Study of scintillation stability in KBr, YAG:Ce, CaF2:Eu and CsI:Tl irradiated by various-energy protons

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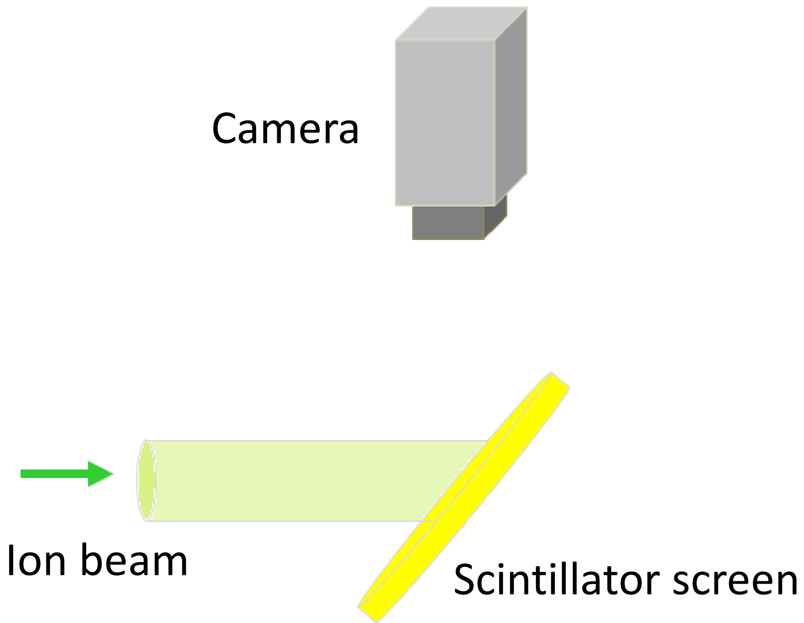
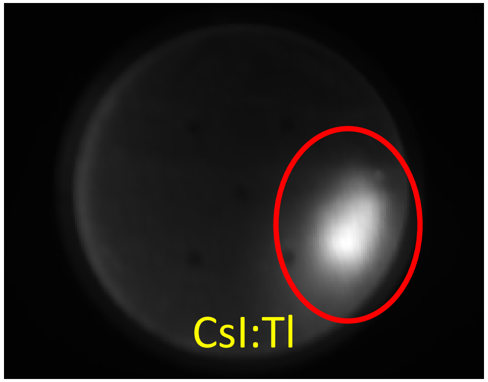
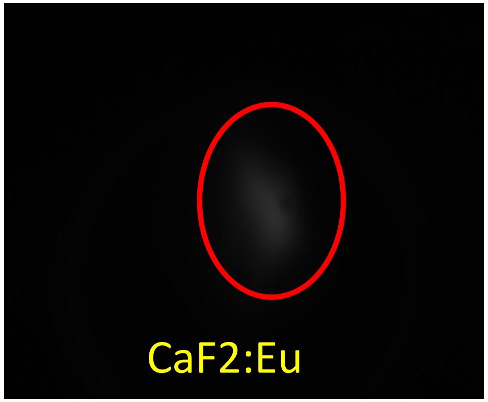
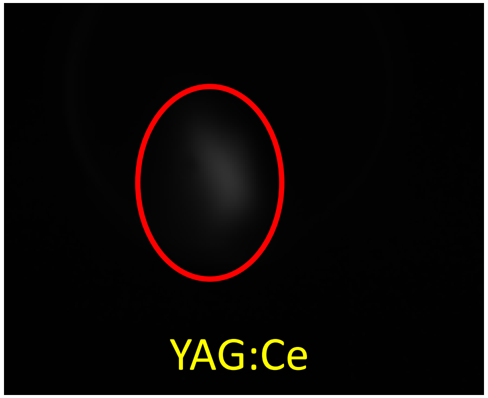
Motivation







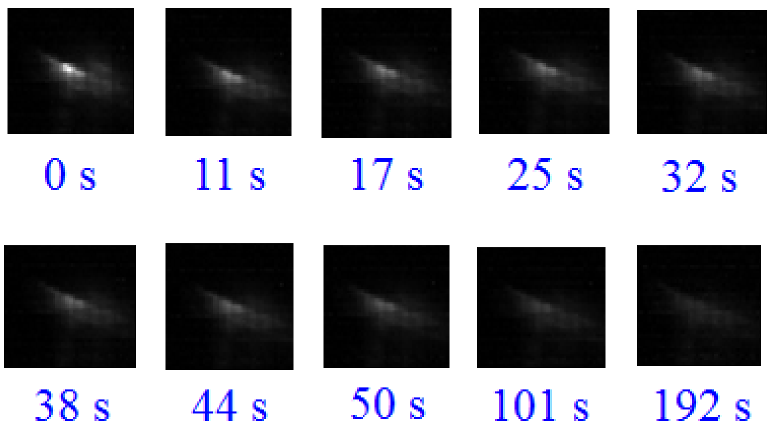


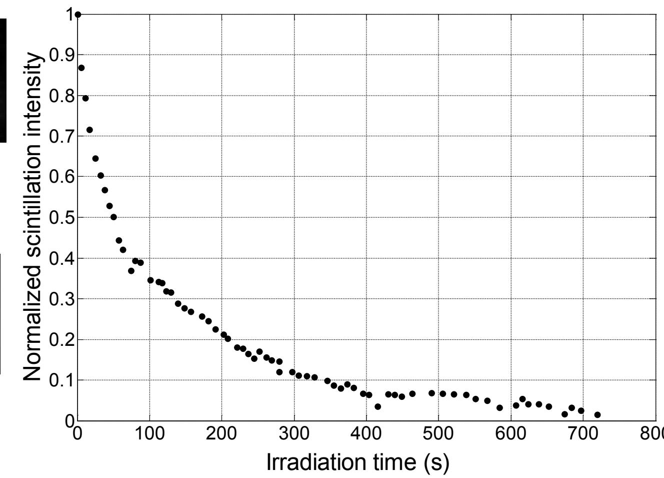
Under $H_2{}^+$ irradiation: 1500 keV , 125 pA

Motivation

YAG:Ce under He^{+} irradiation: 58 keV , 394 pA

Scintillation degradation





ReF: L. Y. Lin et al., "Scintillation degradation of YAG: Ce under low-energy ion bombardment", JINST 6 P07010 (2013).

- The irradiation experiments in the rare isotope ReAccelerator (ReA) facility of NSCL :

A variety of materials:

CsI:Tl
CaF2:Eu
YAG:Ce ($Y_3Al_5O_{12}$: Ce)
KBr

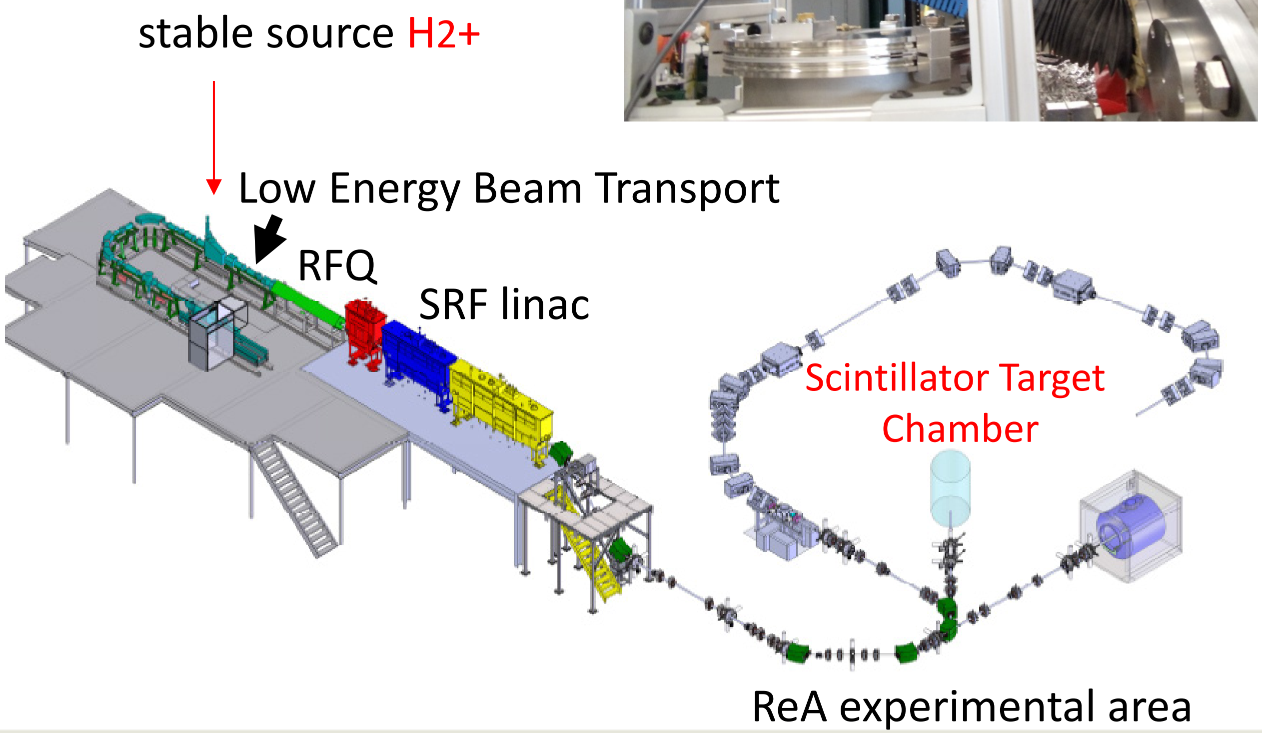
A wide range of irradiation energies:

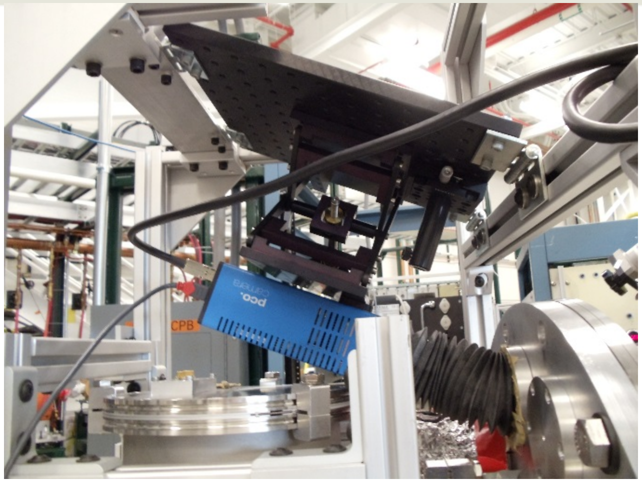
600 keV/u
1010 keV/u
1500 keV/u
2150 keV/u

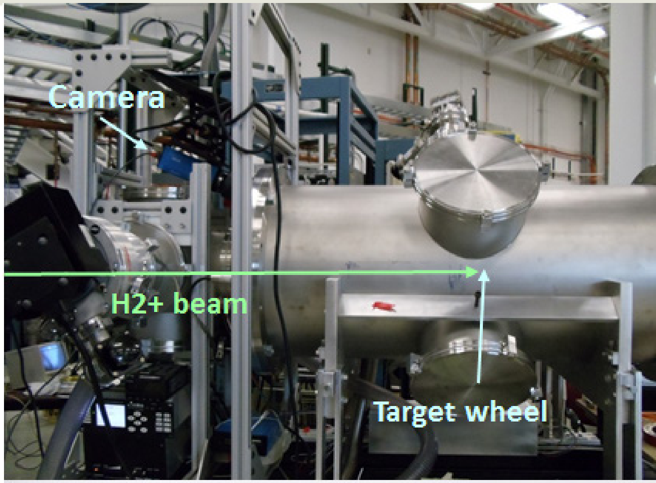
Low irradiation intensity:

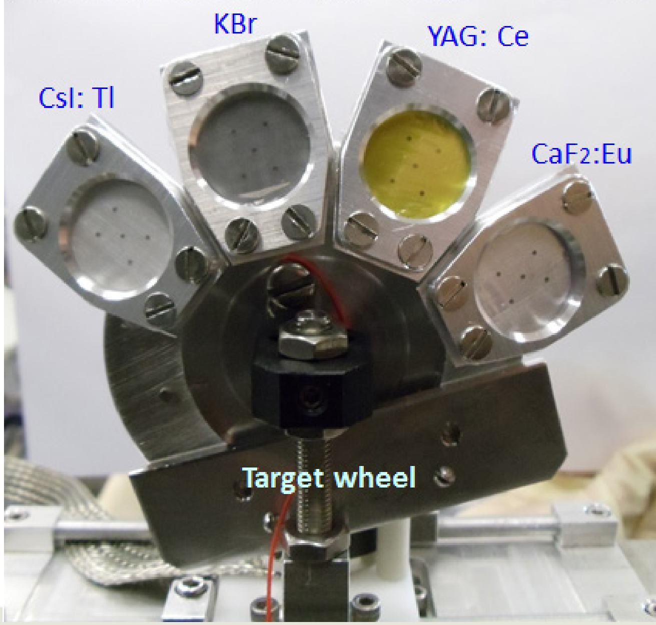
< 400 pA

Experimental Setup



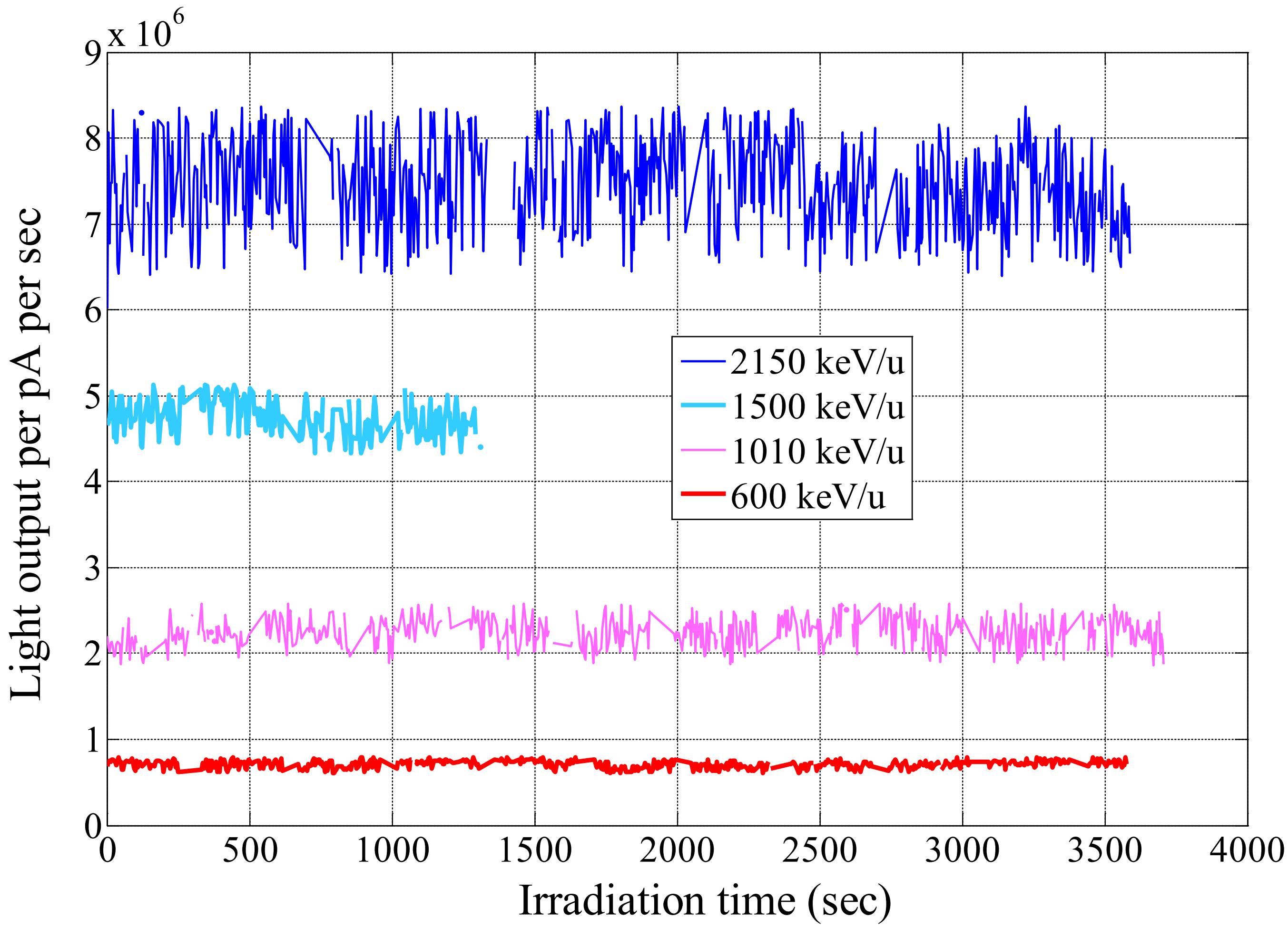






CsI:Tl Scintillation Response

Light Yield VS. Irradiation Time



Beam current

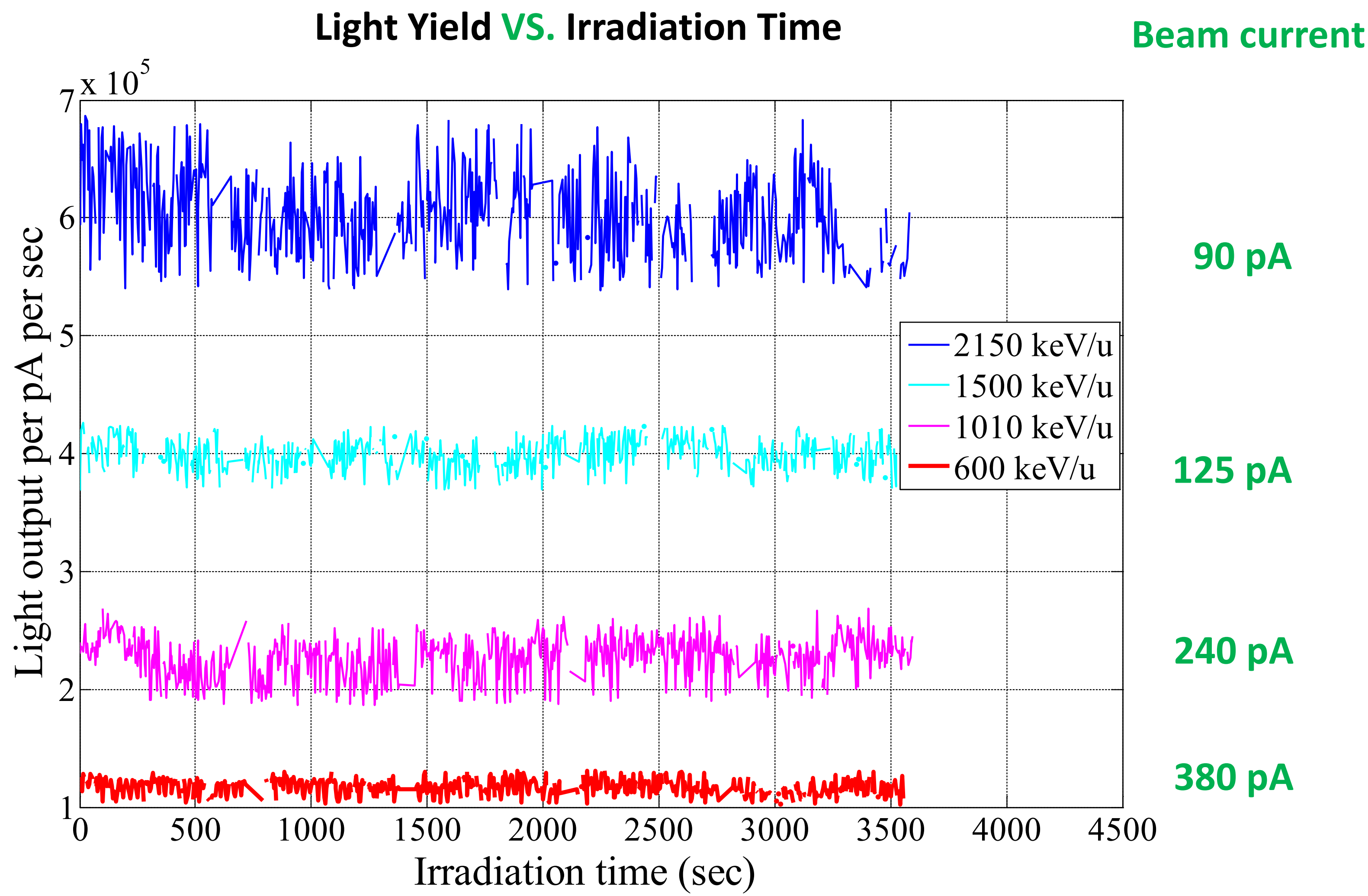
90 pA

125 pA

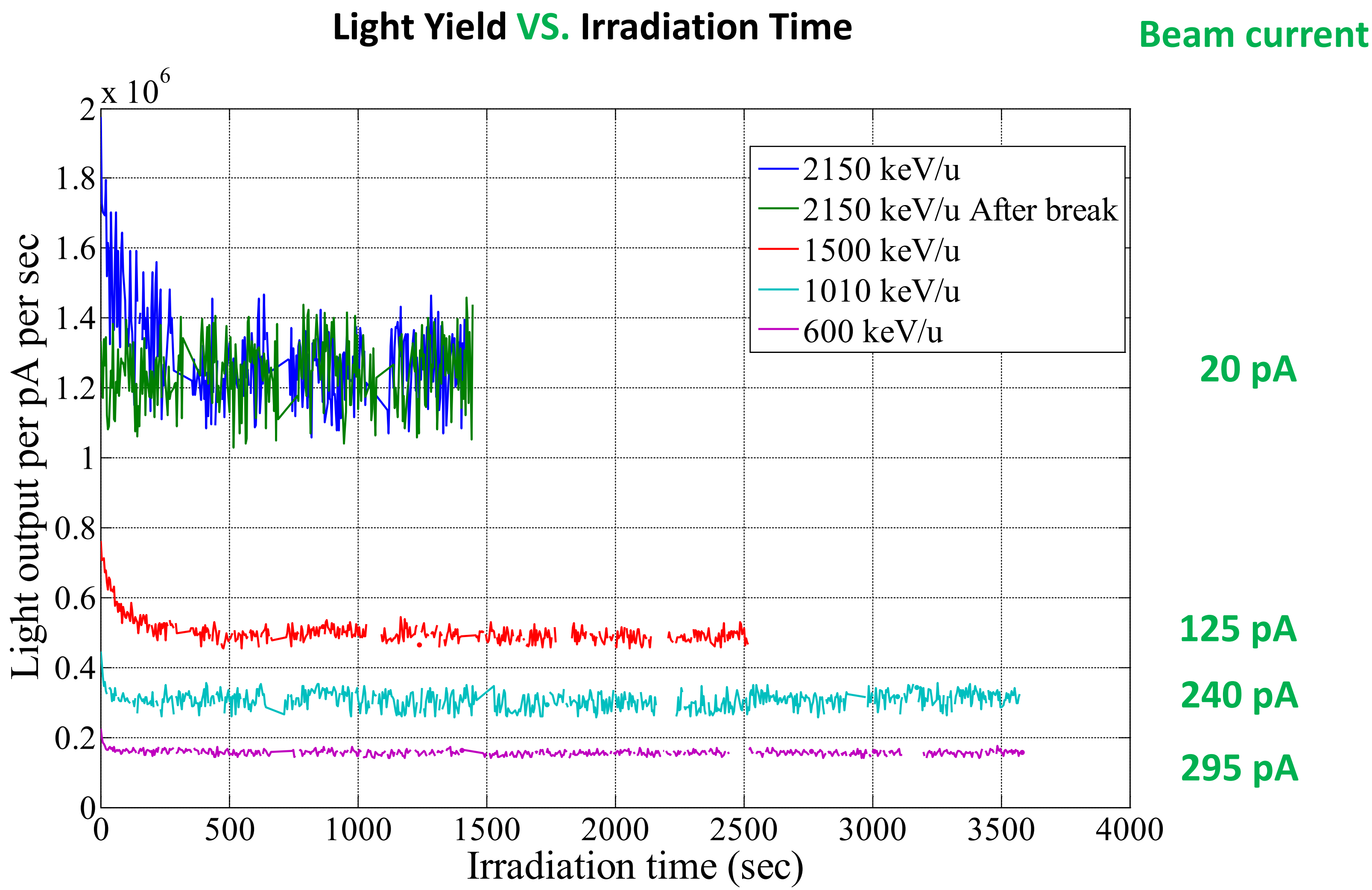
150 pA

175 pA

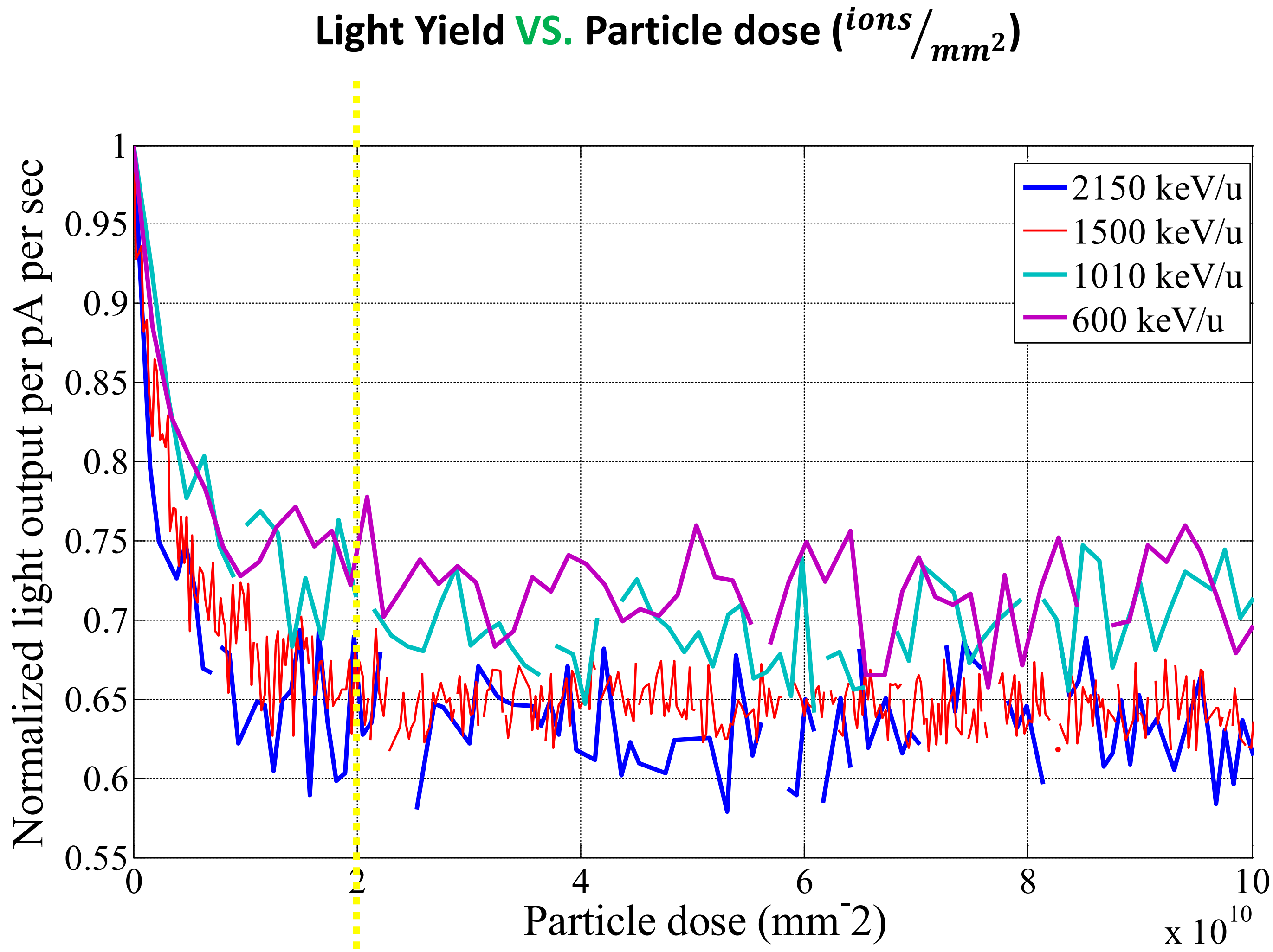
YAG:Ce Scintillation Response



CaF2:Eu Scintillation Response

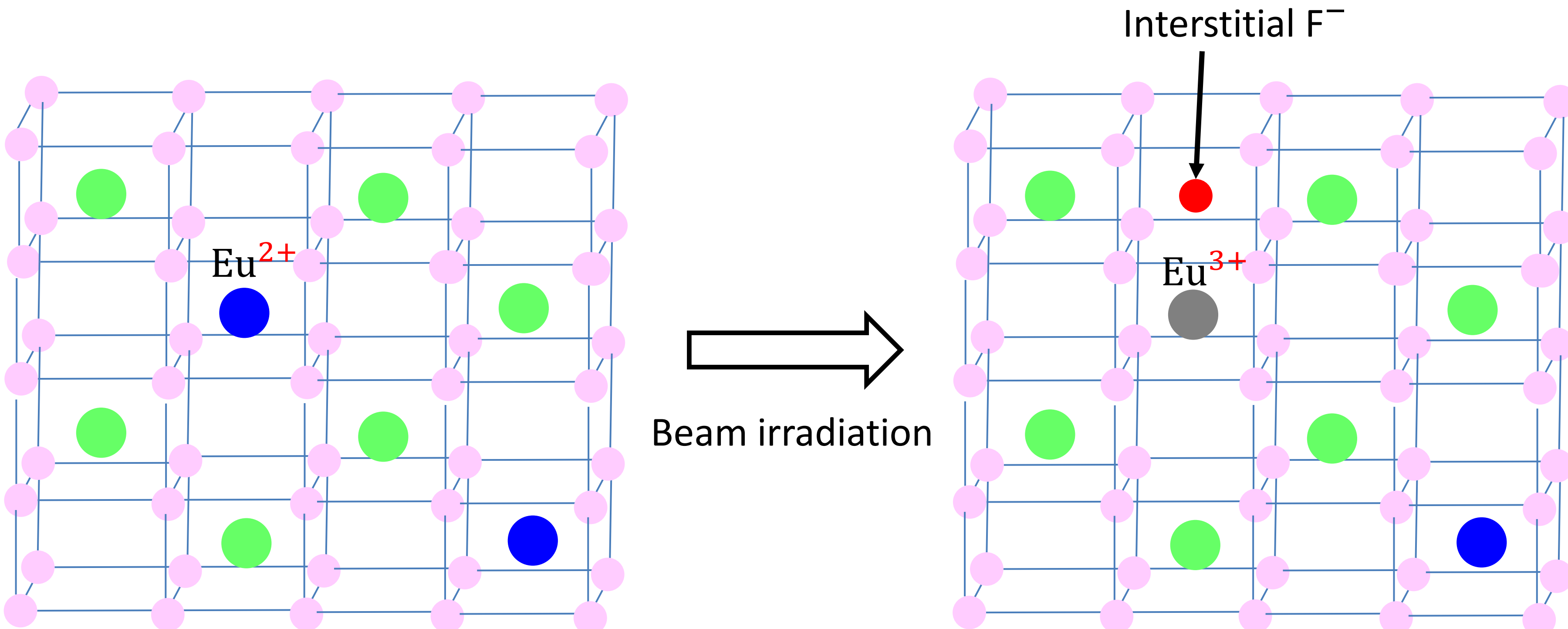


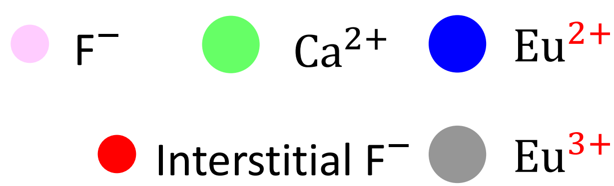
CaF2:Eu Scintillation Response



CaF2:Eu Scintillation Response

- Possible radiation damges of CaF2: Eu at room temperature



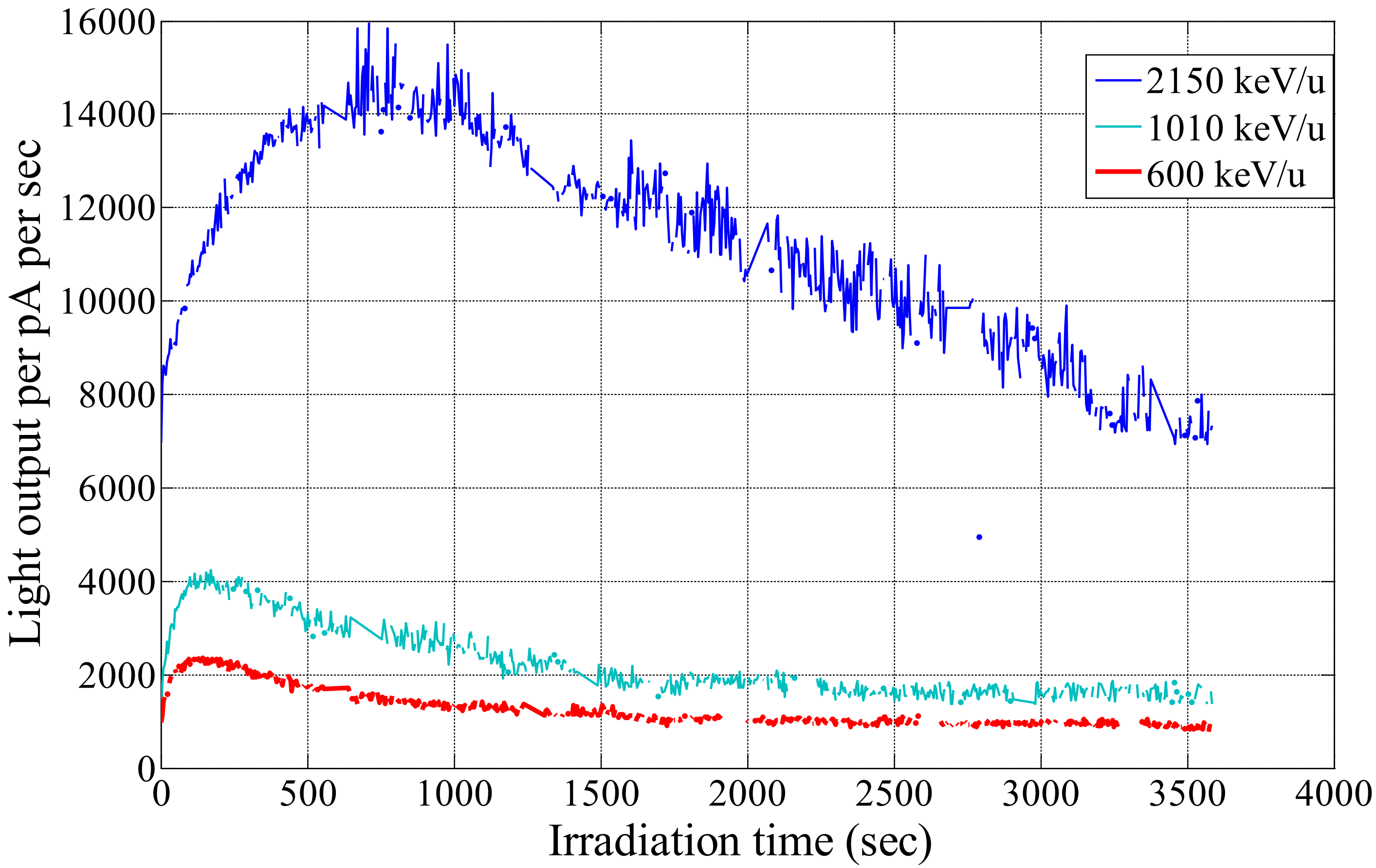


Eu^{2+}	Broad emission at ~425 nm
Eu^{3+}	Sharp emission lines at 574, 612, 626 nm, …

KBr Scintillation Response

Light Yield VS. Irradiation Time

Beam current



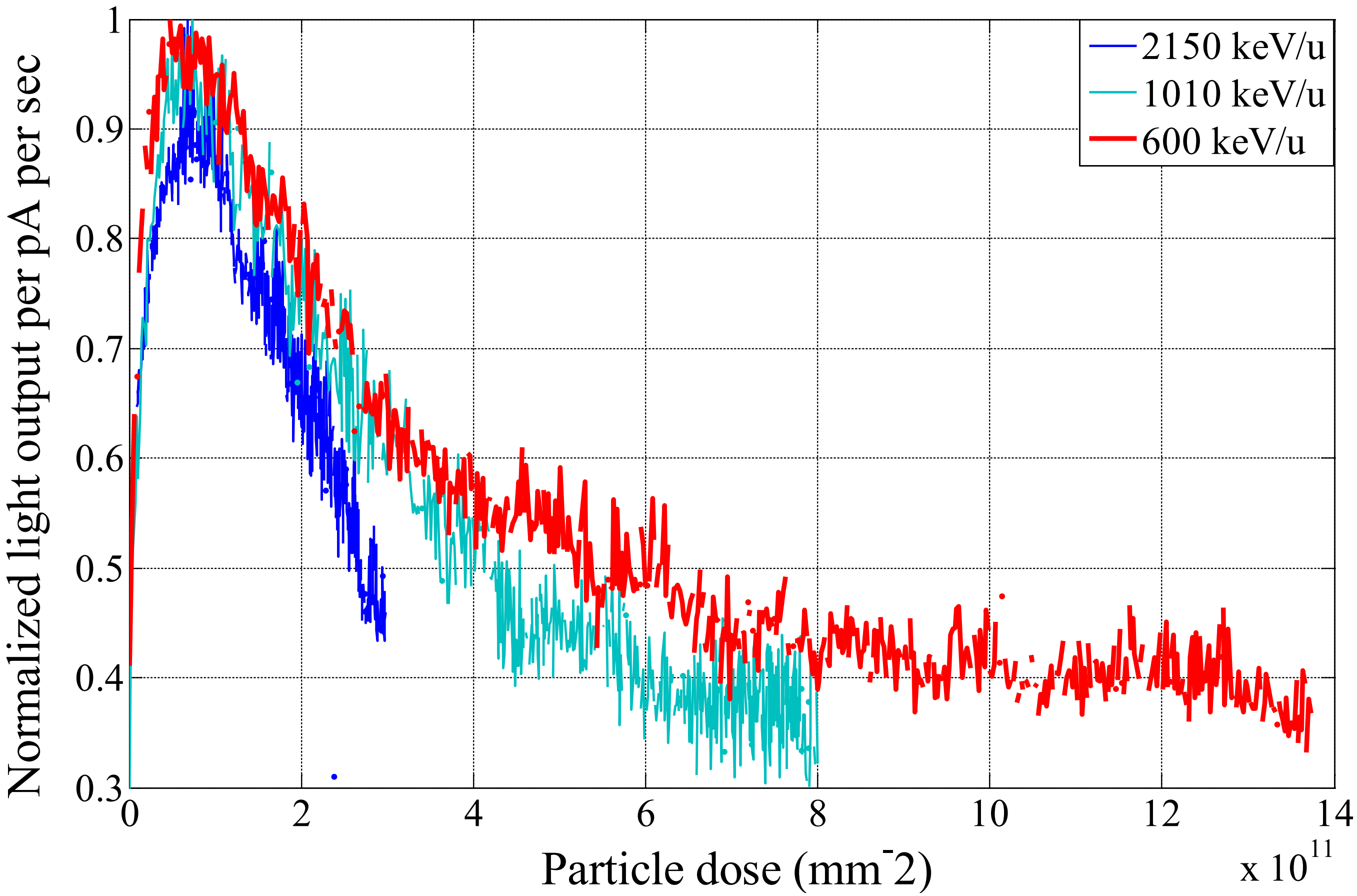
221 pA

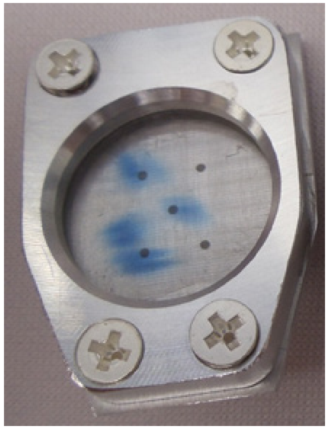
254 pA

370 pA

KBr Scintillation Response

Light Yield VS. Particle dose ($^{ions}/_{mm^2}$)

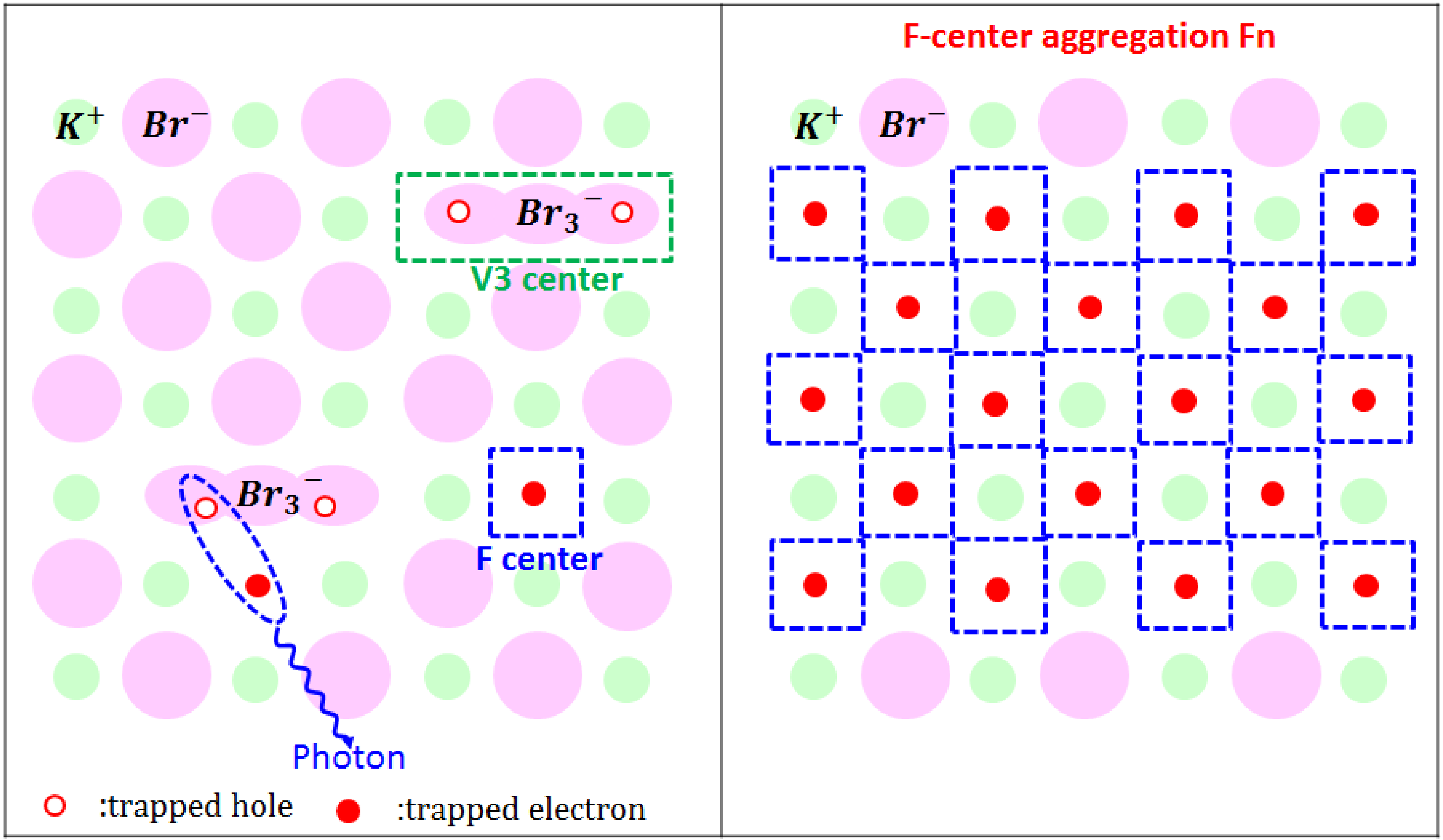




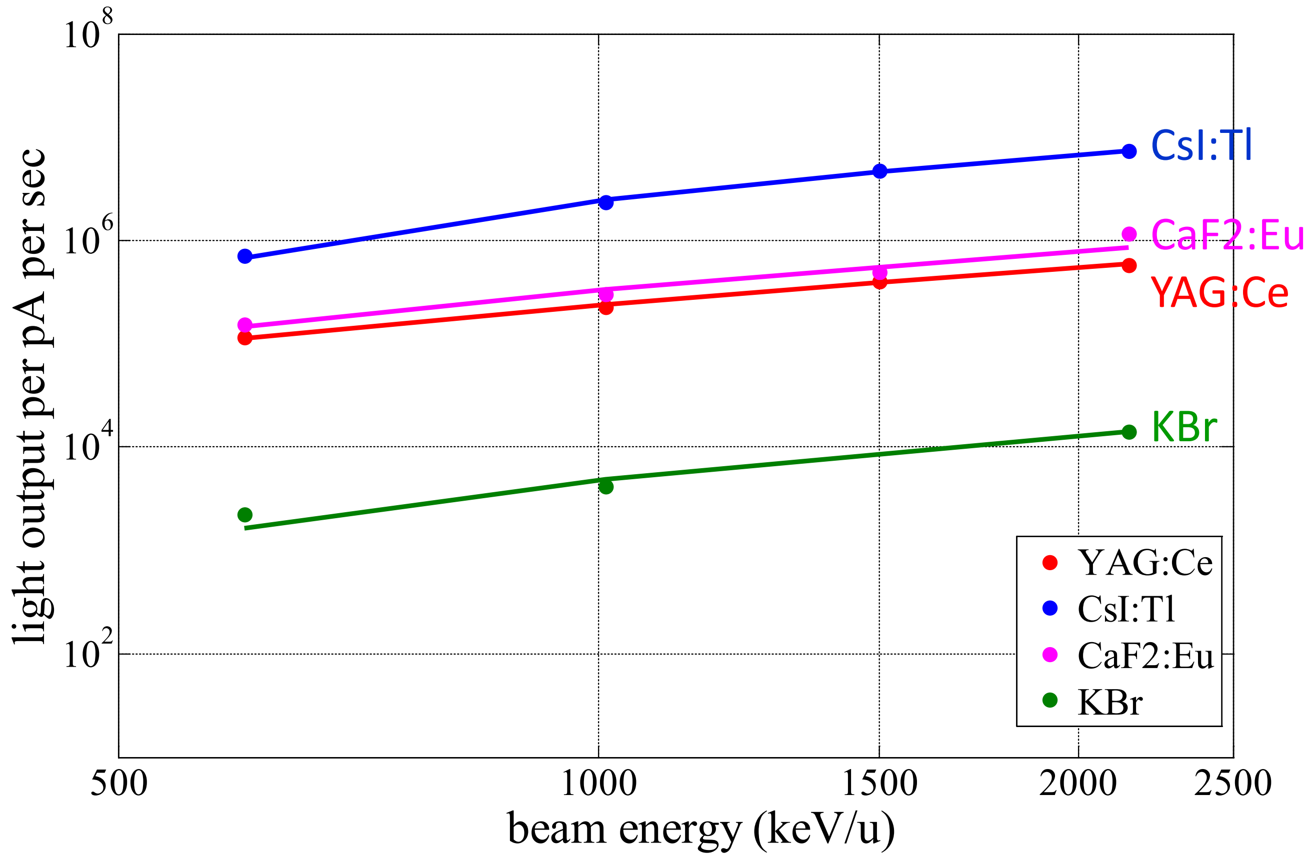
The KBr sample after ion irradiation.

KBr Scintillation Response

- Possible luminescence mechanism of KBr at room temperature



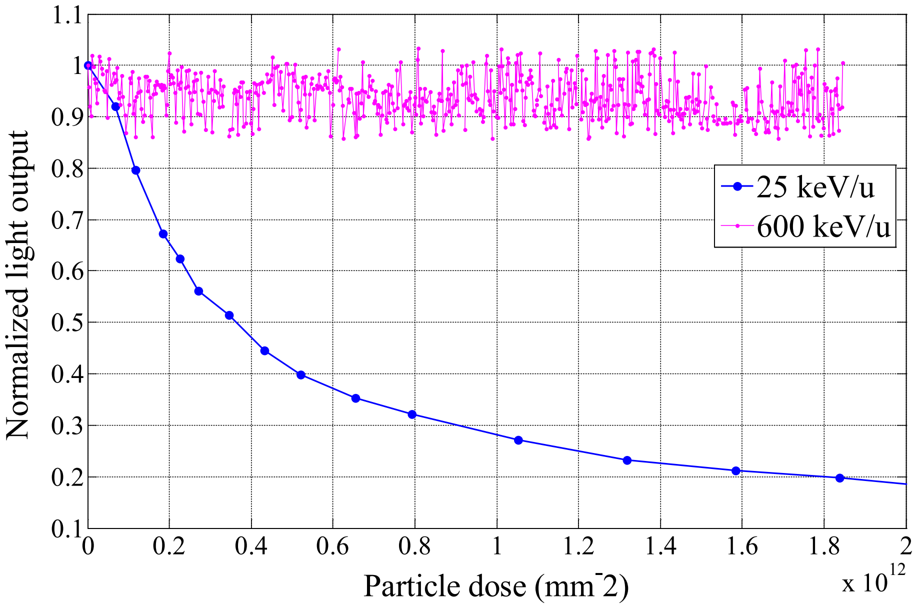
Scintillation Yield comparison



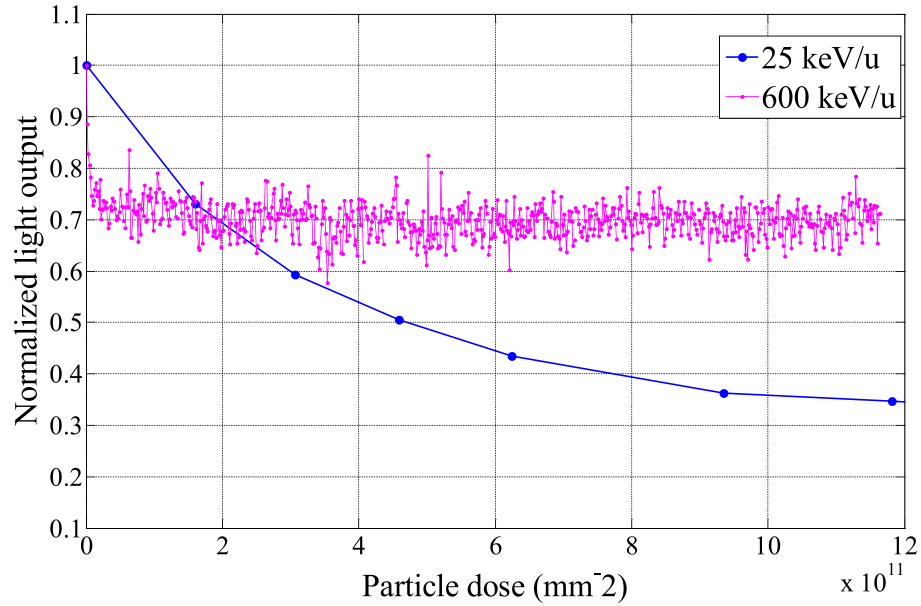
CsI:Tl and YAG:Ce	Average luminescence during irradiation
CaF2:Eu	Average luminescence after it maintains stable scintillation
KBr	Maximum luminescence

Scintillation Response at low and high beam energies

YAG:Ce under H_2^+ irradiation



CaF2:Eu under H_2^+ irradiation

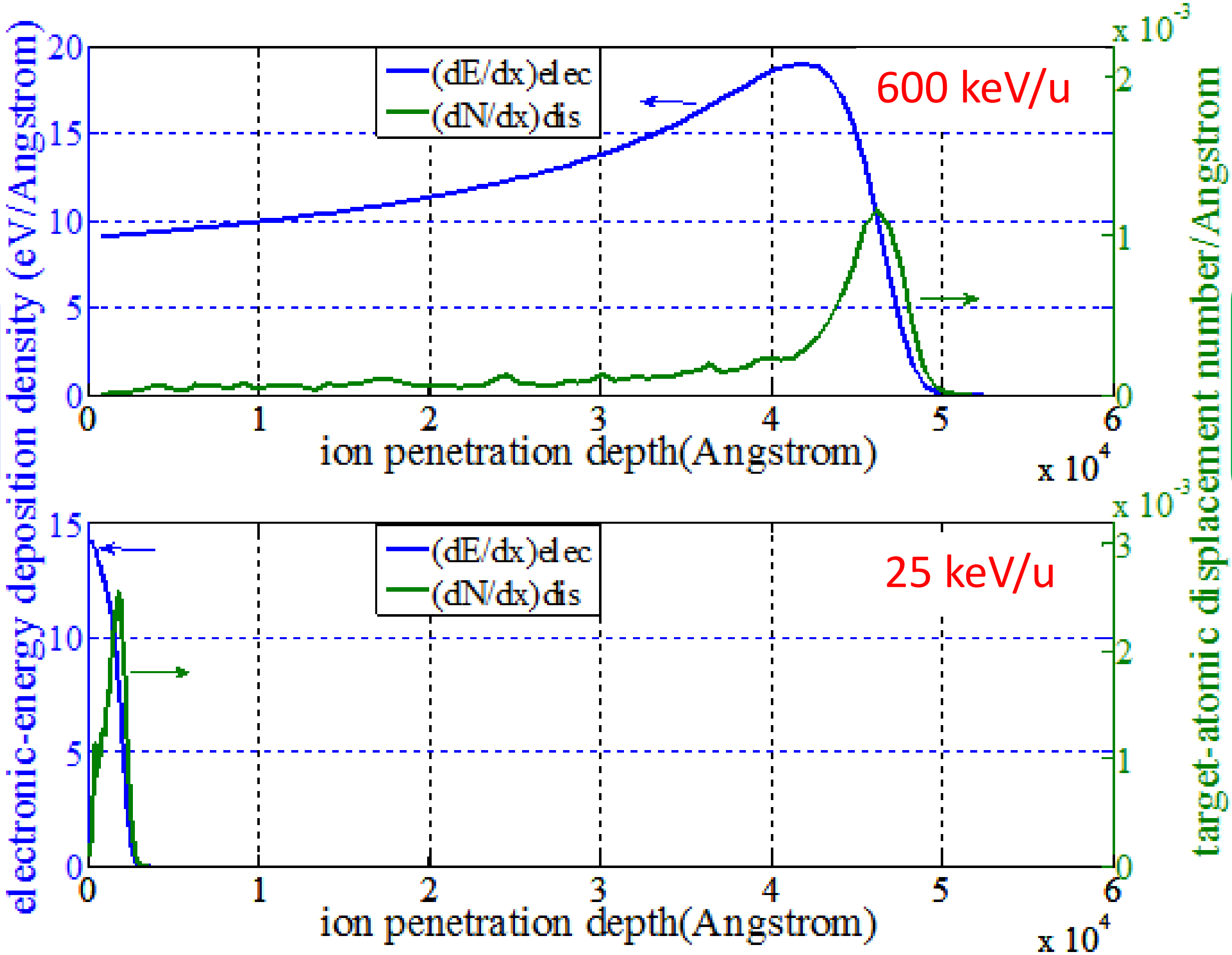


- 25 keV/u data were measured by C. Benatti and G. Perdikakis in the low energy beam transport section of the ReA facility.

Scintillation Response at low and high beam energies

SRIM simulation for YAG under proton irradiation

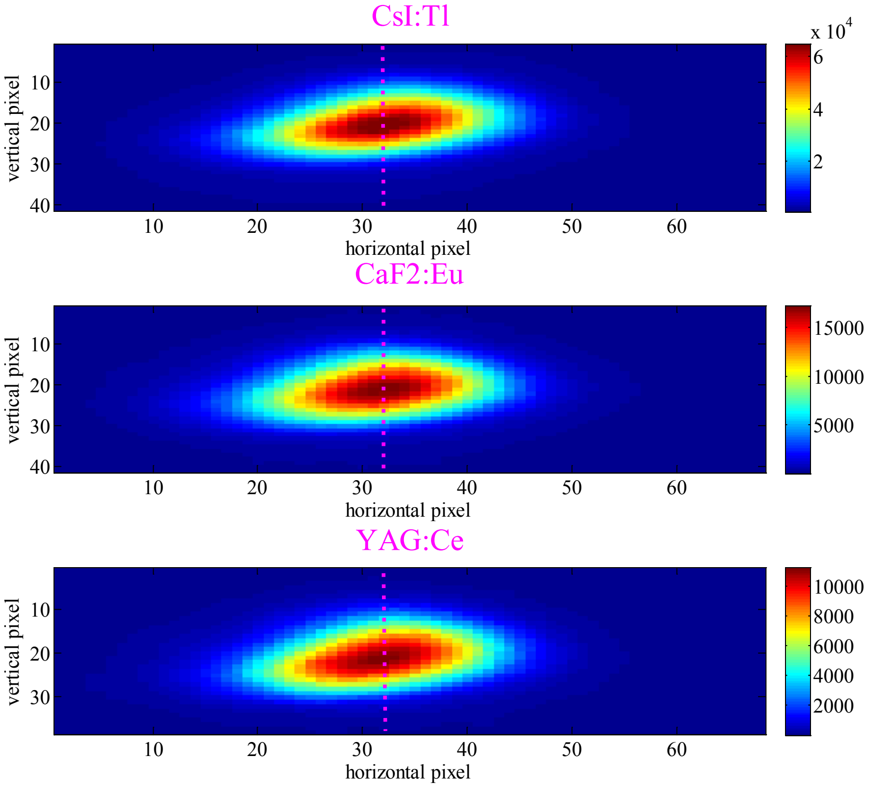
The production of the scintillation photons

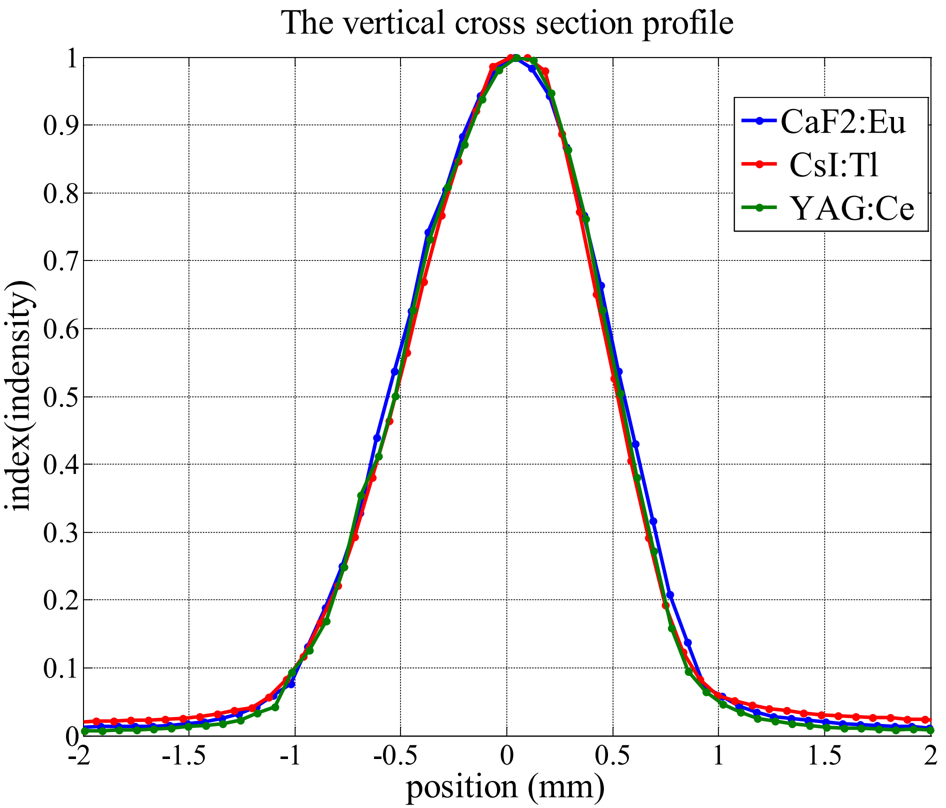


The production of the defects.

Beam Width Comparison

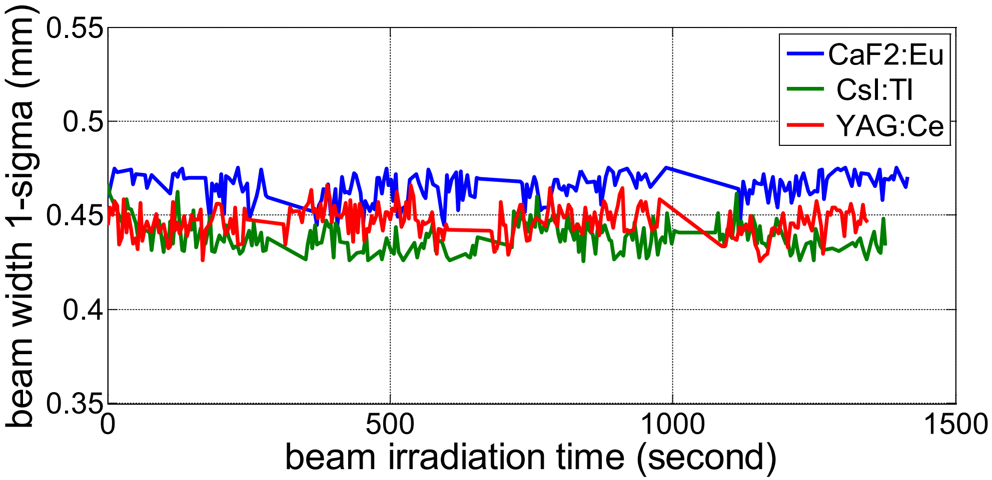
H_2^+ irradiation at the beam energy 2150 keV/u and current 12 pA



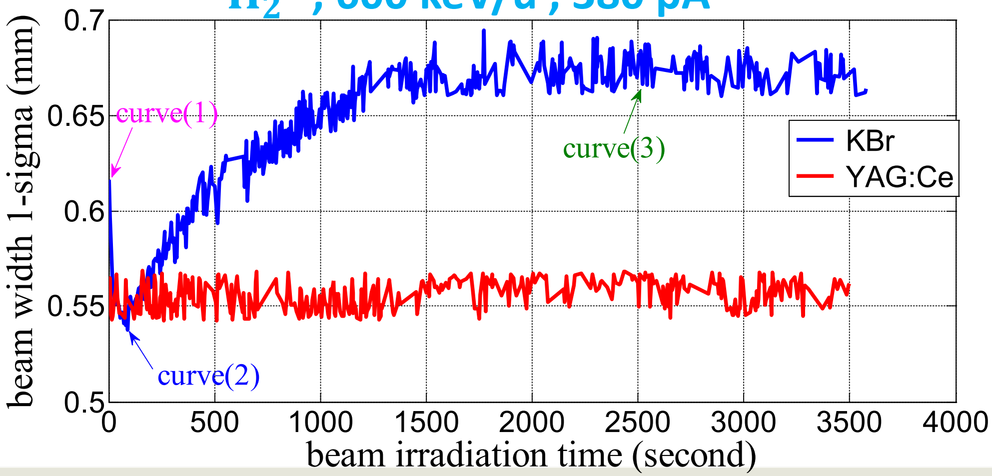


Beam Width Comparison

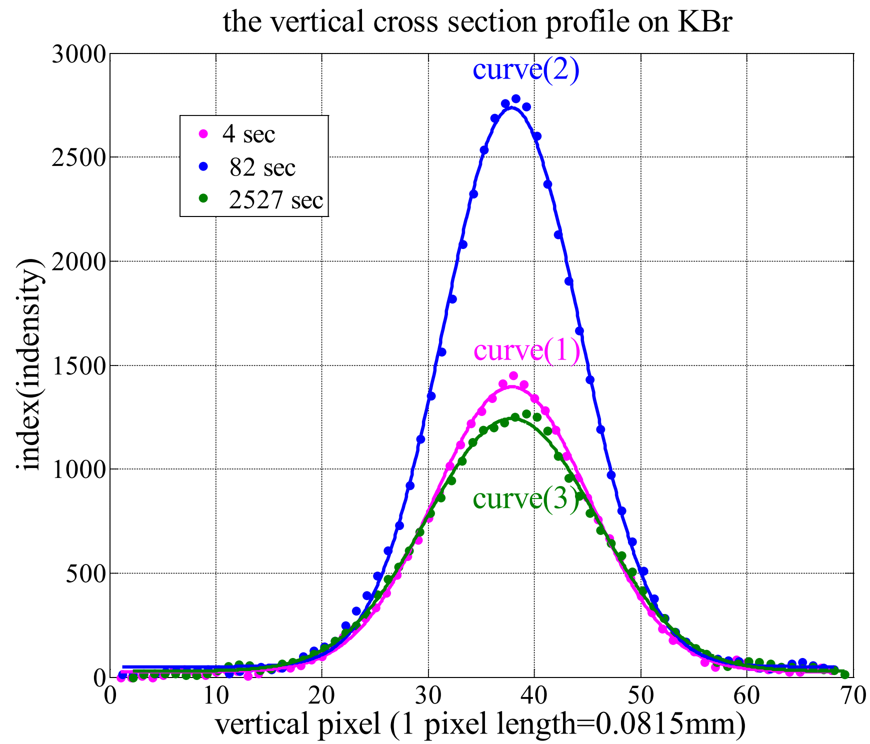
H_2^+ , 2150 keV/u , 12 pA



H_2^+, 600 keV/u , 380 pA



H_2^+, 600 keV/u , 380 pA



The beam width (1-σ):

curve(1)	0.616 mm
curve(2)	0.539 mm
curve(3)	0.674 mm

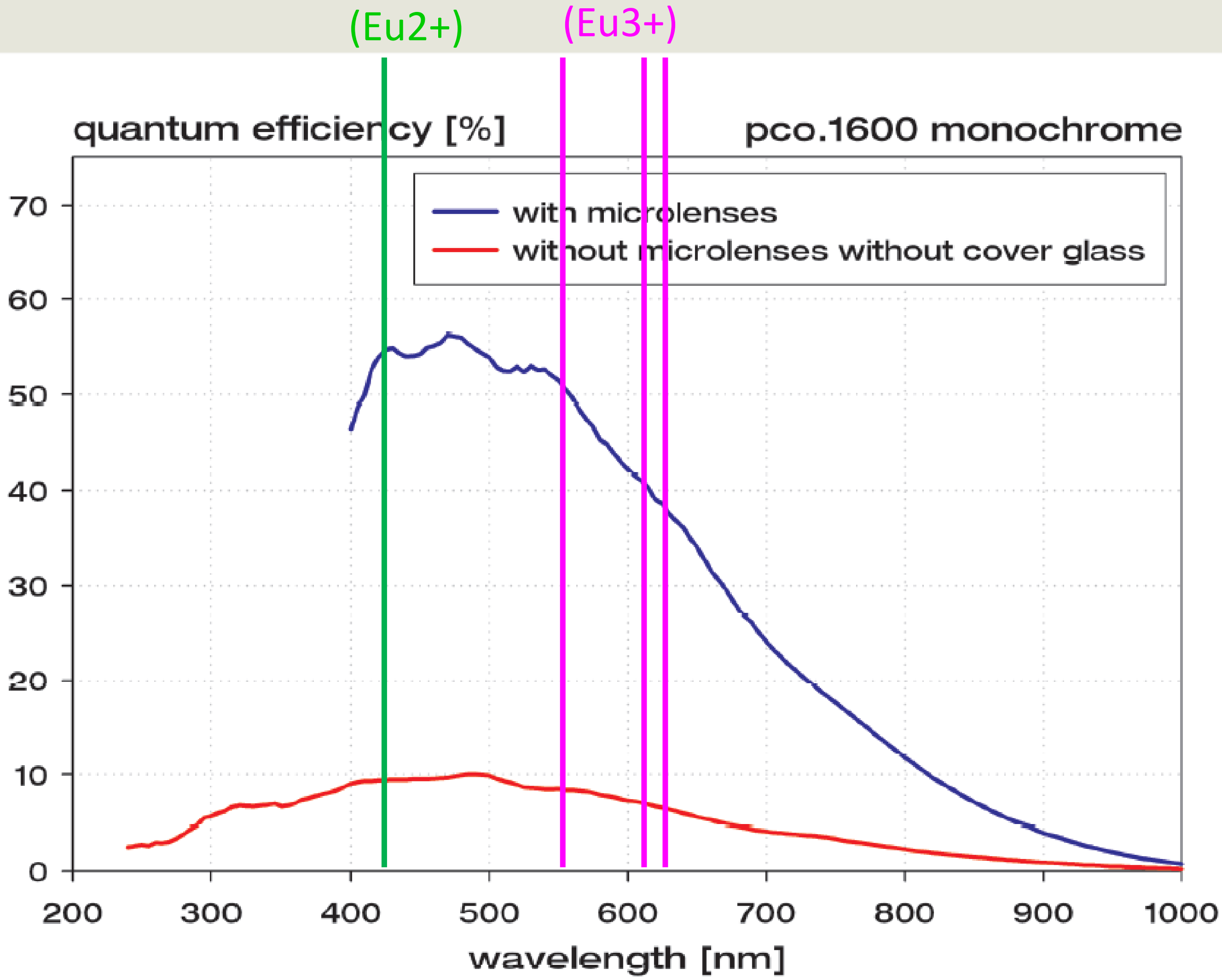
Conclusions

- Under H_2^+ irradiation at the beam energies of 600-2150 keV/u and beam current of less than 400 pA:

	CsI:Tl	CaF2:Eu	YAG:Ce	KBr
Light Yield	CsI:Tl > CaF2:Eu > YAG:Ce > KBr			
Light Yield VS. ion energy	Linear			
Scintillation stability	Stable	After an initical rapid decay, it becomes stable	Stable	Unstable
Beam width	Almost consistent and stable during irradiation			Unstable

- Under low-energy ion bombardment, ion-induced defects are highly efficient to degrade transparency of scintillation photons inside an irradiated scintillator.

Thank you


(Eu2+)
(Eu3+)
quantum efficiency [%]
pco.1600 monochrome
with microlenses
without microlenses without cover glass
70
60
50
40
30
20
10
0
200
300
400
500
600
700
800
900
1000
wavelength [nm]