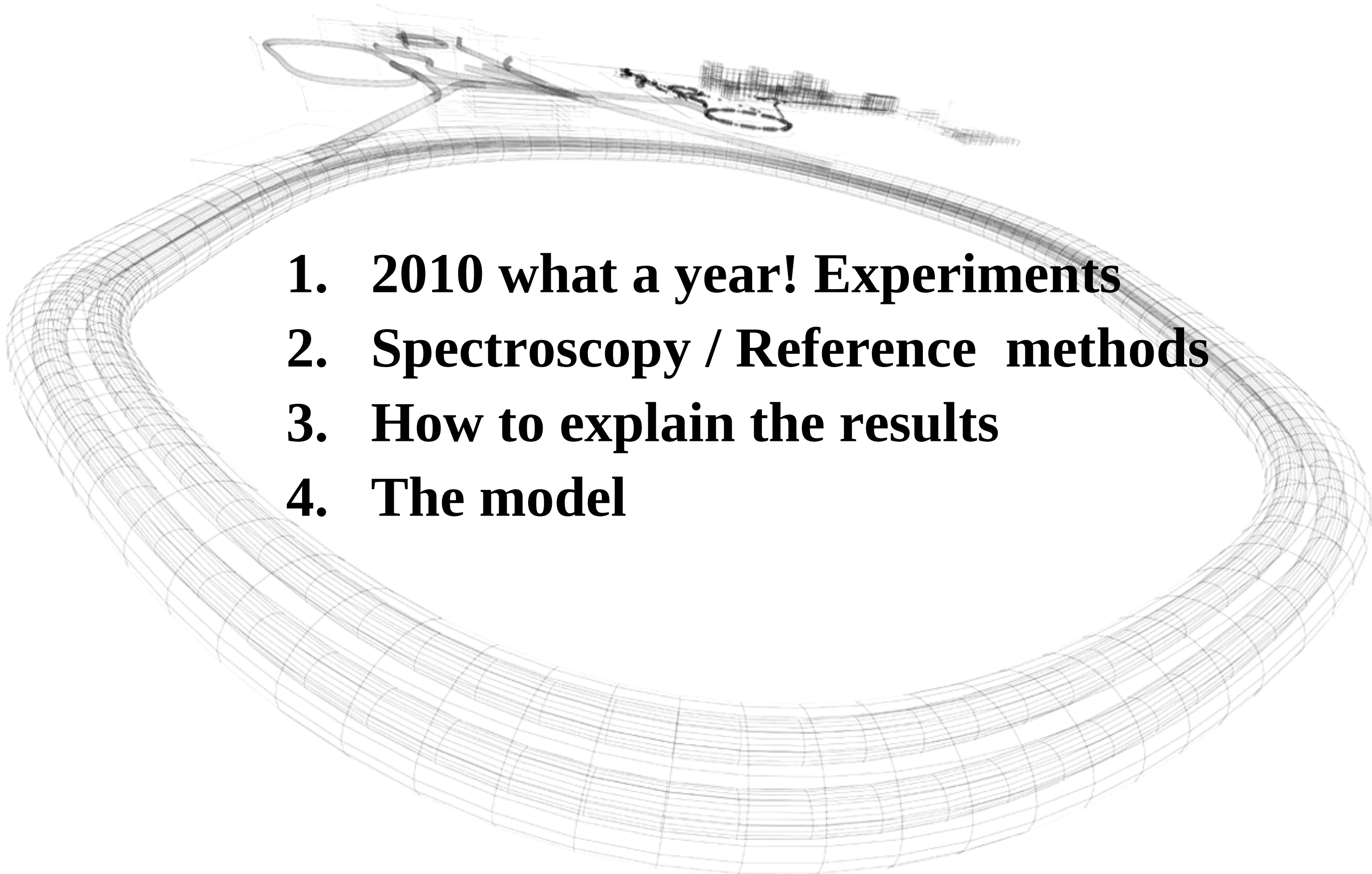
2010, a scintillating year



1. **2010 what a year! Experiments**
2. **Spectroscopy / Reference methods**
3. **How to explain the results**
4. **The model**

The year 2010

- New experimental design for Spectroscopy and the camera setup
- New heating method
- Beam time marathon: March, May, July → each 8 weeks → lots of data
- Due to the huge amount of new data → a lot of programming in SciLab
- Results up to April have beam presented on BIW'10 and DPG-Tagung'10 (Regensburg)
- A lot of literature inquest ....
- Development of a model
- ………..
- ……….

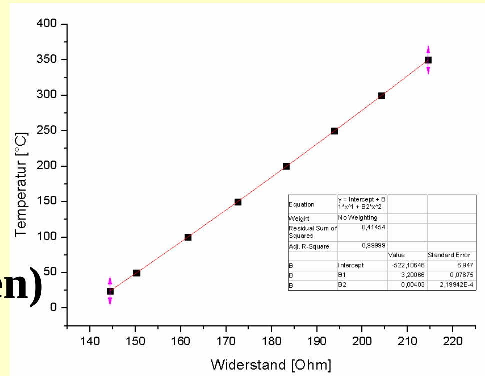
New heating method

- A Pt layer of 250 nm is sputtered on the backside of the sample.
- The layer is connected to the Capton-wire via high temperature conductive glue Elecolit 327.
- The layer is annealed before characterisation to ensure stable conditions.

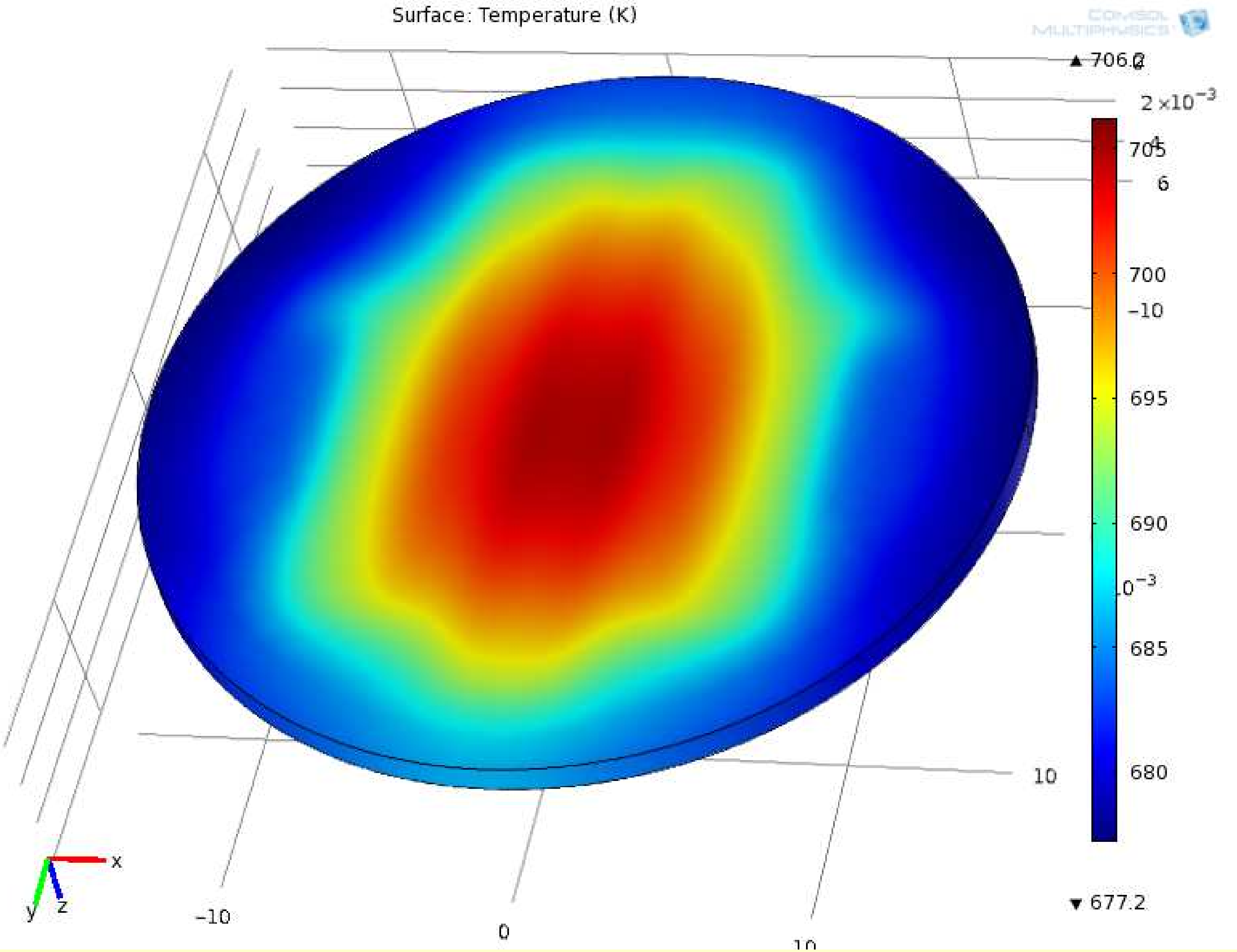
Advantage:

The temperature behavior can be investigated by simultaneous heating and direct 4-point temperature measurement up to 400°C

350°C
→700A/mm²(Pt)
→1,1W/cm²(Screen)



Simulation of the heating



Results:

- **Simulation fit the experimental data**
- **Temperature difference on the area of the typical beam is always smaller then 10°C**

(typically 5°C)

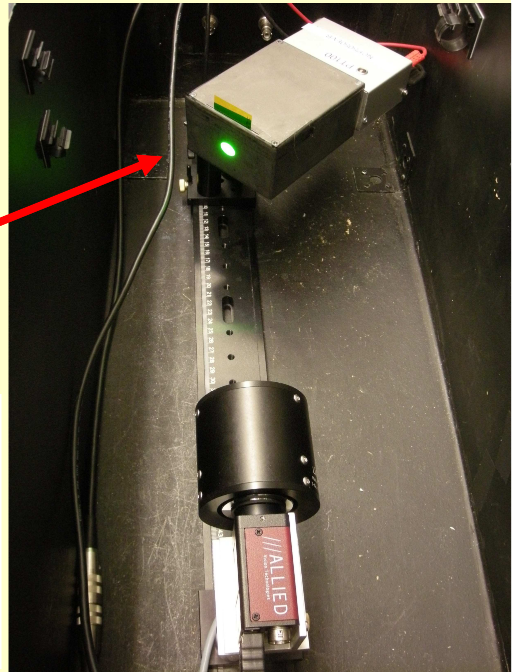
Why is the spectrum important ?

The spectral response can give information about the scintillation mechanism. → once you know it, one can try to make predictions

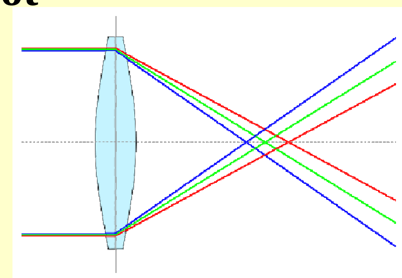
Courtesy of Jan Mäder (GSI)

When the spectrum is different between the outer-part and the centre, it could lead to a wrong representation of the ion beam due to:

- **different response of the states to the deposit energy.**
- **the wavelength dependent sensitivity of the CCD-Chip.**
- **the different chromatic aberration (Farblängsfehler) of the lens-system used.**



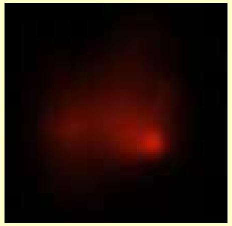
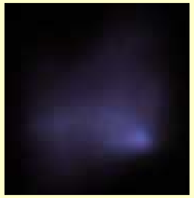
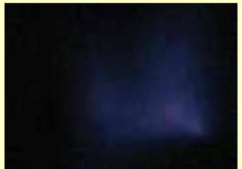
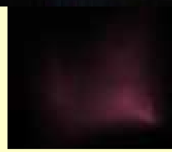
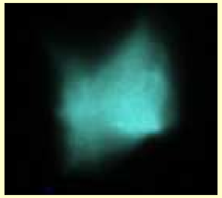
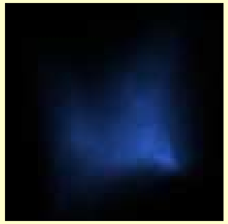
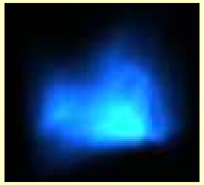
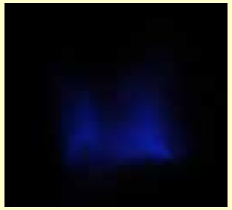
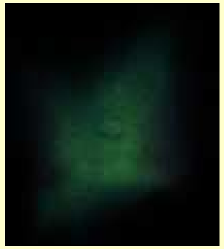
Up to now, the chromatic aberrations (Farblängsfehler) **of the used lens systems have been investigated in the 400-800 nm region, with a purpose-build light source "beam-spot simulator". → Error in Sigma within 1%**



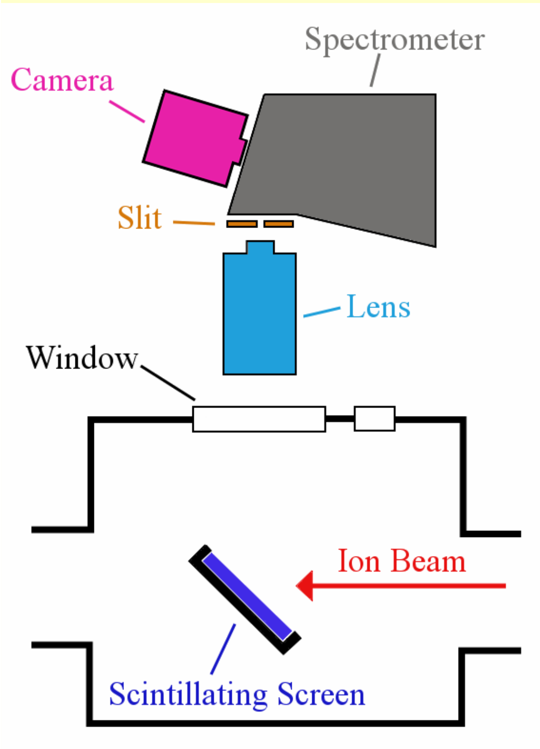
Linearity of the chip (double integration time → double Pixel value)

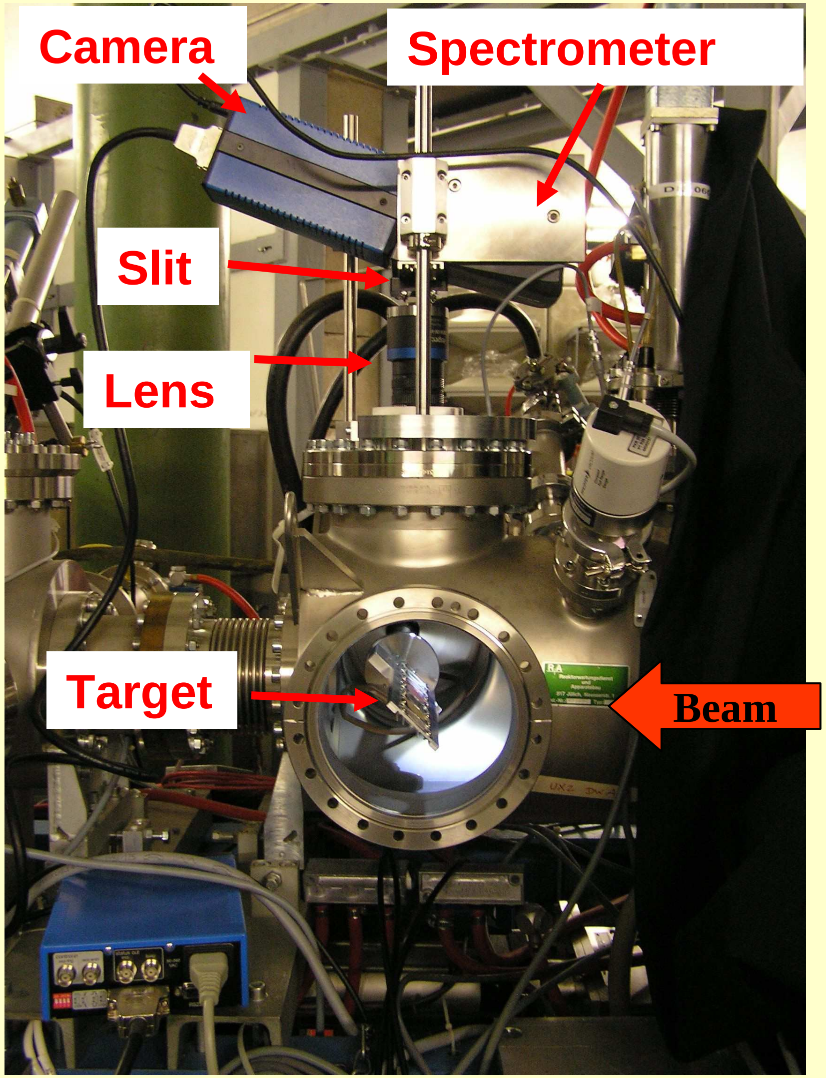
Iris values (Blendenzahlen)

Measurement with colour CCD

	Al_2O_3 : Cr	Al_2O_3	Herasil	ZrO_2	ZrO_2 : Mg	BN
Within the Pulse			 			
Afterglow	the same colour t_2: ~2ms	the same colour $t_2 < 30\mu s$	 $t_2 < 30\mu s$	 $t_2 < 30\mu s$	the same colour $t_2 < 30\mu s$	 $t_2 < 30\mu s$

Advanced experimental setup (spectroscopy)

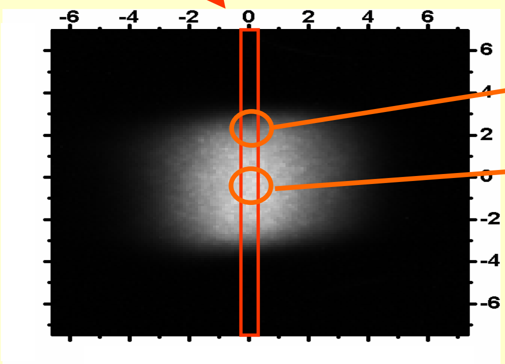




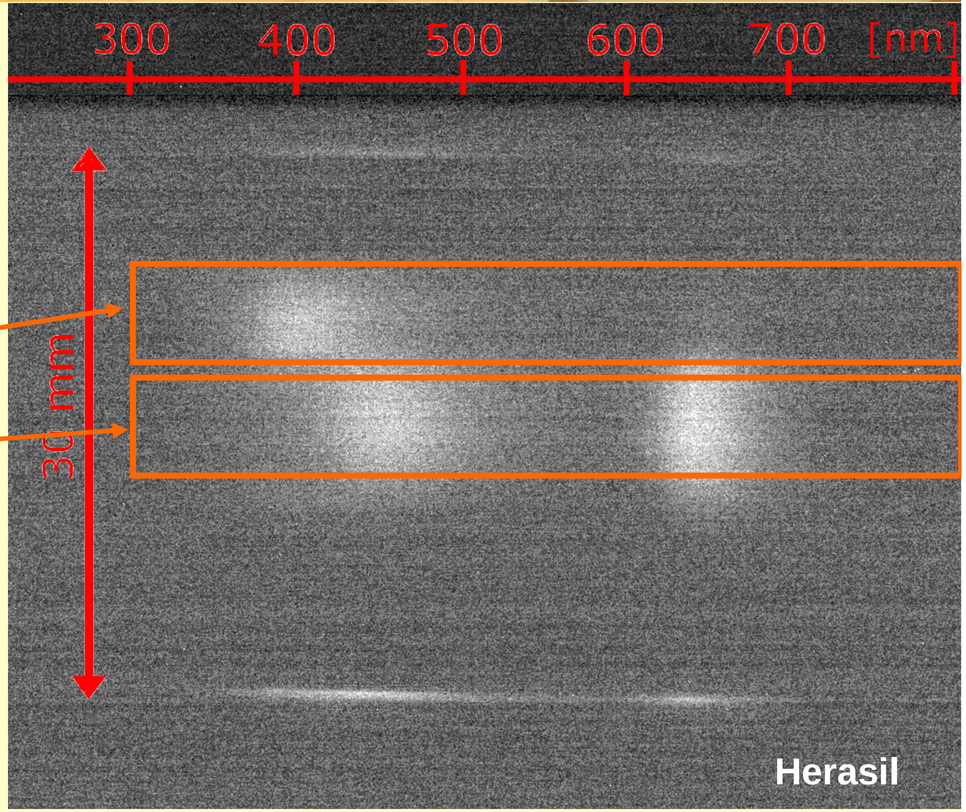
Camera: PCO1600
Spectrometer: Horiba Jobin Yvon CP140-202
Slit: Newport M-SV-0.5
Lens: Linos inspec.x UV-Vis-Lens, 50mm focal length

Spectroscopic investigations

Investigated area of the beam spot for spectroscopic studies



typical width of the stripe is about 1mm and depend on the slit setting

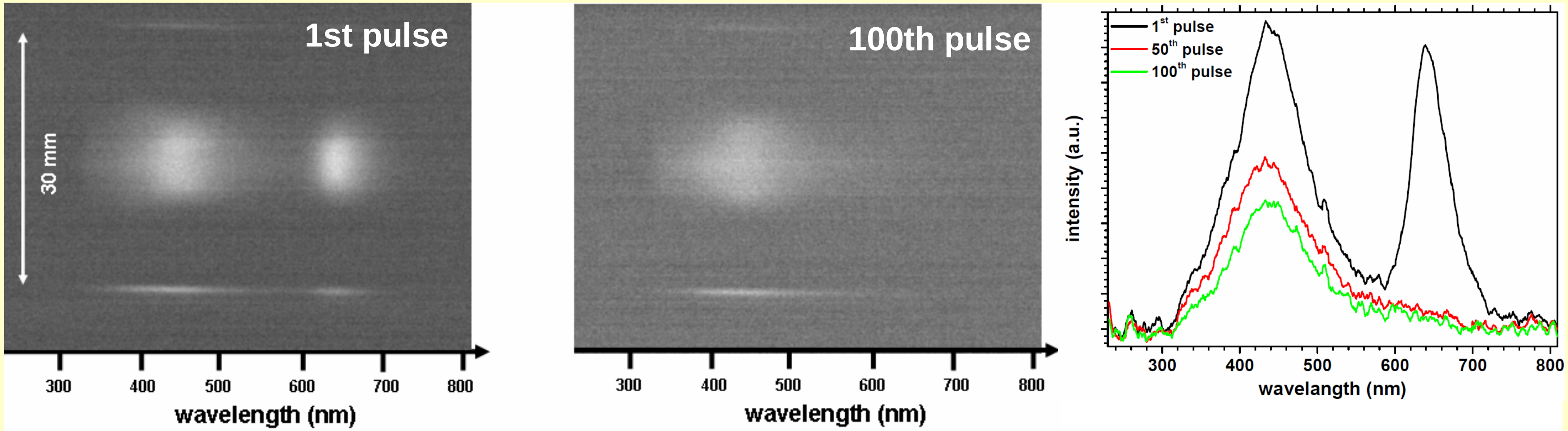


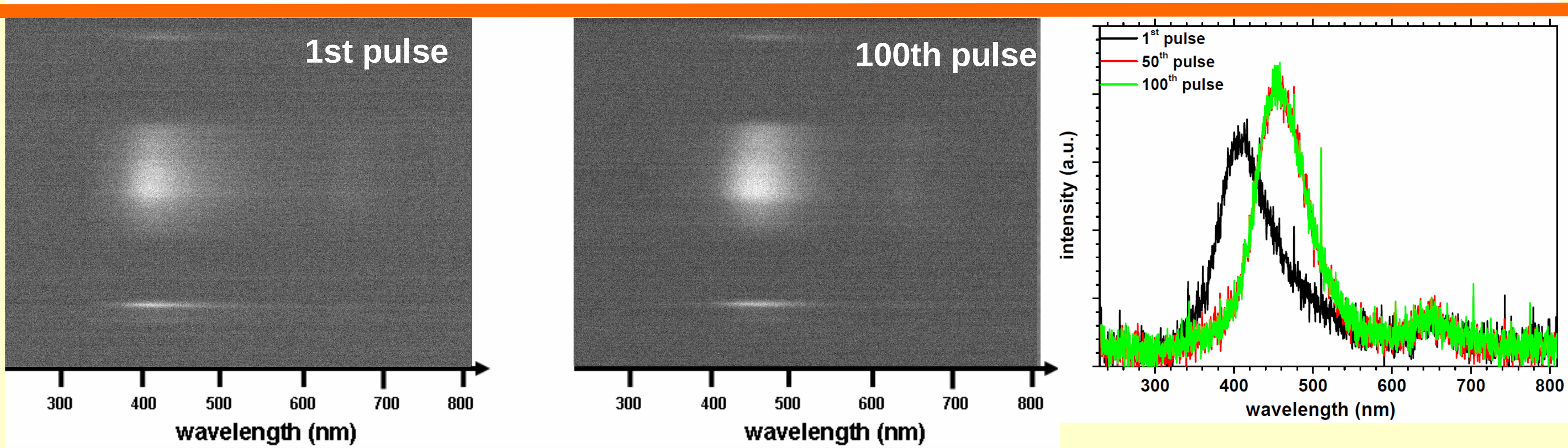
Advantage:

- **influence of the ion flux on the spectra can be analysed over the flounce, for each macro pulse**
- **the whole screen is observed**

Spectroscopic investigations on Herasil

Beam parameters: U^{28+}, 4.8MeV/u, 5.2*10^{10} Ions/Pulse in 0.8ms



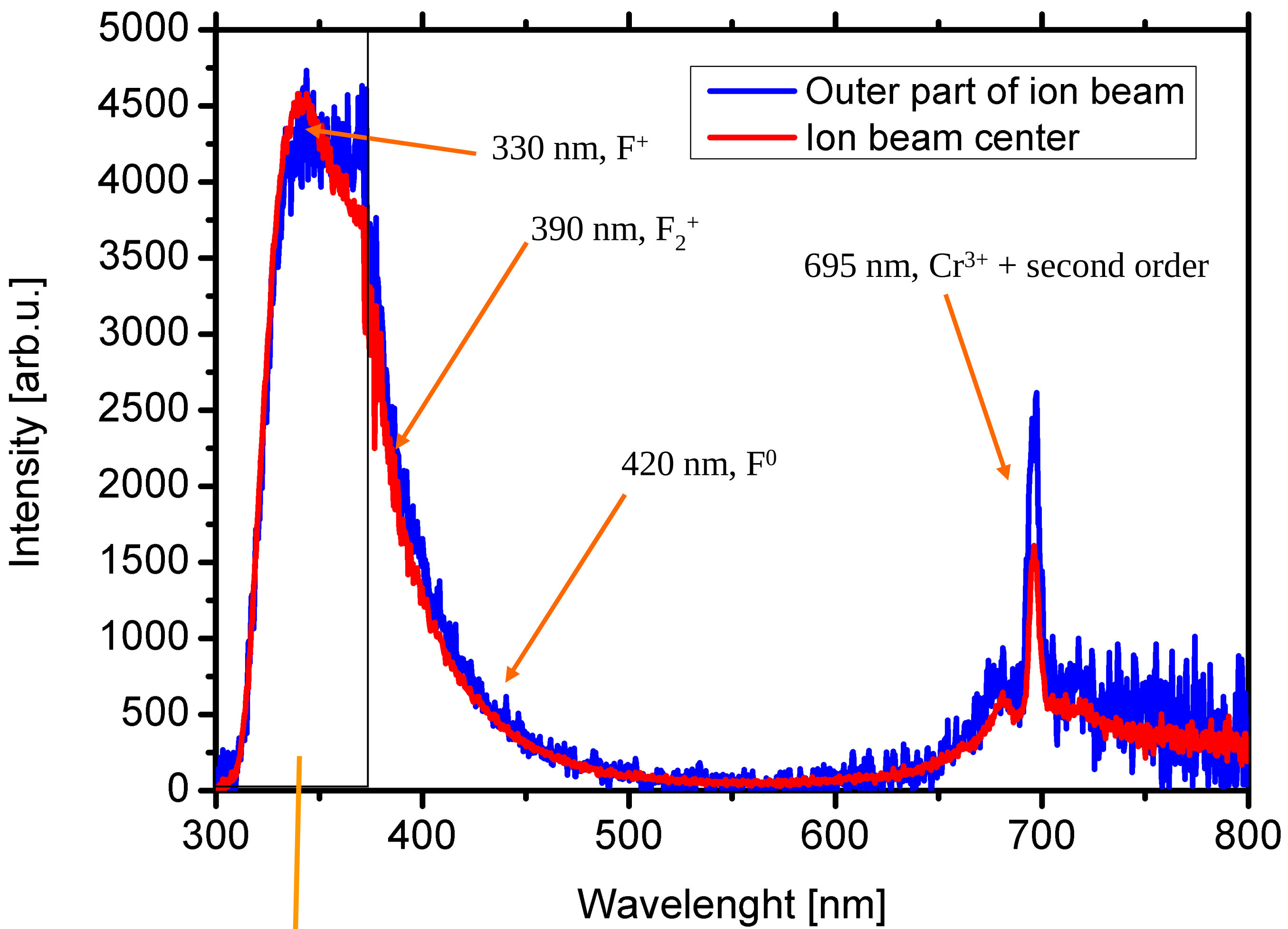


Beam parameters: Ca^{10+}, 4.8MeV/u, 9*10^{10} Ions/Pulse in 5.3ms

Result: The Spectrum can depend on the ion and on the dose!

Spectrum of Al_2O_3 for $^{48}Ca^{28+}$ @ 4.8MeV/u

Beam parameters: $^{48}Ca^{10+}$, 4.8MeV/u, 5.2*10^{10} Ions/Pulse in 3ms, 1Hz



Region that can not be observed with standard, not UV enhanced optics

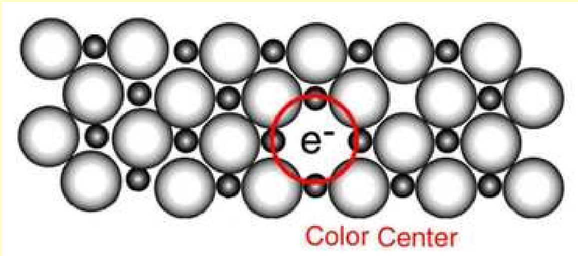
Results:

- **Spectra of outer and centre are similar to each other**
- **No F^0 ←→ F^+ conversion @ 4.8 and 11.4 MeV/u**
- **High current results correspond to low current results in the literature**

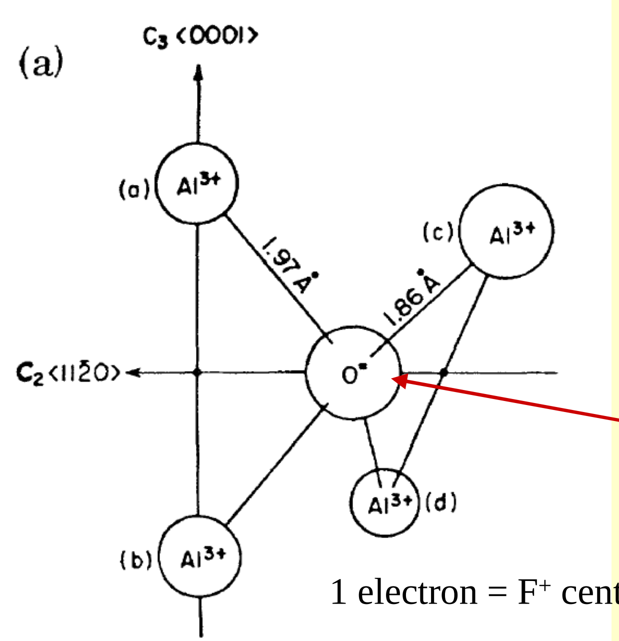
Effective response of the optical system for standard measurements @ 370nm is < 10 % of 500 nm

Colour Centres in Al_2O_3

Example for a color center →



The Al_2O_3 lattice



1 or 2 Electrons

e⁻

1 electron = F^+ centre, 3.8 eV (326 nm), τ=1.7 ns

2 electrons = F^0 centre, 3.0 eV (413 nm), τ=25 ms

VOLUME 50, NUMBER 19 PHYSICAL REVIEW LETTERS 9 MAY 1983

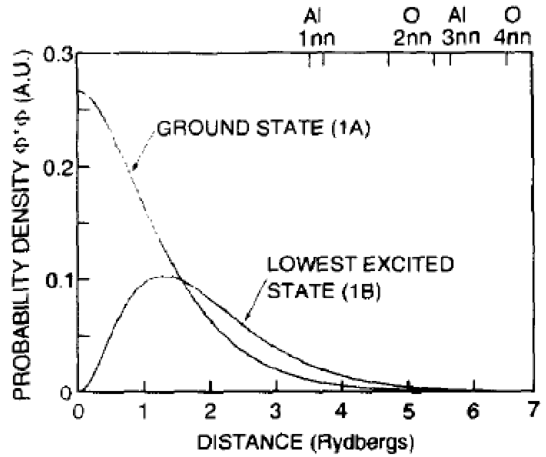
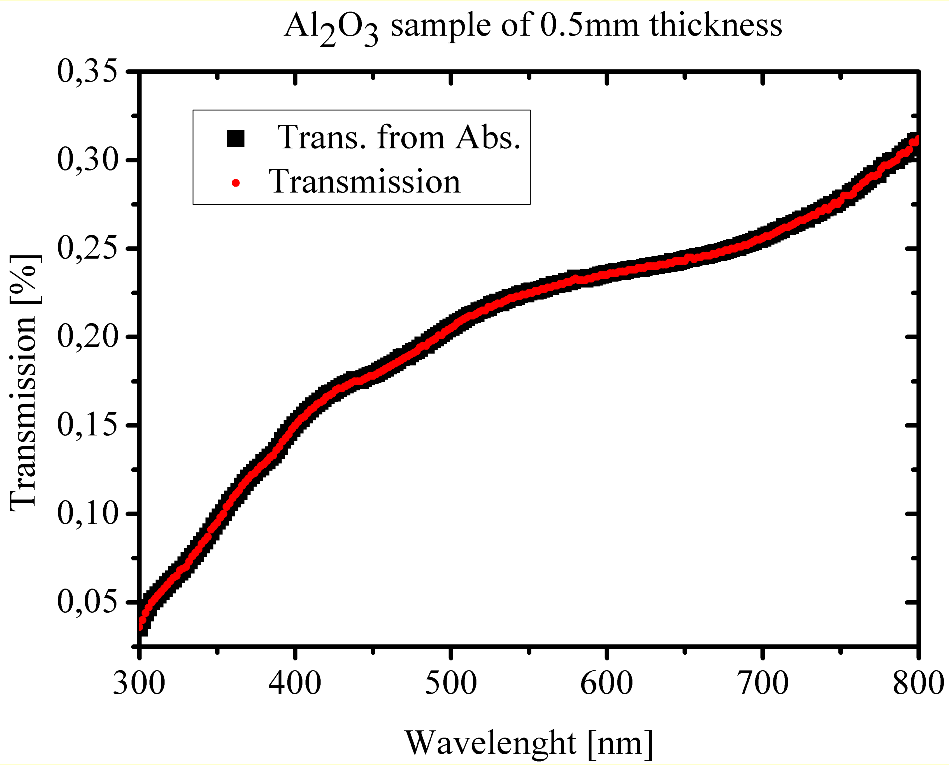


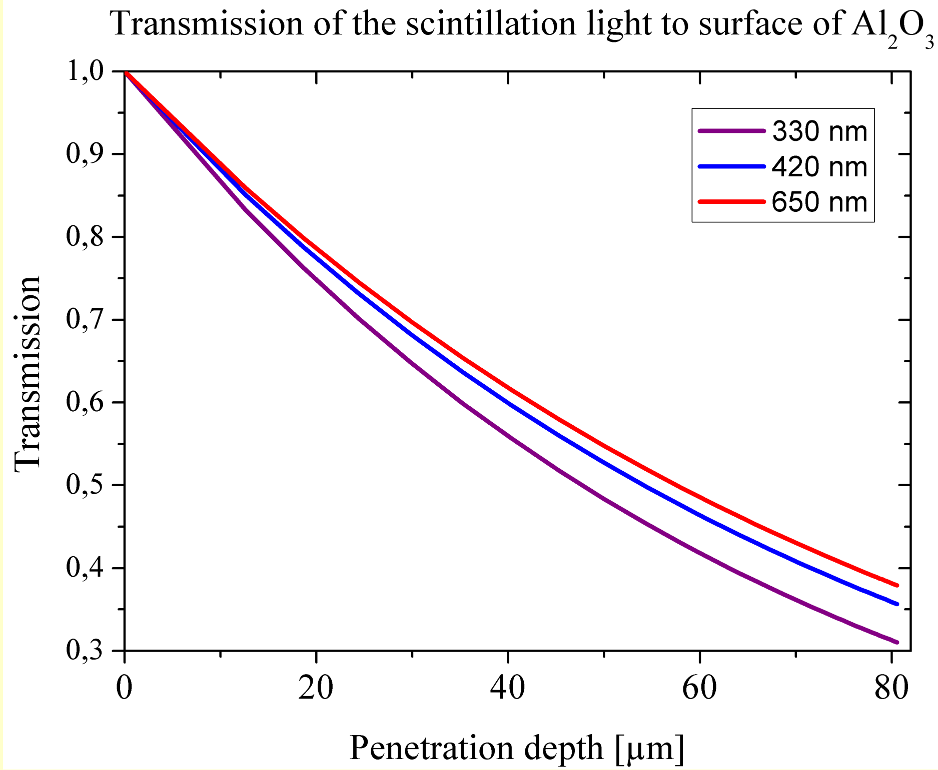
Fig. 2. F^+ center relative probability density $\Phi^*\Phi$ in α-Al_2O_3, calculated from wave functions derived in Ref. [38]. For a typical ground state (1A) distribution, that along the *y*-axis in Fig. 1 is depicted; the 1B-level distribution shown is along the *x*-axis, out of the plane of Fig. 1.

B.D. Evans / Journal of Nuclear Materials 219 (1995) 202–223

Result: The F^+ emission is might be more resisted against quenching because of the less extended wave function and the shorter live time.

Transmission of Al_2O_3





Result: There is no important contribution from reflections in the material to the detected scintillation signal. → backside to surface reflection @ 420nm would be reduced to 1E-5, and for 0.5mm sample to 2E-11 for 1mm.

Interesting previous low current investigation

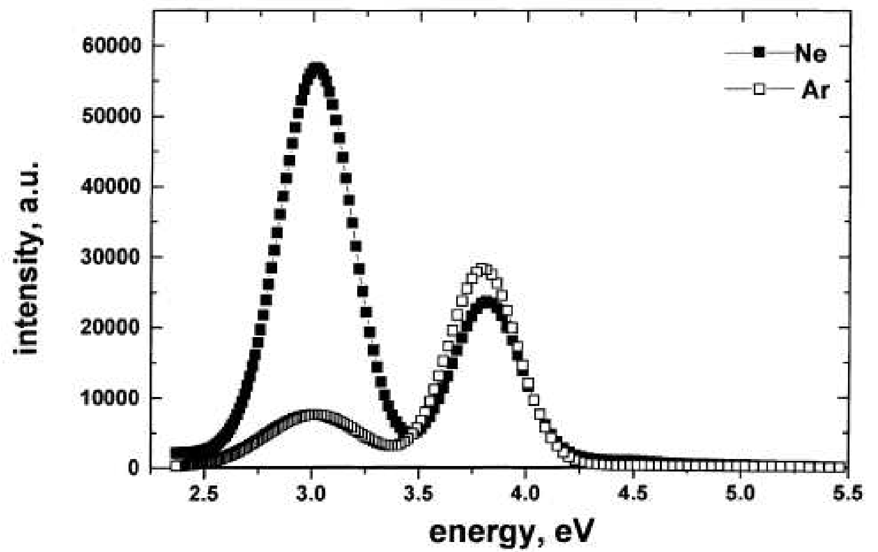


Fig. 5. Luminescence spectra from α-Al_2O_3 measured under Ne and Ar ion irraditation at $T = 80$ K and damage dose $> 10^{-4}$ dpa (intensity saturation stage).

V.A. Skuratov / Nucl. Instr. and Meth. in Phys. Res. B 146 (1998) 385–392

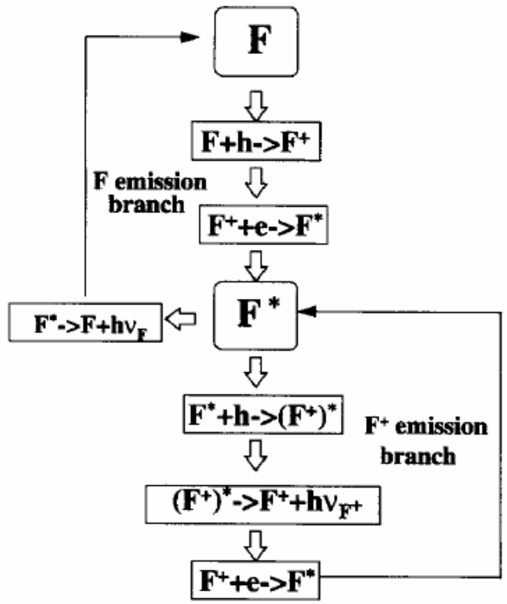


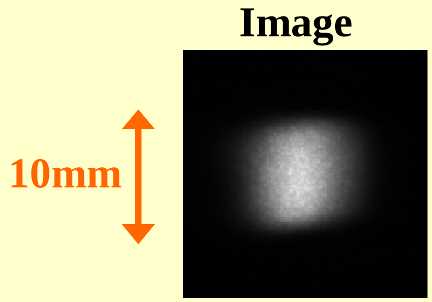
Fig. 6. Flow diagram for the F and F^+ luminescence processes.

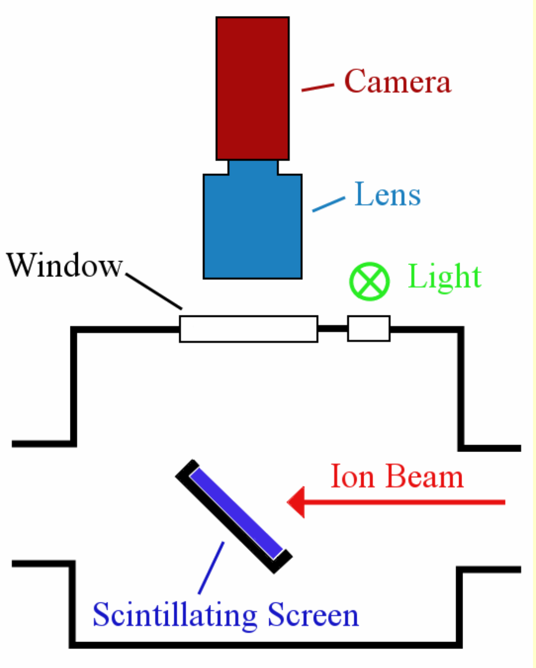
A. Moroño, E.R. Hodgson / Journal of Nuclear Materials 249 (1997) 128–132

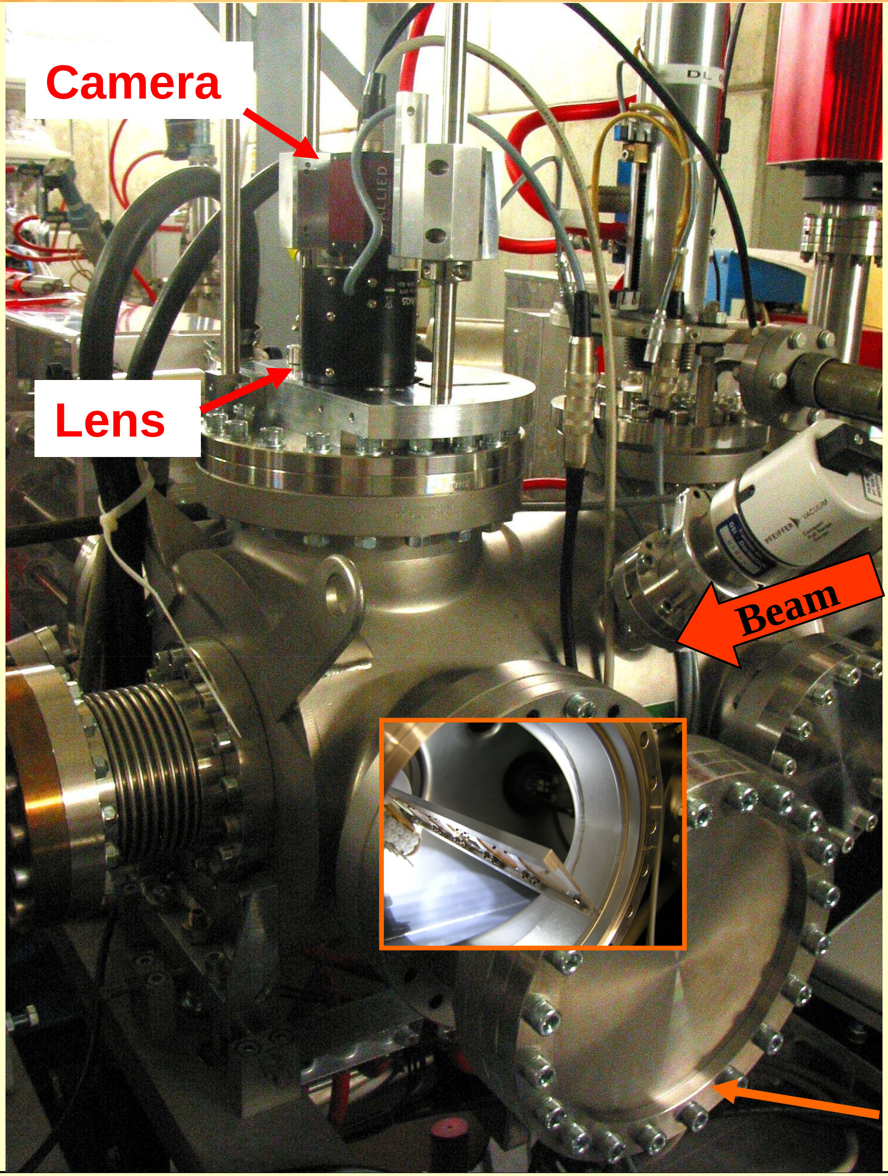
Results: **The spectrum of Al_2O_3 depend on the ion species.**

It is considered possible that F^+ and F^0 can convert into one another, depending on the ionization desity, i.e. the e-h population .

Advanced experimental setup (imaging prop.)







Camera: AVT Stingray F033B (VGA monochromatic), FireWire interface
Lens: Linos ROD Mevis, 2516, stepping motor driven
Resolution: 10 pixel/mm
DAQ: Industrial PC with FPGA

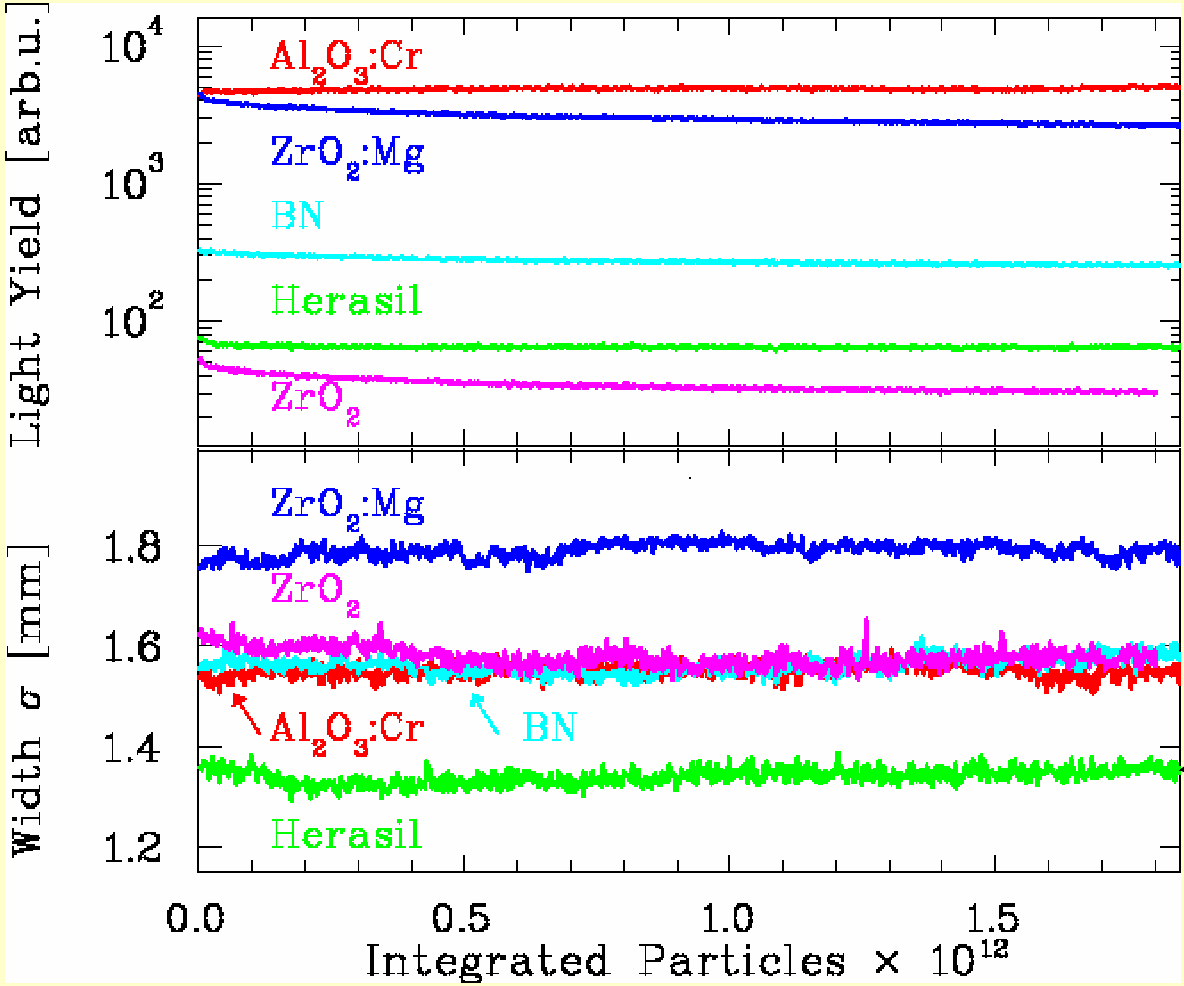
Advantage:

- **back-fitting time from spectrometer to normal camera is about ~25 min.**
- **new DAQ stores the number of particles synchr. for each image → new@GSI**

Flange diameter 200 mm

Light yield and profile width @ low intensity

Beam parameters: $^{40}Ar^{10+}$, 11.4MeV/u, **$2*10^9$** Ions/Pulse in 100µs, ~30µA, 2.4Hz, 1000 beam pulses



Results:

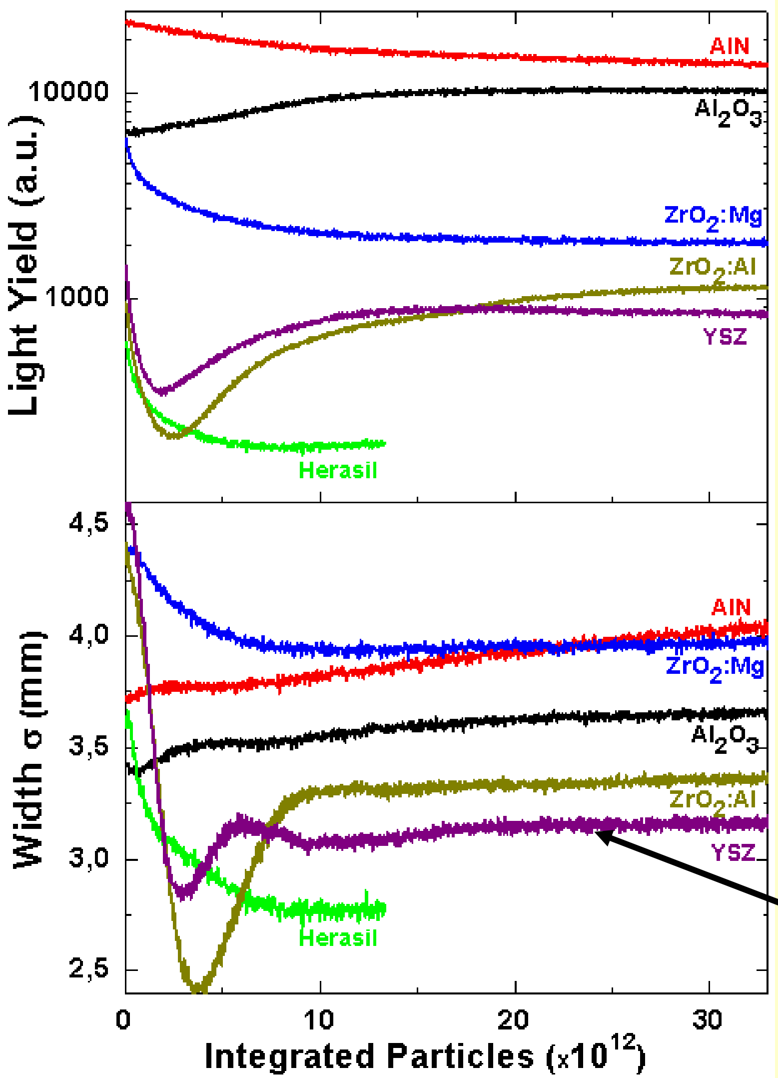
- **reproducible behavior**
- **different light yield and width reading**
- **light yield does not correlate with beam width**
- **different beam shape (from higher stat. moments)**

Difference of 14% in profile width is not negligible for quantitative evaluation

Average temperature: ~47°C (backside of ZrO_2:Mg)

Light yield and profile width @ higher intensity

Beam parameters: Ar^{10+}, 11.4 MeV/u, **3.3*10^{10}** Ions/Pulse in 0.2ms, 260µA, 1.7Hz, 1000 Pulse



~10 times higher beam current

Results:

- **light yield and profile width depend on material**
- **different dynamical behavior**
- **possible reasons: material modification and temperature dependency**
- **for the zircon oxides the behavior is clearly temperature dominated**

Difference of 30% in profile width is not negligible for quantitative evaluation

Average temperature: ~200°C (backside of Al_2O_3)

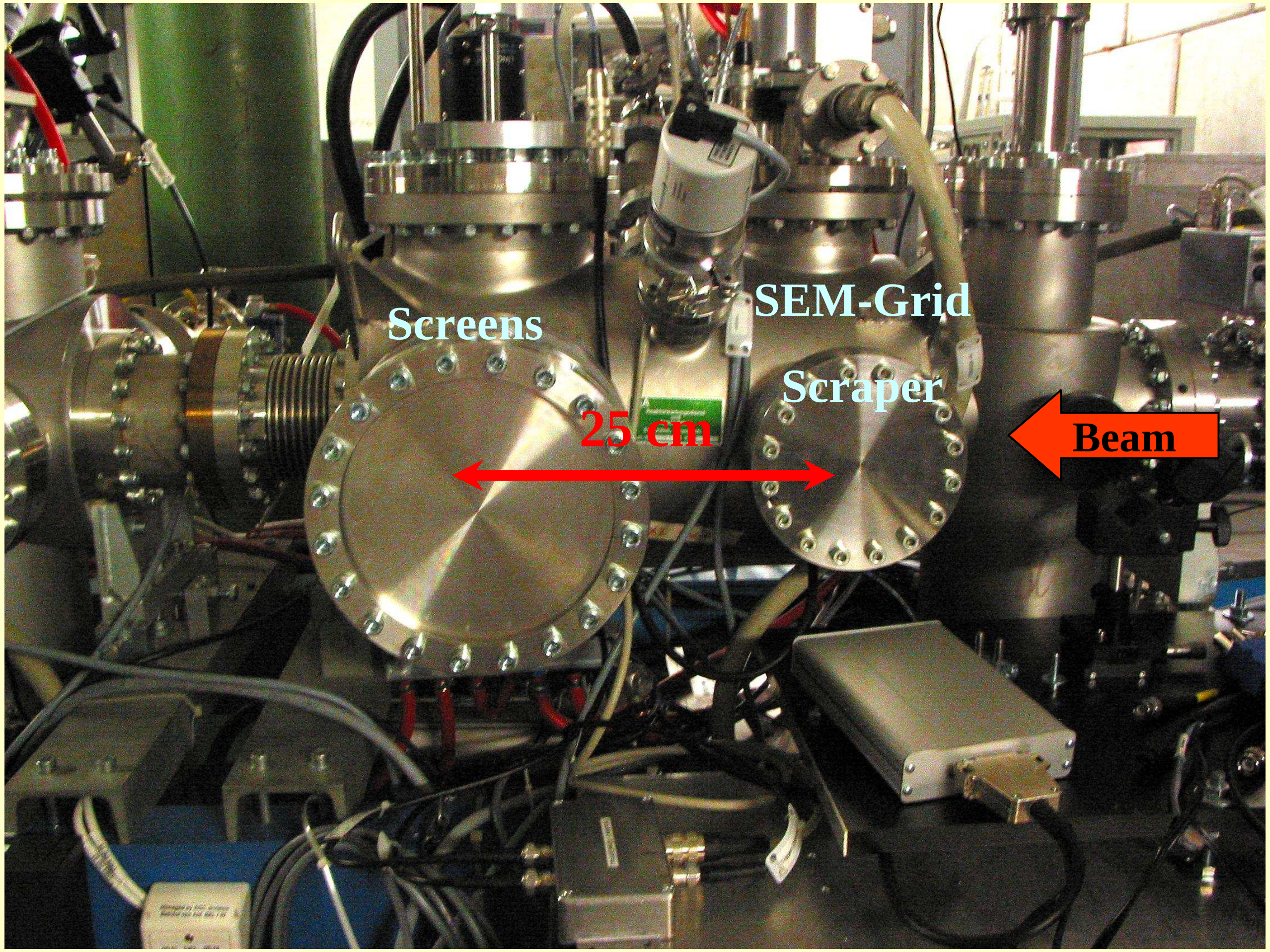
What we have seen up to now

The different materials measure different values for the transversal beam parameters for the same ion beam!

Which one is right, or are they all wrong?

What are the parameters of the ‚real‘ ion beam ?

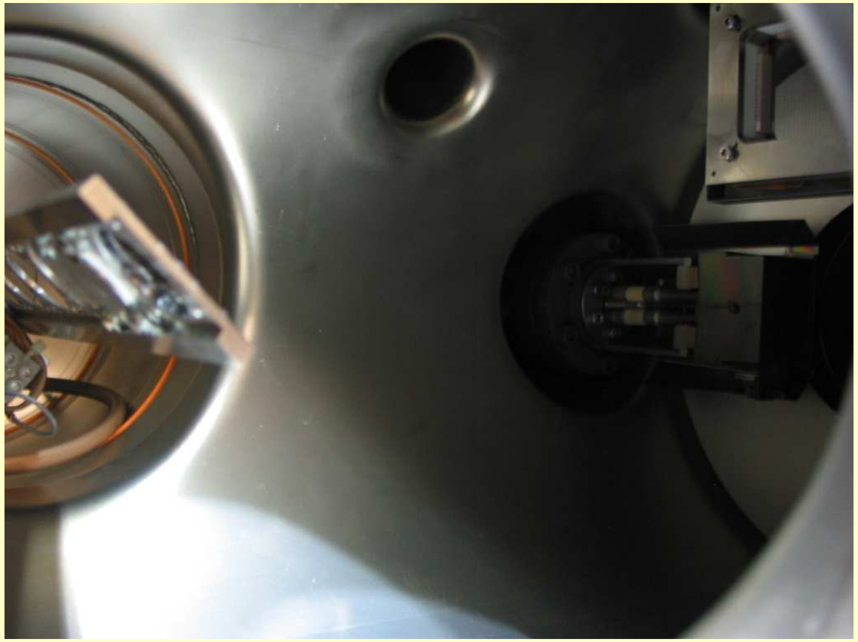
Comparison with reference methods

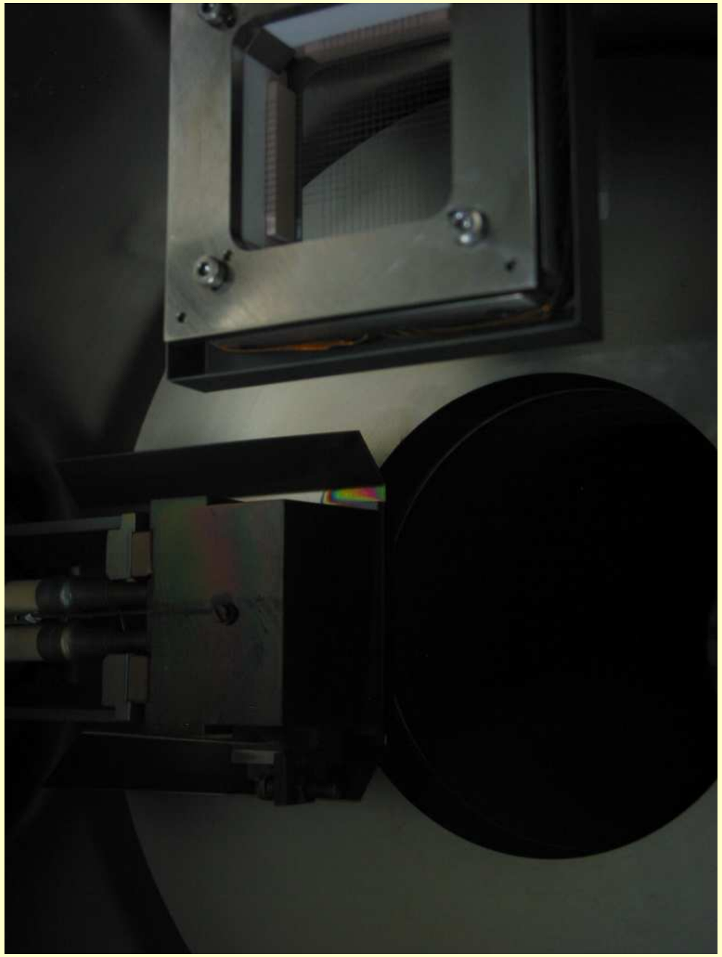


- One can measure a reference profile 25cm in front of the screens.

Limitation:

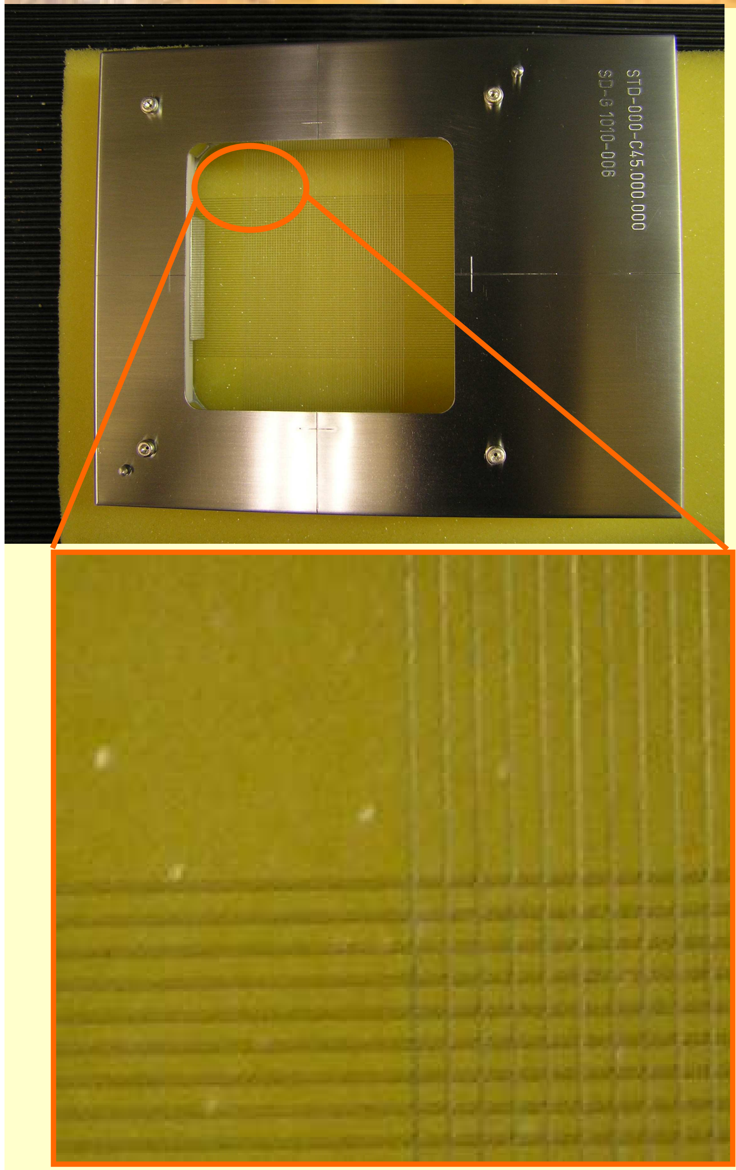
- Due to the lack of space it is not possible to take reference profiles at the same optical position as the screens.
- The profile grid is unable to measure the profile of the entire macro pulse





Secondary electron emission (SEM) grid

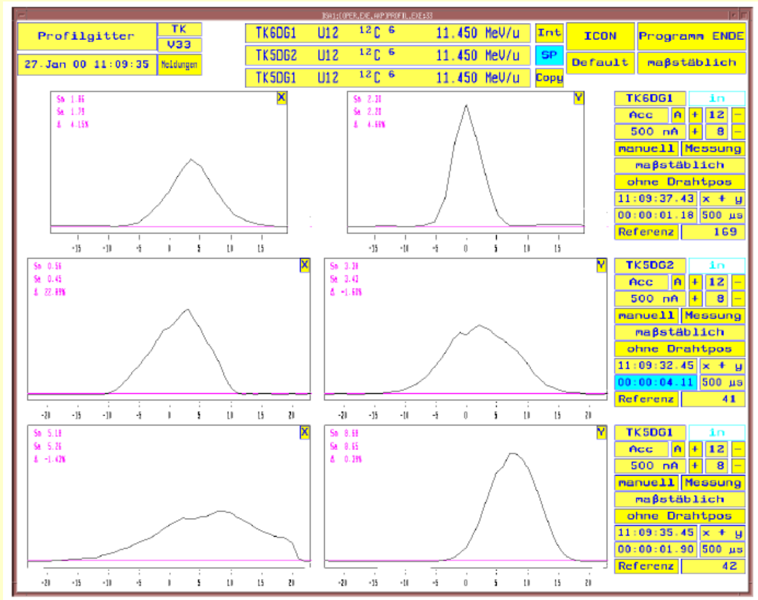
(Standard method)



When particles hit a surface, secondary electrons are liberated and escaping form the surface. For the profile determination, individual wires or ribbons interact with the beam; this is called a **S**econdary Electron **EM**ission grid.

Limitation:

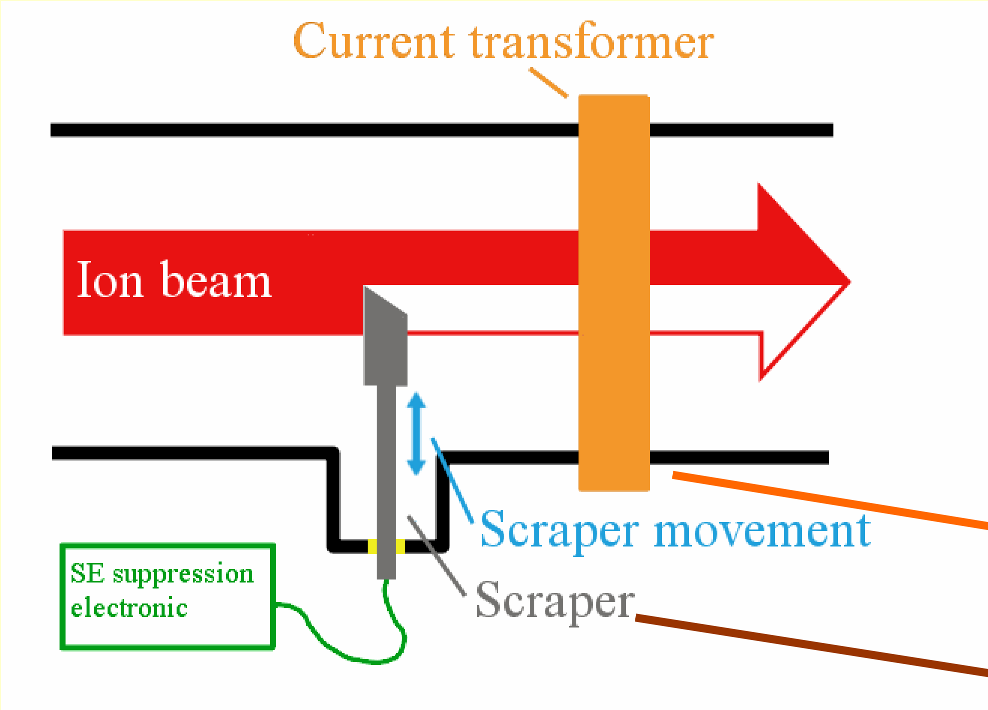
distance between wires:
~ 0.8 - 1.5mm

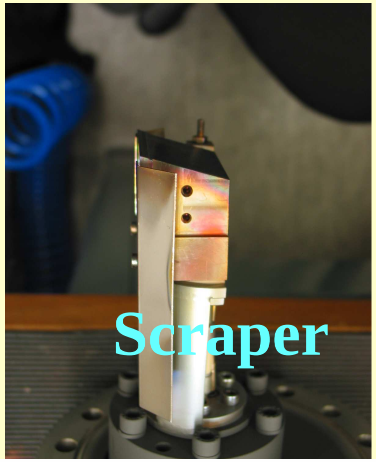


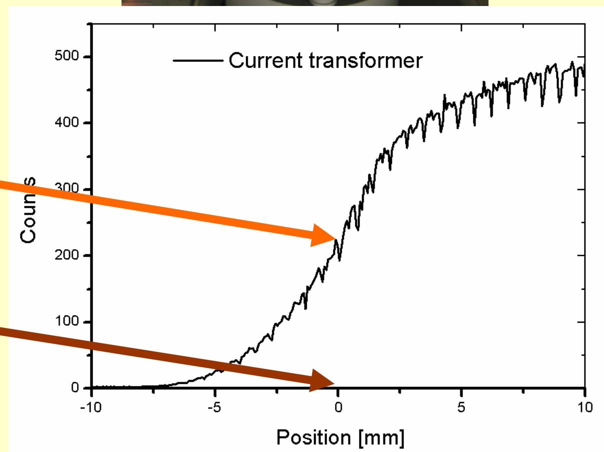
The 2nd reference method?

• **How can one obtain a trusted beam profil with a better spatial resolution then a SEM-Grid**

One can try to obtain a beam profile by using a scraper

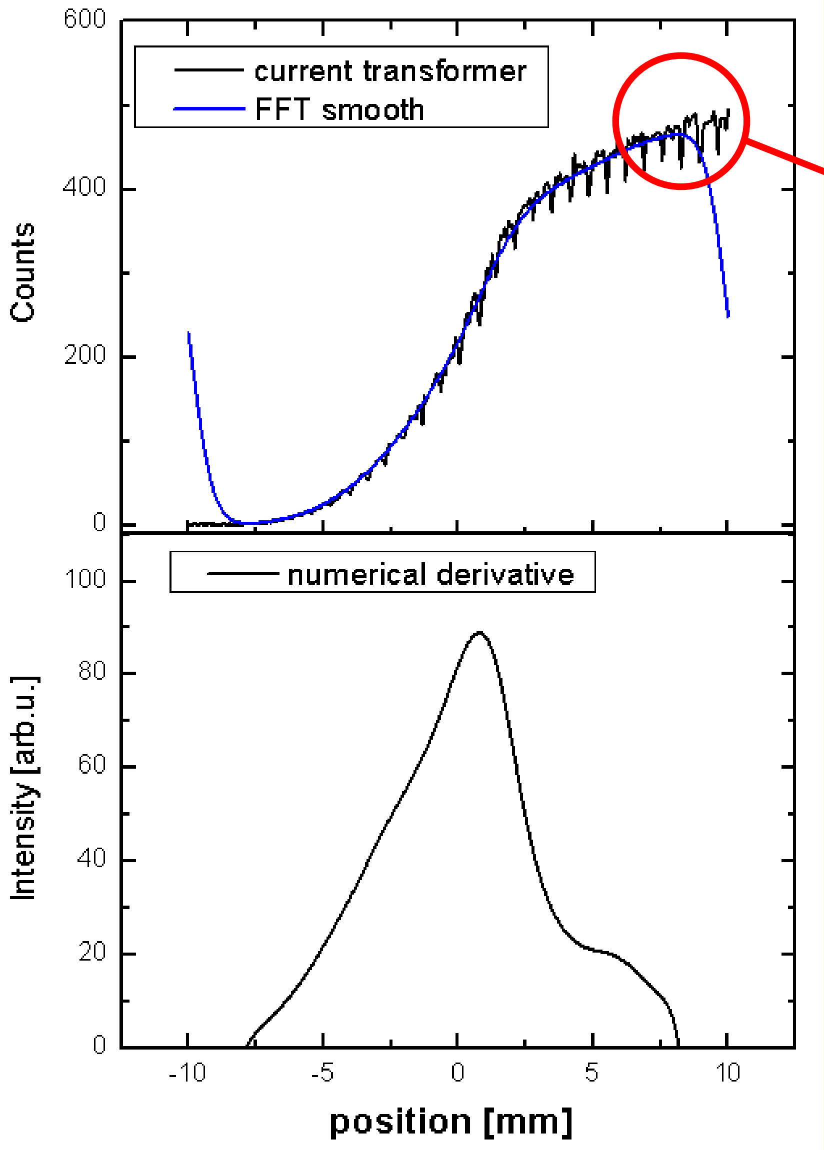


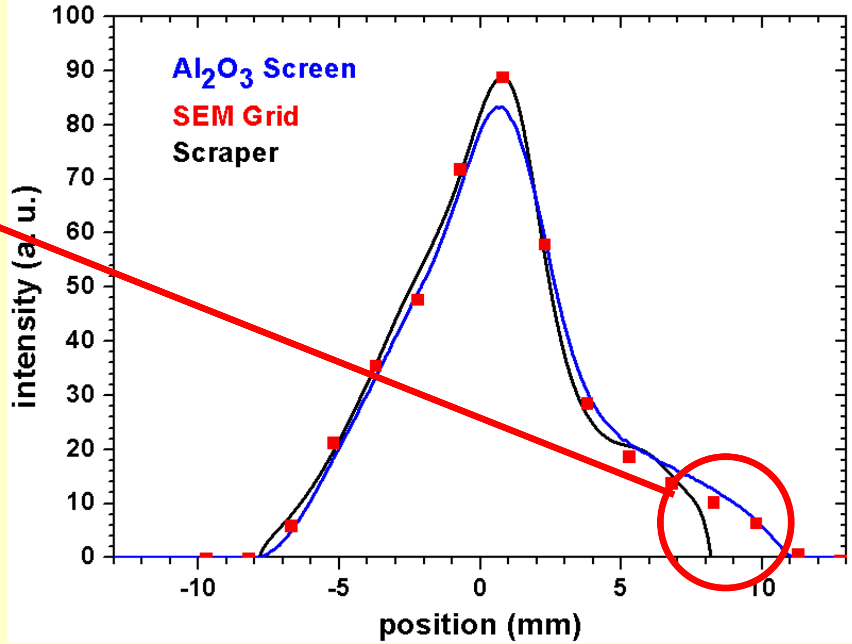




SE suppression electronic ensures that no electrons affect the transformer measurements

Evaluation of data and comparison of diff. methods





Results:

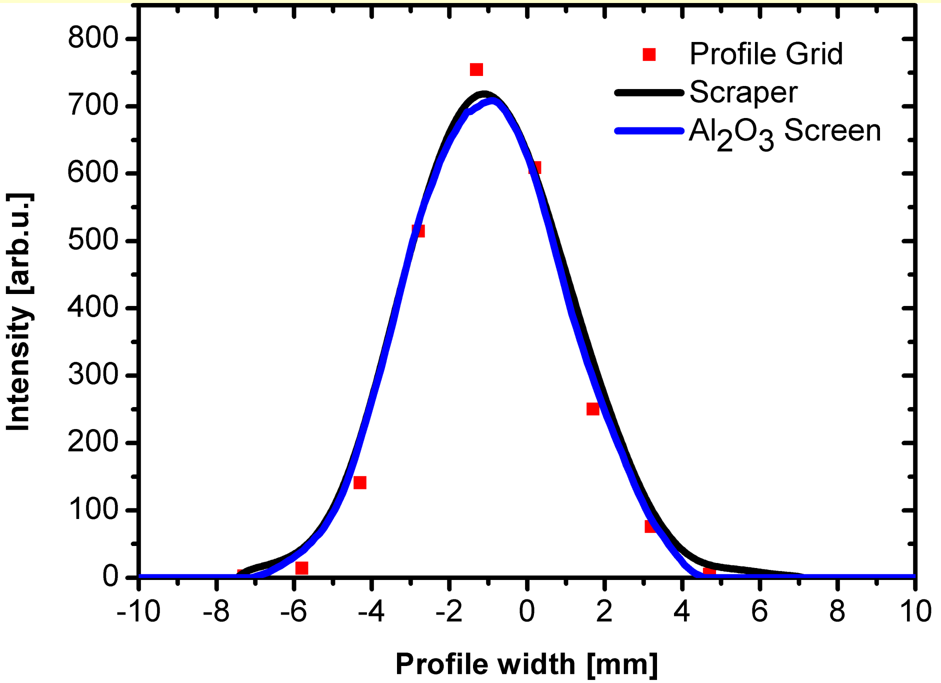
• **SEM Grid and Scraper are in good agreement.**
→ One can obtain a beam profile with a scraper with a much higher resolution then a SEM Grid

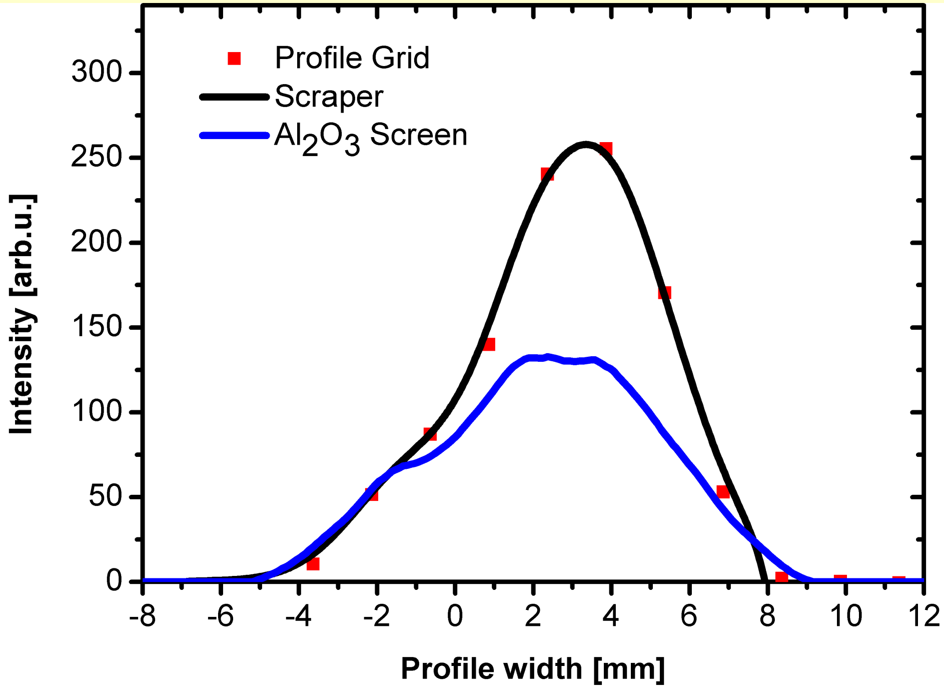
• **Allows to determine the response of the scintillator**

• **Method needs a stabile ion beam**

What is the useful operating range of an Al_2O_3 Screen?

4.8 MeV/u		11.4 MeV/u
$4.3*10^{10}$ ppp	← Same pulse energy →	$1.8*10^{10}$ ppp
5ms		1,2 ms





Result: **Light yield is the same for both energies. For the 11.4 MeV/u case, the imaged beam profile does not math to both reference methods. No F^0 → F^+ conversion (Spectrum)**

What could be an explanation for the results?

There are models that describe the light output of scintillators, but:

- for single particles
- only one species, e.g. Tl^+
- can not predict changes in spectrum for diff. ions
- low doses (no damage)
- .....

Light output is proportional to dose (e-h pairs) up to a quenching density ρ_q , above this dose the light output is constant. Fitting parameter: ρ_q

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Nuclear Instruments and Methods in Physics Research A 356 (1995) 297–303

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

Scintillation response of nuclear particle detectors

K. Michaelian, A. Menchaca-Rocha, E. Belmont-Moreno

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Received 26 July 1994

Different ansatz with δ electrons. 4 fitting parameters

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Nuclear Instruments and Methods in Physics Research A 482 (2002) 674–692

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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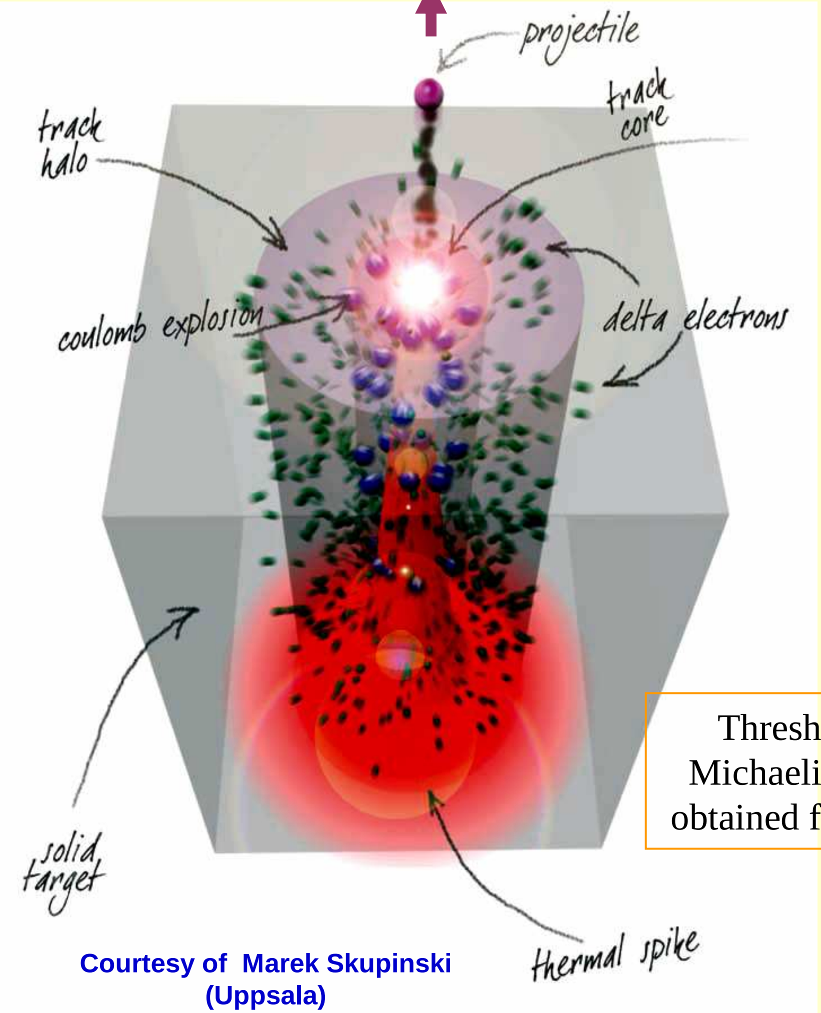
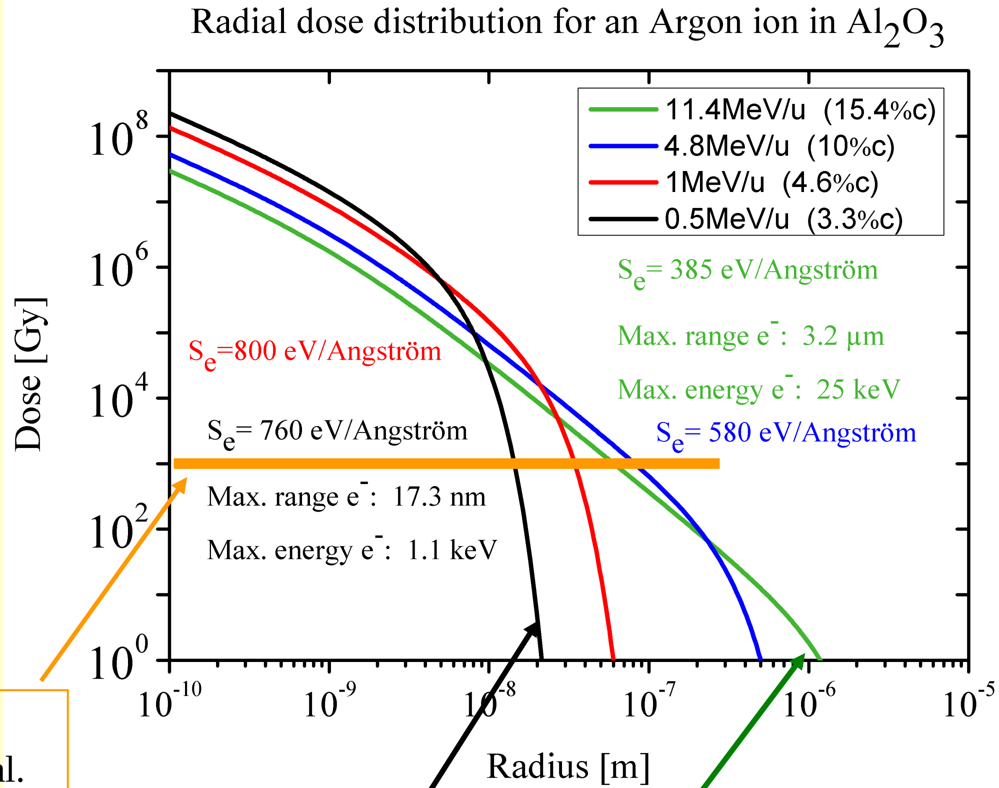
Response of CsI(Tl) scintillators over a large range in energy and atomic number of ions Part I: recombination and δ-electrons

M. Pârlog[a,b], B. Borderie[b,*], M.F. Rivet[b], G. Tăbăcaru[a,b], A. Chbihi[c],

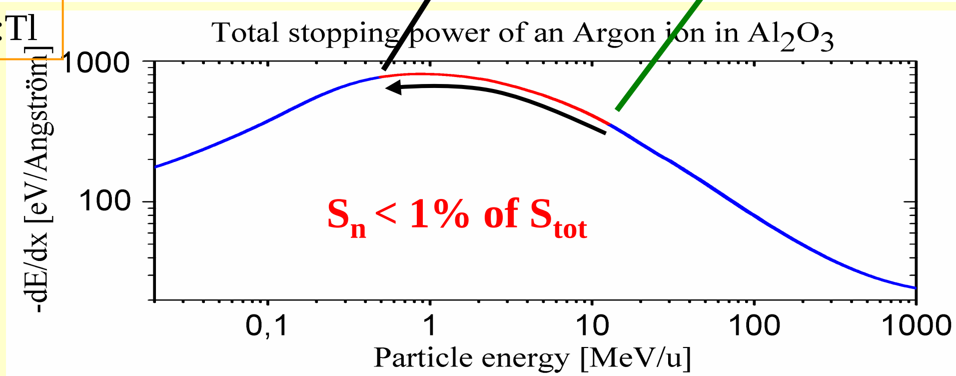
Due to the complexity of the scintillating mechanisms, it is still under investigation

The radial dose distribution of an ion track



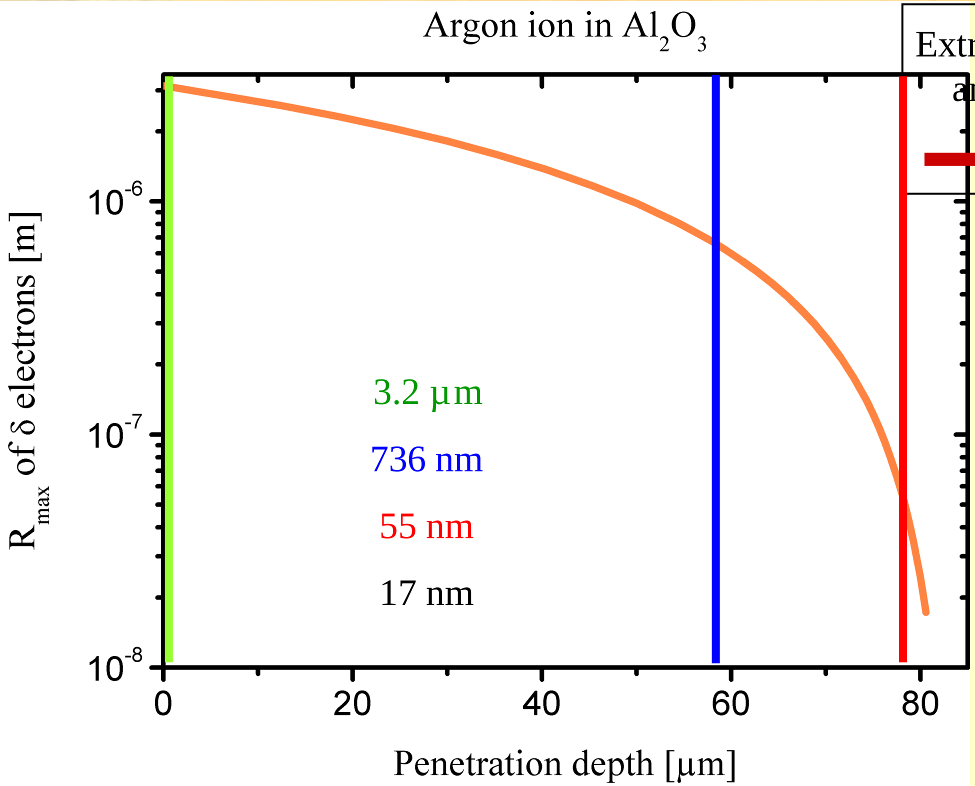


Threshold of Michaelian et al. obtained for CsI:Tl



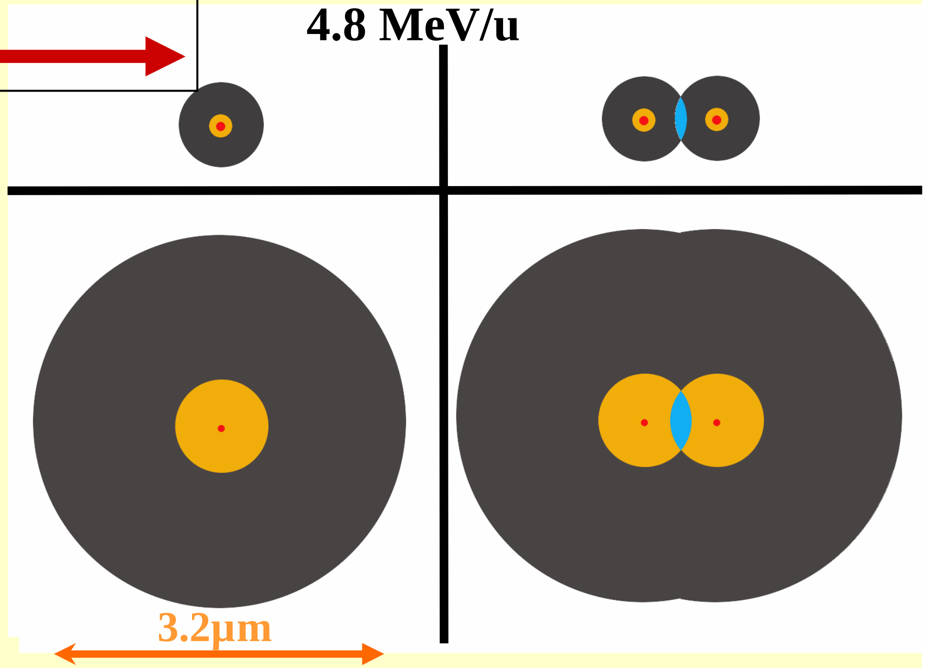
The camera can see all energies (depth) weighted with a Lambert-Beer absorption

Penetration depth and R_{max}



Extrapolation for an ion beam

Schematic overlap of ion excitation tracks in space and time



Particle energy: 11.4 MeV/u, 4.8 MeV/u, 1MeV/u

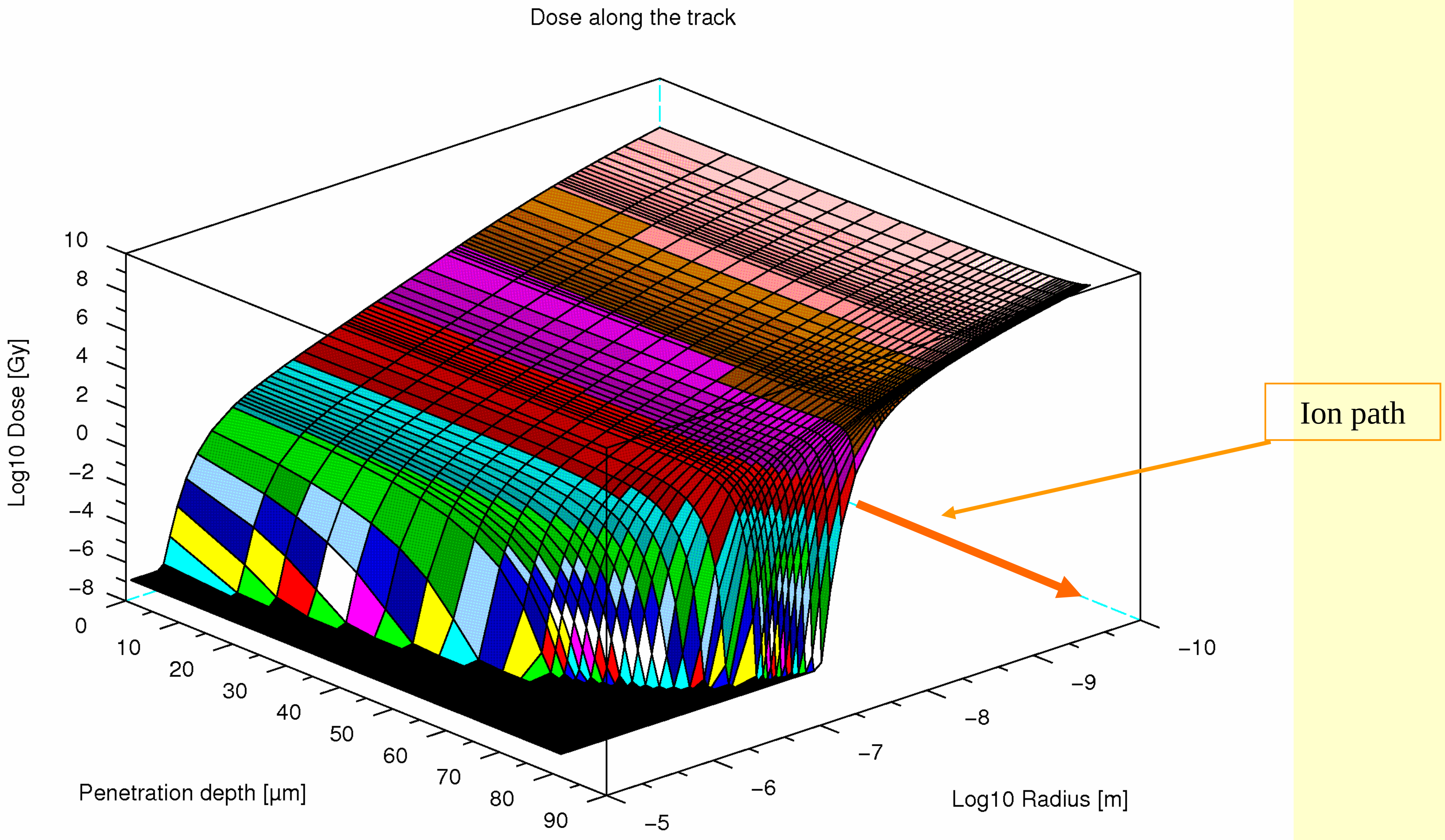
1E9 particles/cm² within the lifetime of the state.

The camera can see all energies (depth) weighted with a Lambert-Beer absorption

Result:

Higher light yield for faster particles but on the other hand, overlapping excitation tracks in the centre of the ion beam → F^0 centre could be ionized again! → → Spectrum?

Penetration depth and R_{max}



The Model

For a time dependent 4D Monte Carlo Model, e.g. for Al_2O_3 , one would need in my opinion the cross-sections for:

- Electron capture at F^{2+} and F^{+}
- Hole capture at F^{0} and F^{+}
- Ionization of F^{+} and F^{0}

..... and the hole dynamic of charge carrier production, movement and trapping in the bulk material in dependence of ionization density.

Each one of them is a separate PhD-thesis, and it seem difficult to me to measure them independently of each other.

So lets try an time independent model

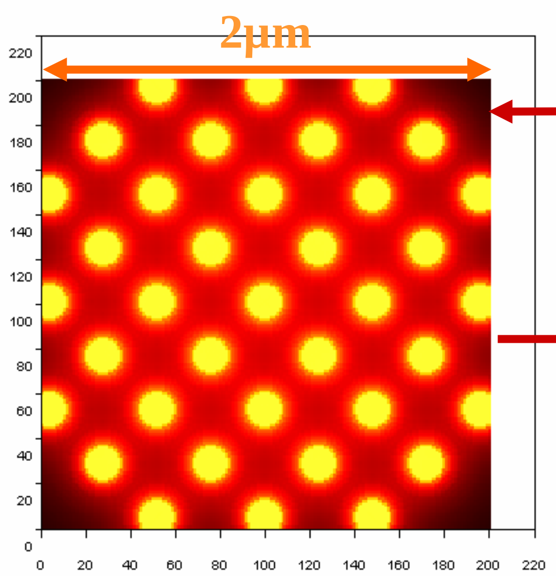
The Model

Assumption:

1. The radial dose distribution with the parametrization of Katz et al. '96 is valid
2. There is an ionization threshold like the one proposed by Michaelian et al.
3. The re-ionization process has a linear behaviour
4. The pulse length is smaller then e-h recombination+lifetime of the state (at least valid for F^{0*} state of Al_2O_3)

!The only fitting parameter is the ionization threshold ρ_i!

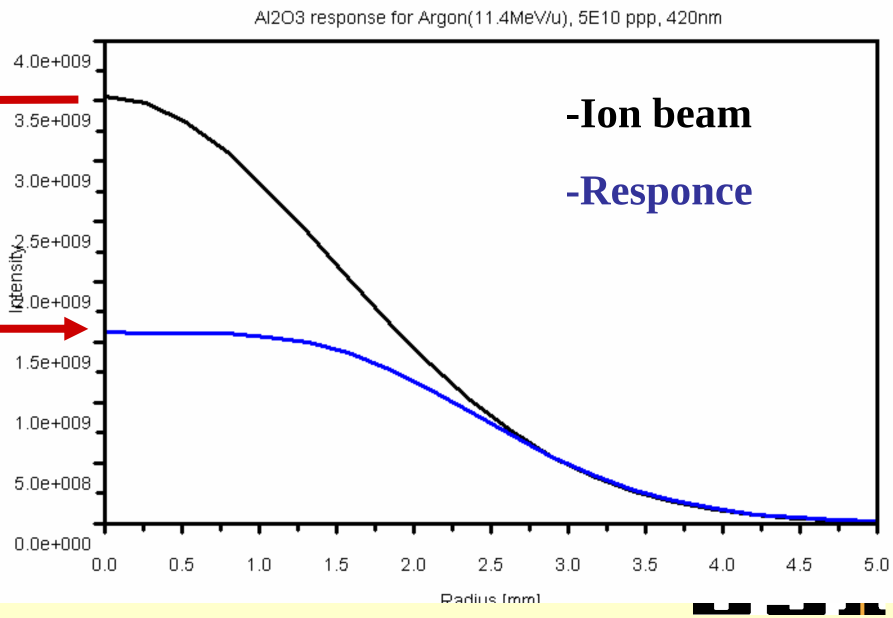
3.5E9 ions/cm²



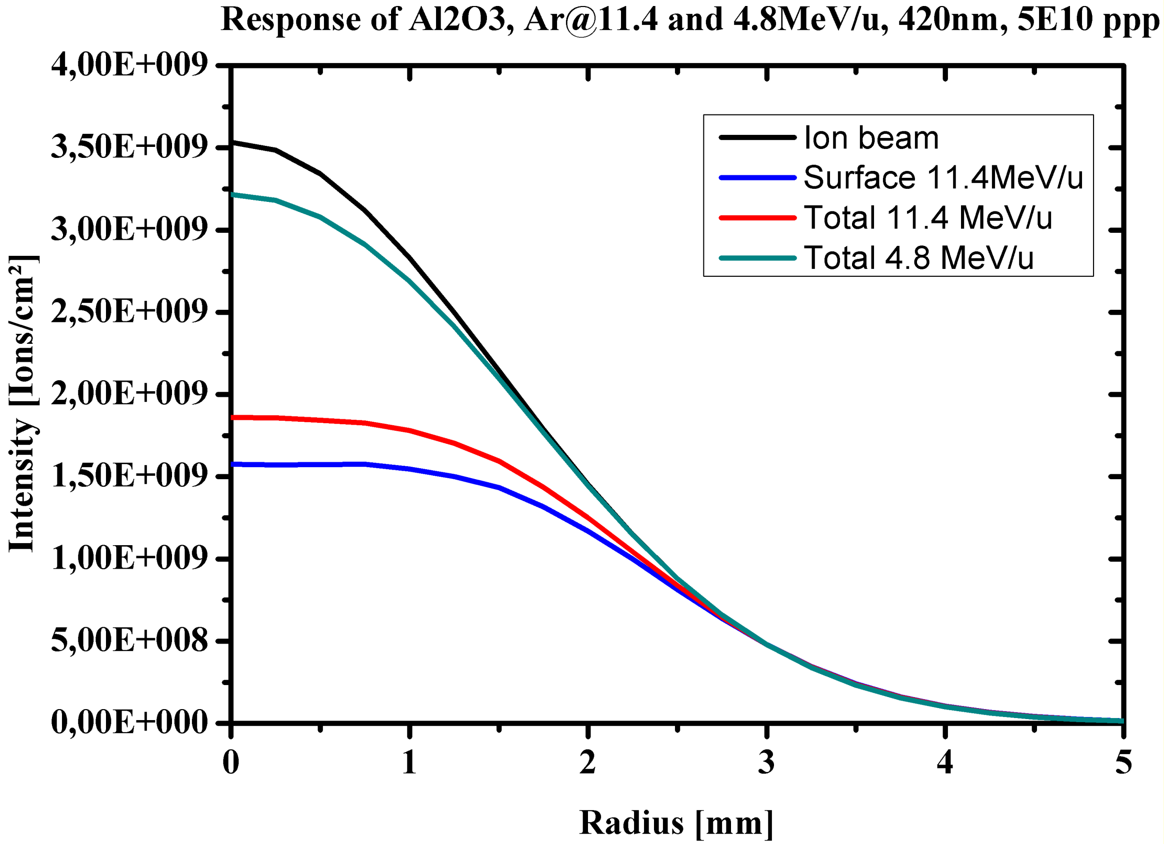
occupation density

response

Only ~720 lines of SciLab-Code ☺



The prediction..... 'Tadaaa'



5E10 ppp

ionization thershold = 5E2 Gy

Results: The Model fits the experimental results quite well

For a gaussian ion beam, Al_2O_3 screens, Argon @ 11.4 MeV/u, and 5E10 ppp;

The projection of a 4.8MeV/u ion beam is way less deformed then the one of 11.4 MeV/u, if one looks at the F^0 (420nm) emission → F^+ (330)mn. And there is no big contribution to the signal from the end of the ion track.

What about some other materials….

Herasil is not suitable for high current due to:

- Crack formation
- Has a treshhold for light-output→ measures wrong (The smalles beam profile is not always the correct one)
- Can have reflections from the back-side, due to its transparancy
- Very low light-output

ZrO_2:Mg (Z507) is suitable fot high current operation, but

- Has lower light-output then Al_2O_3
- “Saturates” earlier then Al_2O_3

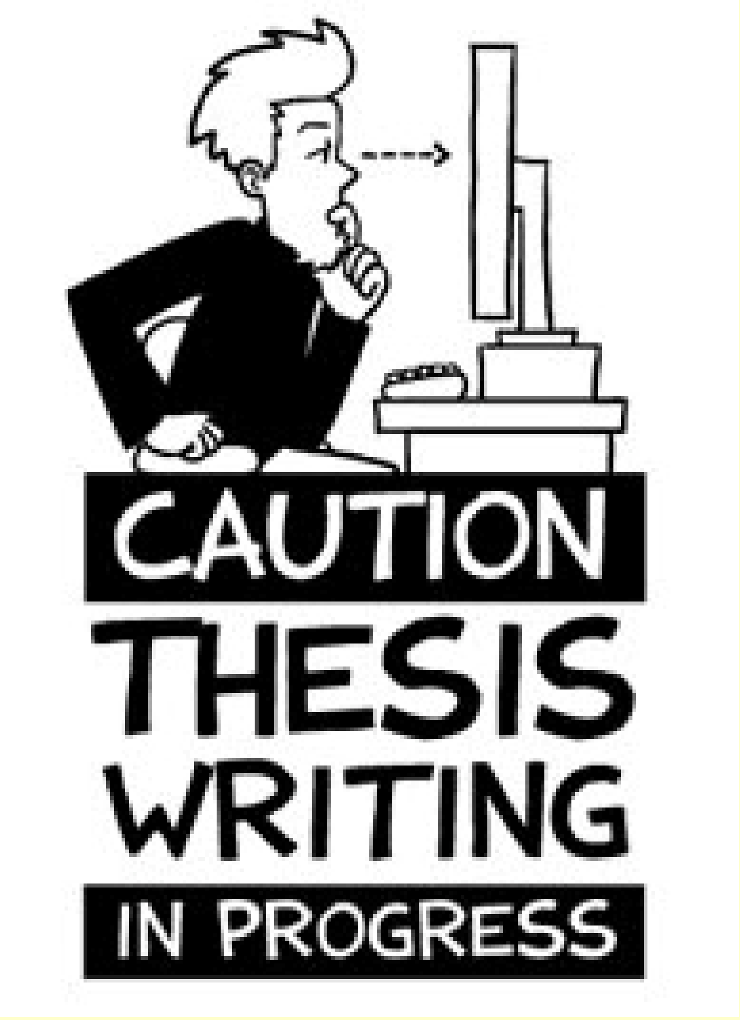
ZrO_2:Y (Z700) is suitable for high current operation, but

- Has a treshhold for light-output→ measures wrong
- Has low light-output

and the winner is: **Al_2O_3**

Summary of 2010

Winter / Spring 2011



Should be ready in April 2011

Summer 2011

The defens

2011, August

Fätsch