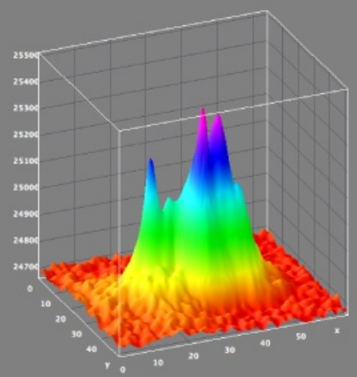
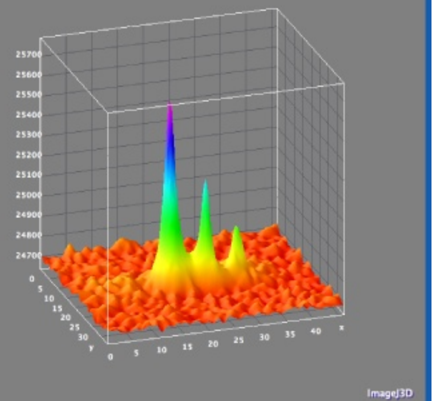
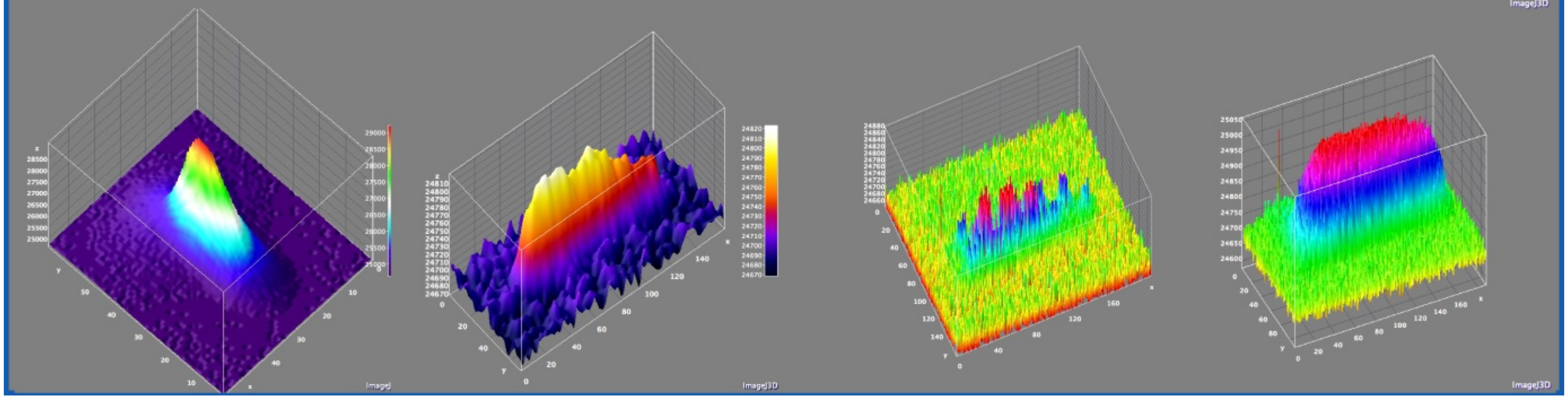
Screens for low current beams



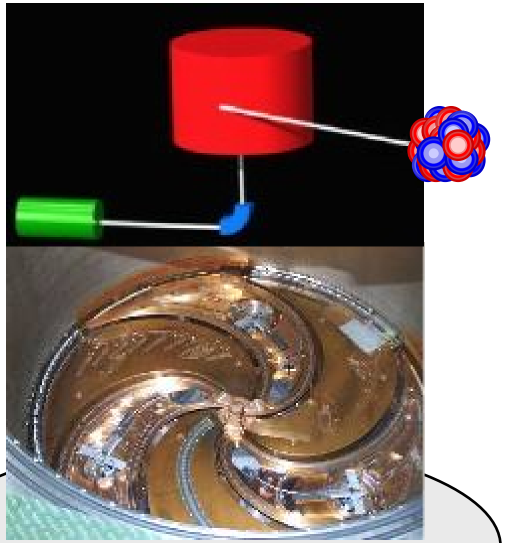
P.Finocchiaro, L.Cosentino, A.Pappalardo

INFN - Laboratori Nazionali del Sud
Catania, Italy



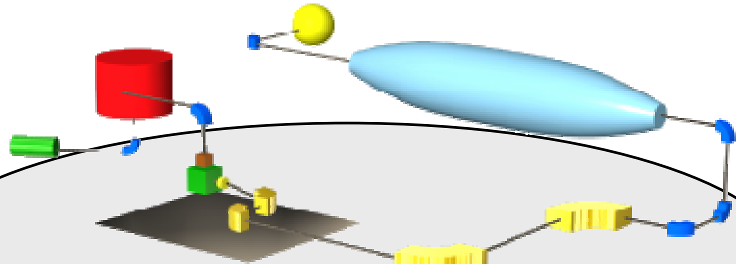


Ion accelerators at LNS



Superconducting Cyclotron
<80MeV/amu

Tandem 15MV



EXCYT facility: ISOL radioactive ion beams

- Low-energy AND low-intensity ion beams

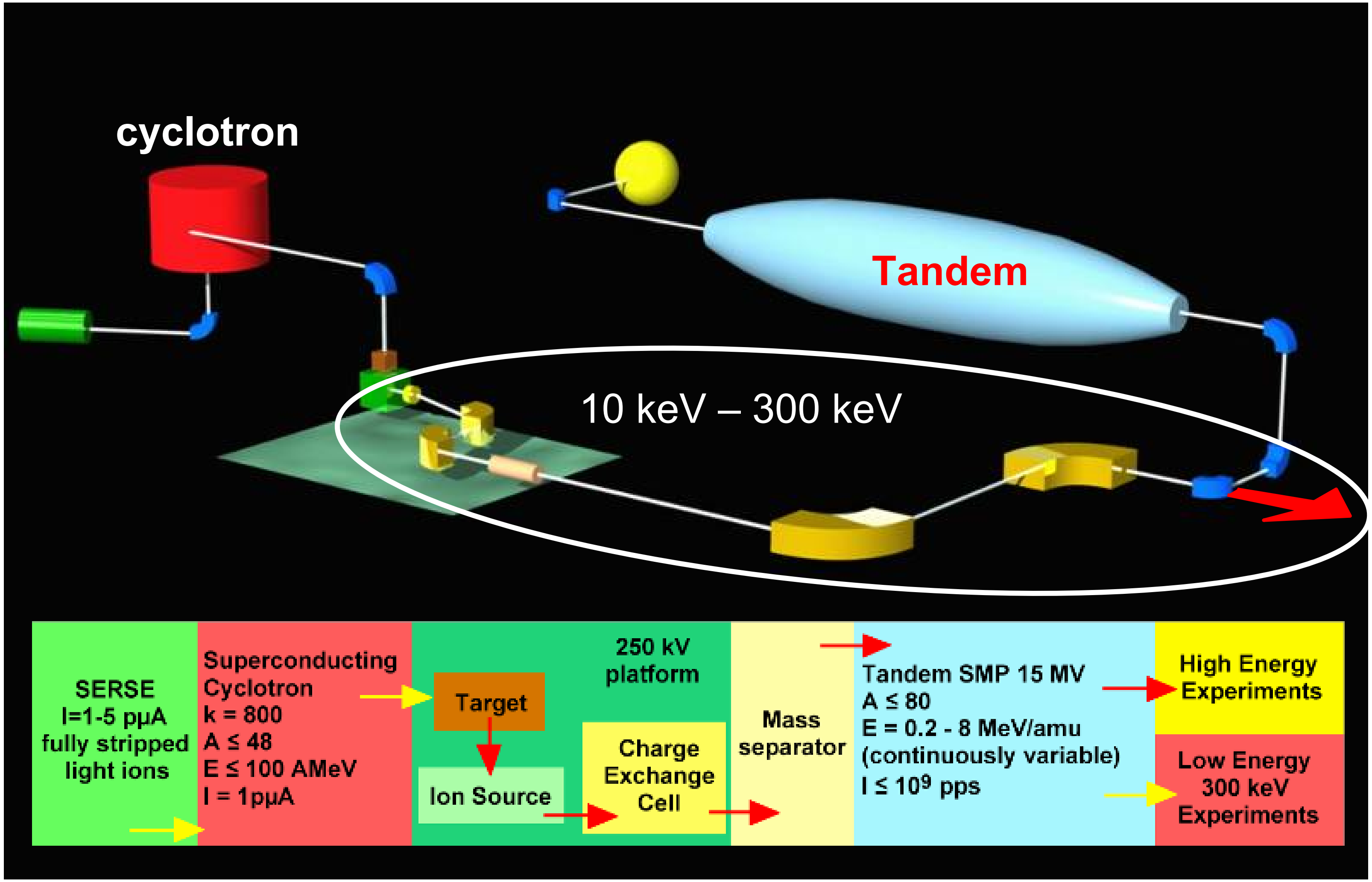
FRIBs: in-flight fragment separator

What kind of beams?

• *Low-intensity ion beams*	***I << 10^9 particles per second (pps): nuclear physics, irradiations (materials, biological samples, IC), deep implantation, lithography with ions, ion beam therapy,...***
• *Low-energy ion beams*	***E < 1 MeV/amu: material analysis, irradiations (materials, biological samples, IC), ion implantation,...***
• *Low-energy AND low-intensity ion beams*	***combination of the two previous cases,...***
• *Microbeams*	***∅ < 1mm: nuclear physics, material analysis, irradiations (materials, biological samples, IC), deep implantation, lithography with ions,...***
• *Radioactive ion beams*	***short-lived unstable nuclei: nuclear physics,...***

Can be low-energy AND low-intensity

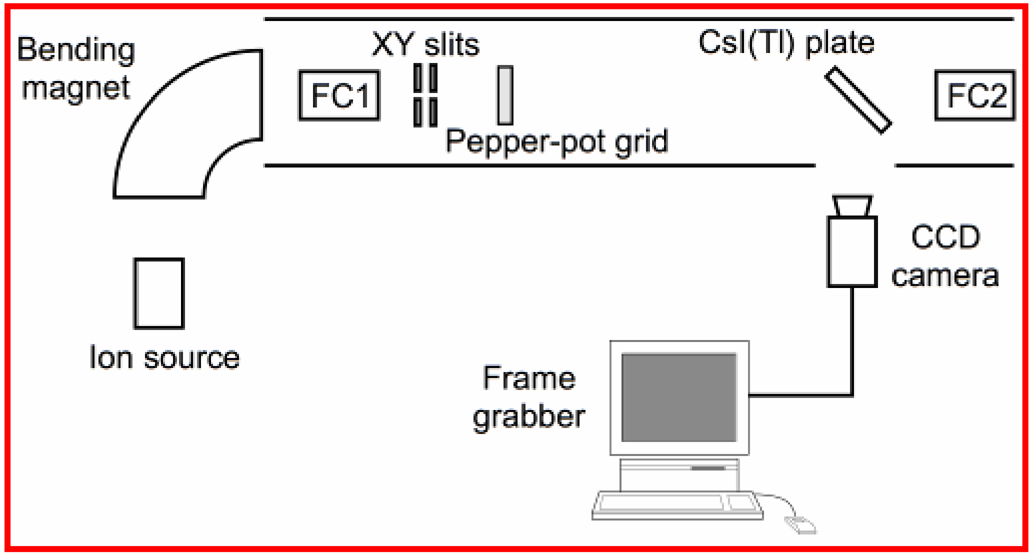
We started with beam diagnostics for the EXCYT facility



Low energy beam imaging

CsI(Tl) scintillating plate with CCD video camera

beam diagnostics of very low-energy and low-intensity ion beams from the Tandem injector at LNS

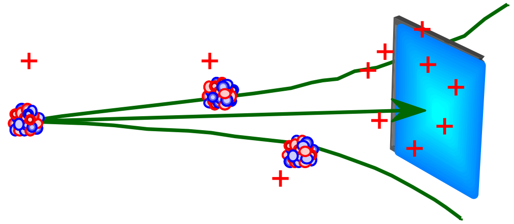


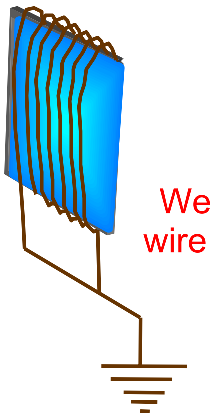
High light yield of CsI(Tl) ~ 65000 photons/MeV (for gamma rays)

Mass n.	Ion species	Beam current [nA] FC1	Beam current [pA] CsI(Tl)
12	C^-	-	- 1.3
16	O^-	325	CCD saturation
17	$^{17}O^-$	-	- 3.2
18	$^{18}O^-$, H_2O^-	-	- 2.4
19	F^-	-	- 0.3
24	C_2^-	-	- 0.4
27	Al^-	-	- 3.4
(*) 32	O_2^-, S^-	1	- 5.3
34	$^{34}S^-$, $H_2O_2^-$	-	- 5.0
35	Cl^-	-	- 3.8
43	AlO^-	48	CCD saturation
58	$^{58}Ni^-$	16	CCD saturation
60	$^{60}Ni^-$	6	CCD saturation
62	$^{62}Ni^-$	-	- 4.2
(*) 74	$^{39}K^{35}Cl^-$	2	- 9.4
76	$^{39}K^{37}Cl^-$ + $^{41}K^{35}Cl^-$	-	- 4.2
107	$^{107}Ag^-$	11	CCD saturation
109	$^{109}Ag^-$	9	CCD saturation

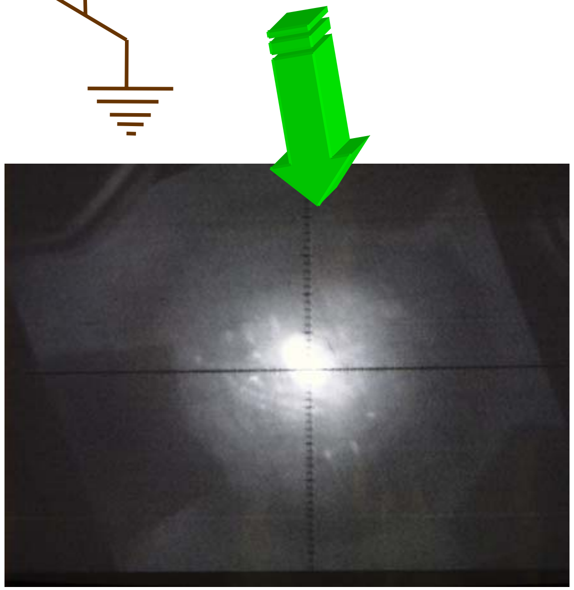
CsI(Tl) scintillating plate with CCD video camera

CsI is an insulator and could get charged-up



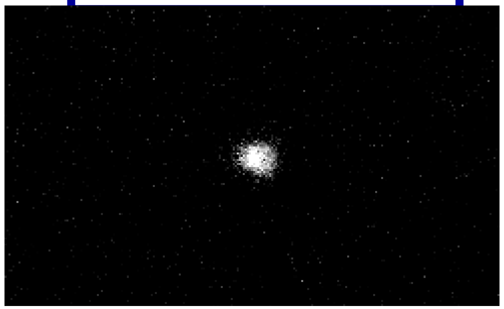


What did we do?
We wound it with a conductor wire which was then grounded

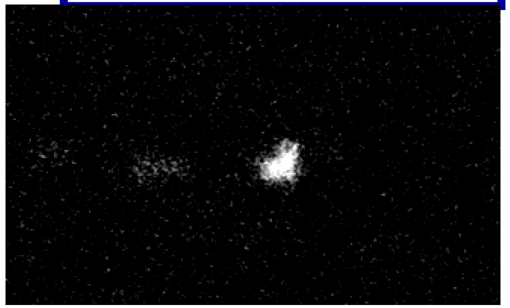


Oxigen
Current: µA (??)
Energy: 80 keV

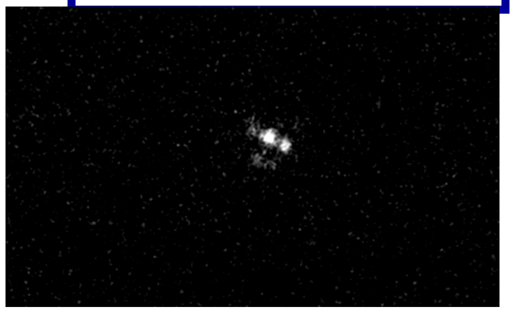
Silver
Current: 4 pA
Energy: 170 keV



Oxigen
Current: a few pA
Energy: 50 keV



Protons
Current: 0.03 pA
Energy: 170 keV

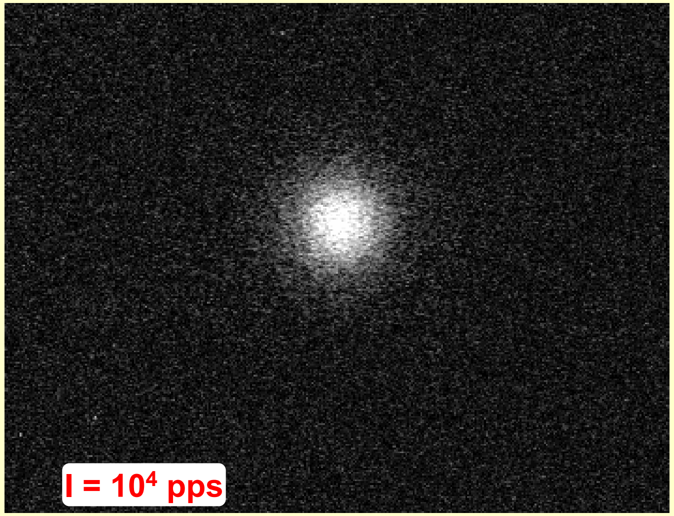


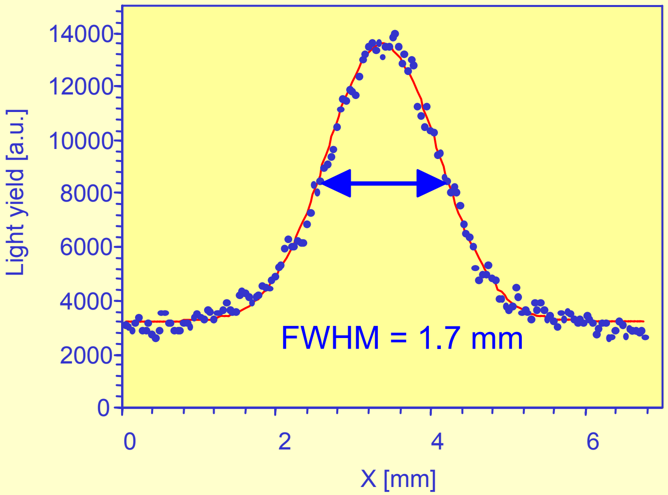
CsI(Tl) scintillating plate with CCD video camera

^{90}Sr beta source to simulate radioactive beam decay

2 beta particles, endpoint E= 546, 2280 keV

- Collimated source, collimator diameter = 2 mm
- CsI(Tl) scintillator plate 50x50x2 mm^3





EXCYT beam diagnostics: LEBI

Low Energy Beam Imager-Identifier

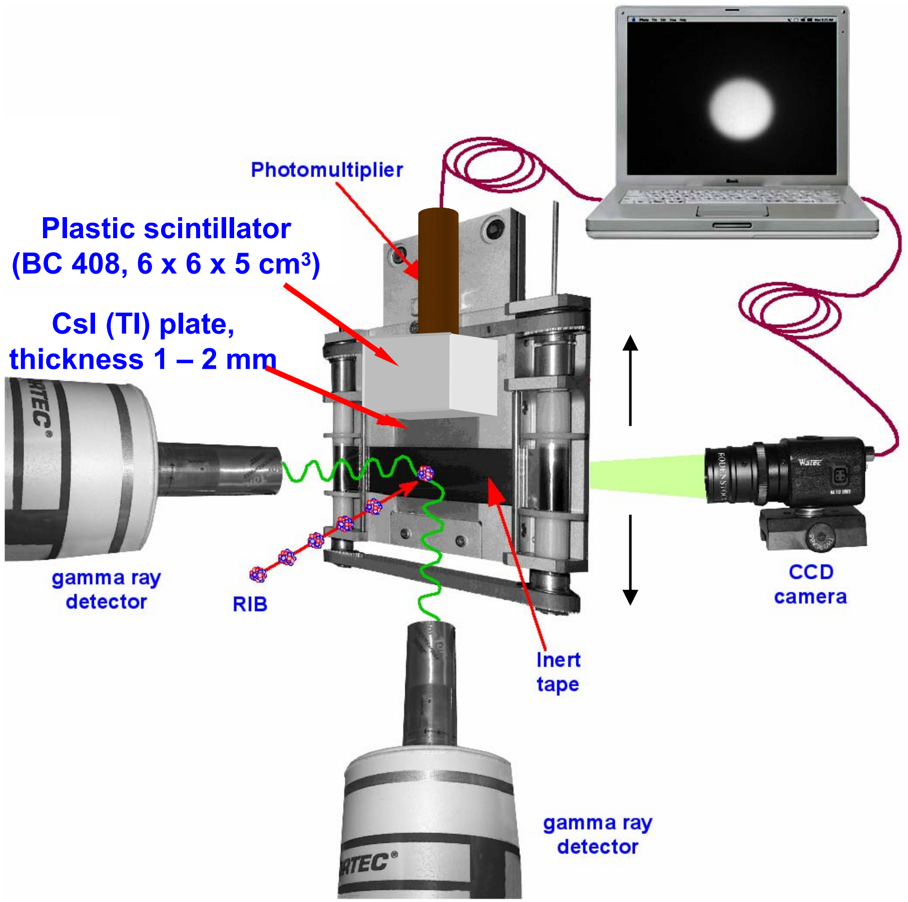
A complex diagnostics station that combines several techniques for beam detection and identification

CsI(TI) plate + CCD camera for direct imaging of stable beams

CsI(TI) plate + CCD camera for beta-ray imaging of implanted RIBs

Plastic scintillator + PMT for radioactive decay counting of implanted RIBs (determination of $T_{1/2}$)

Gamma detectors for RIBs spectroscopic fingerprinting



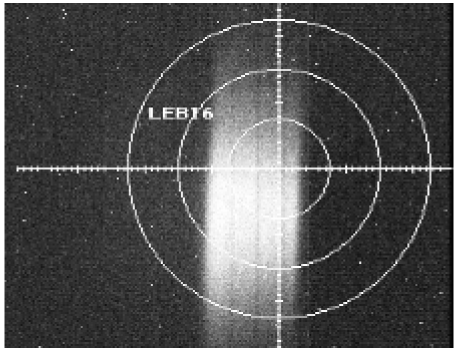
10 LEBIs working along the EXCYT beam line

Sensitivity for beam imaging

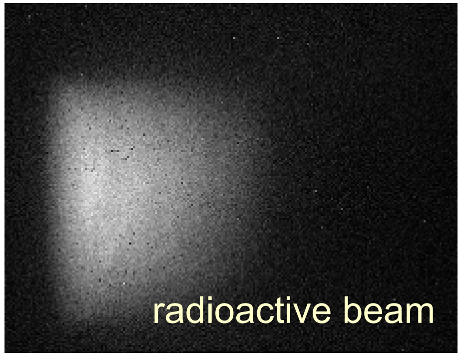
- $E_{threshold}$ = 5 keV
- $I_{stable\ beam} \sim 10^4$ pps/mm^2
- $I_{radioactive\ beam} \sim 10^3$ pps/mm^2

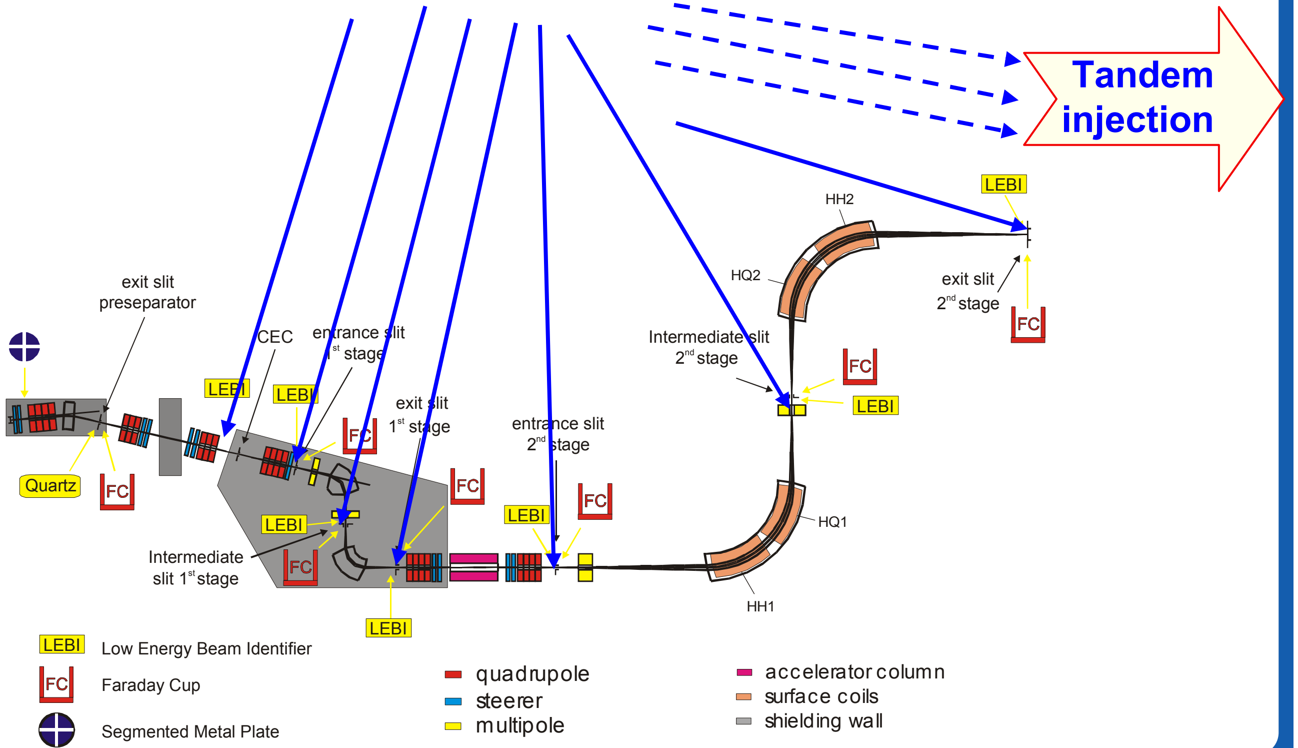
resolution < 1mm

^{7}Li   I = 10 pA   E = 10 keV



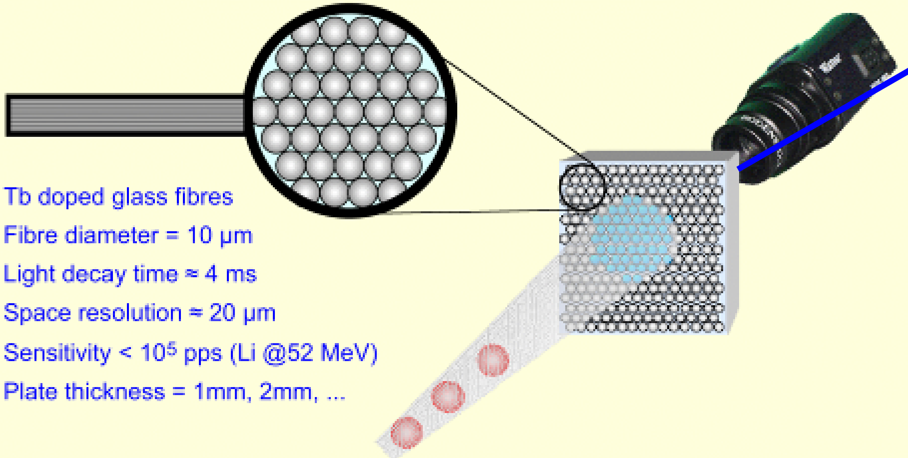
^{8}Li   I = 100 fA   E = 10 keV



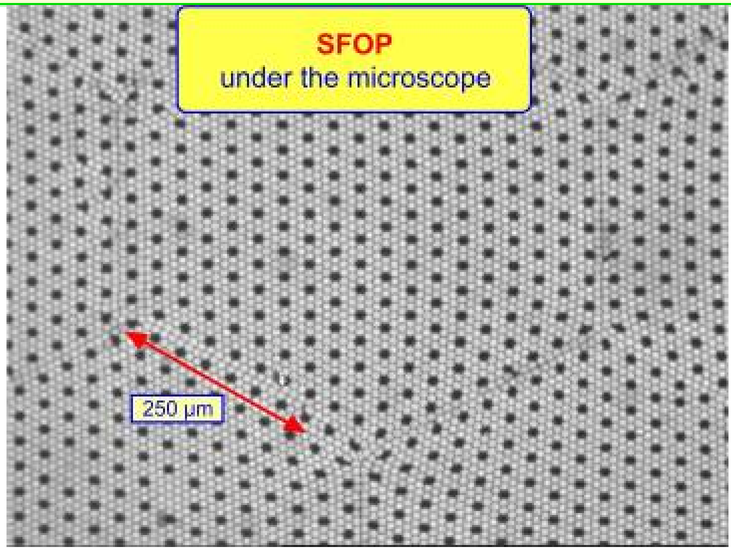


Micro-beam diagnostics: the SFOP

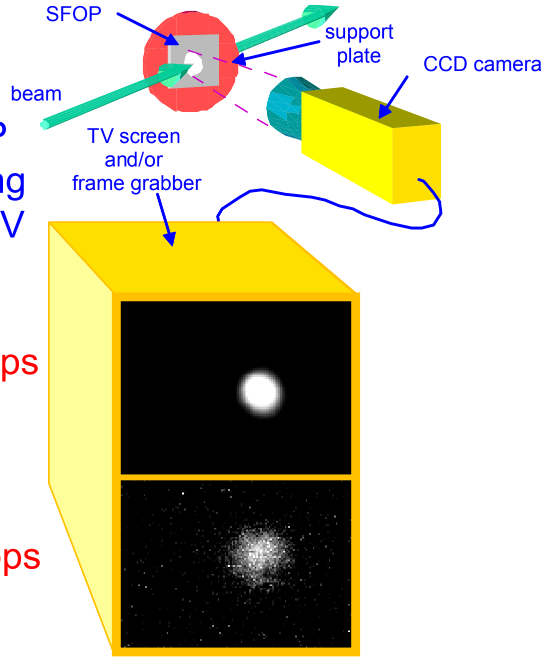
SFOP
Scintillating Fiber Optic Plate



- Tb doped glass fibres
- Fibre diameter = 10 µm
- Light decay time ≈ 4 ms
- Space resolution ≈ 20 µm
- Sensitivity < 10^5 pps (Li @52 MeV)
- Plate thickness = 1mm, 2mm, ...



Tb-glass SFOP
2D beam imaging
with ^{7}Li at 52MeV



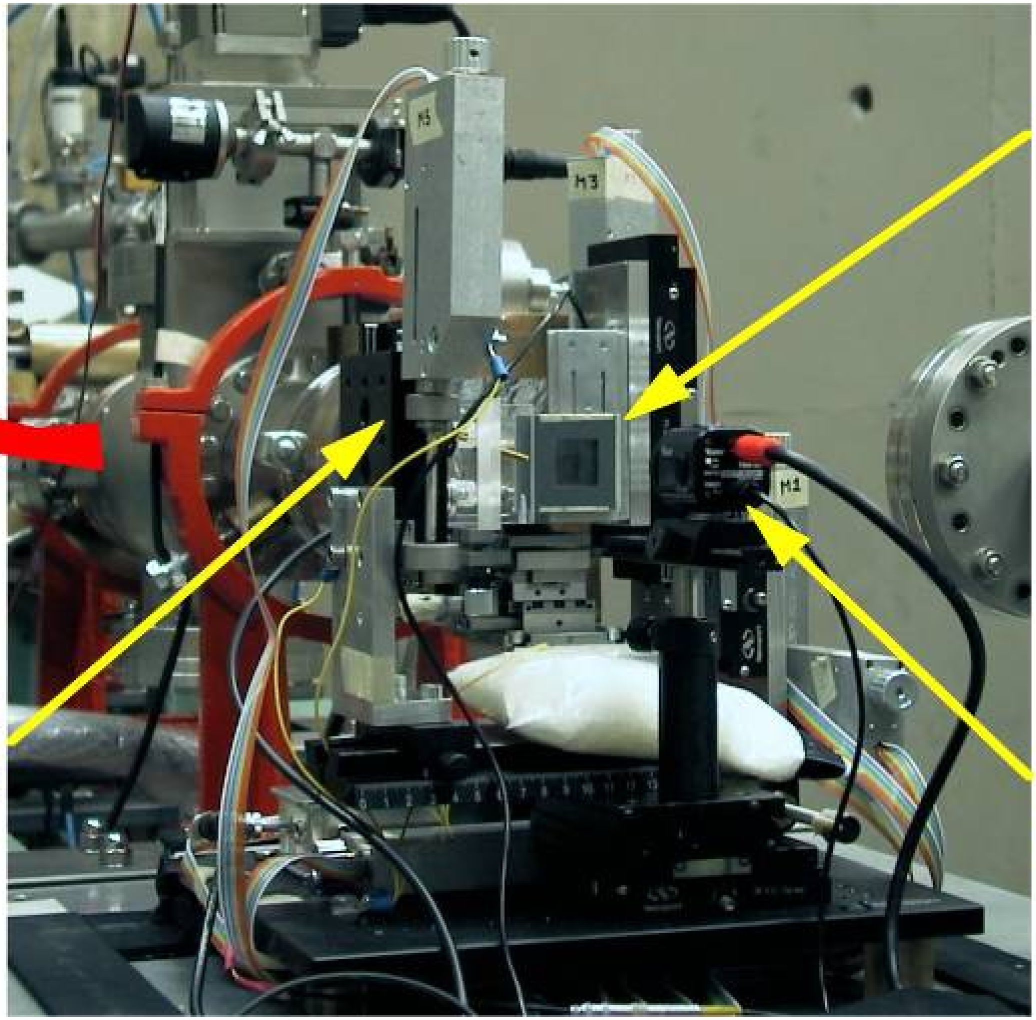
beam current = $2{\cdot}10^7$ pps

beam current ≈ 10^5 pps

μ-SFOP

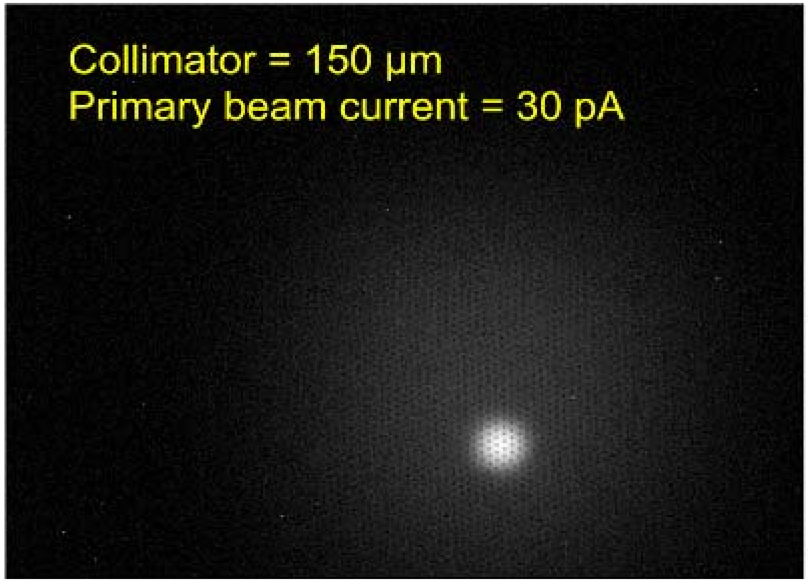
Beam

SFOP



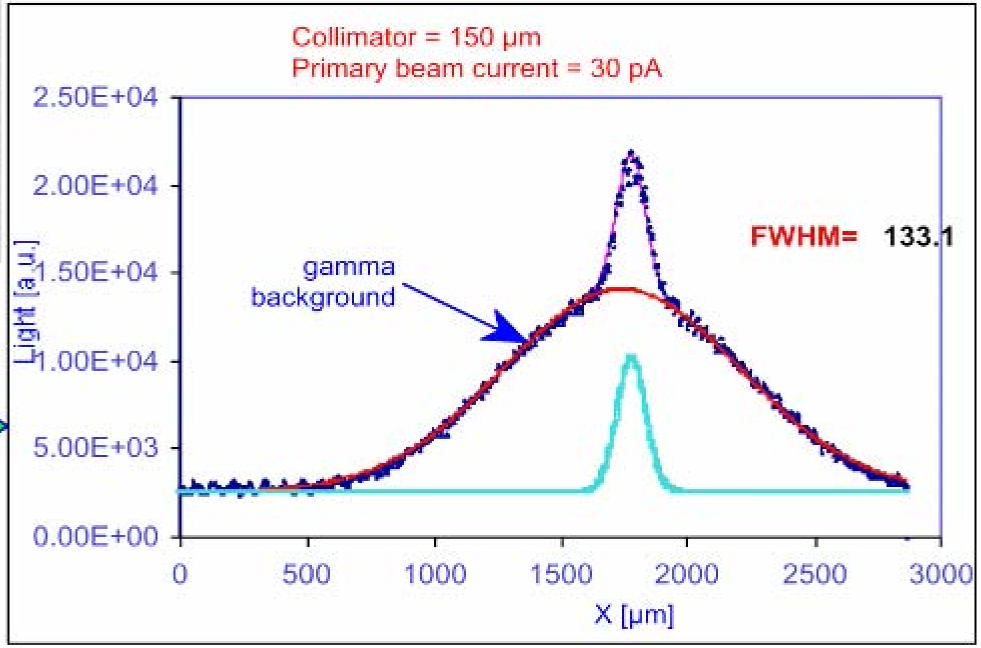
High precision translation stage for the collimators

CCD camera

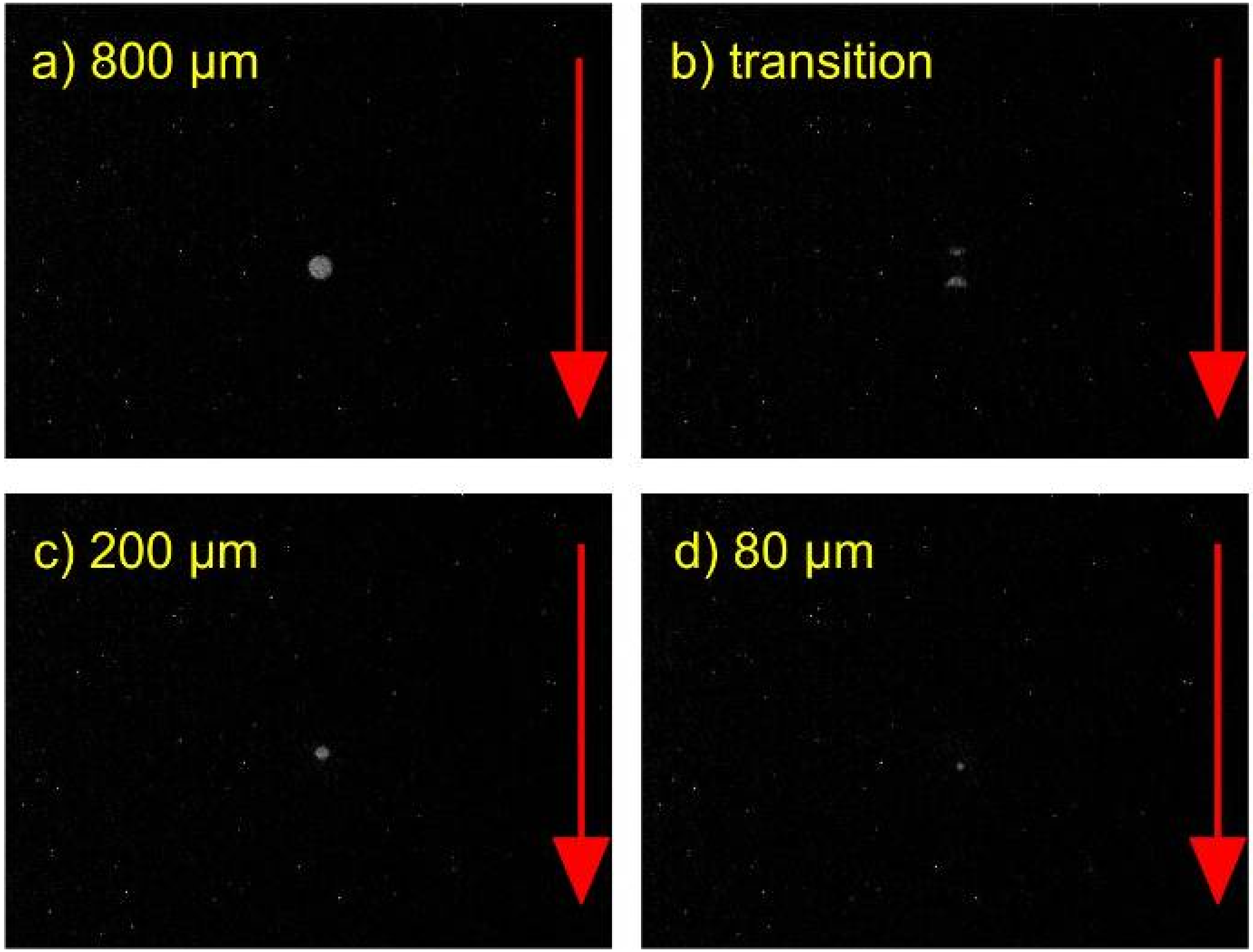


µ-SFOP

Projecting on the X axis we get ...



4 frames extracted from a real time movie taken while the multi-collimator mask was sliding down



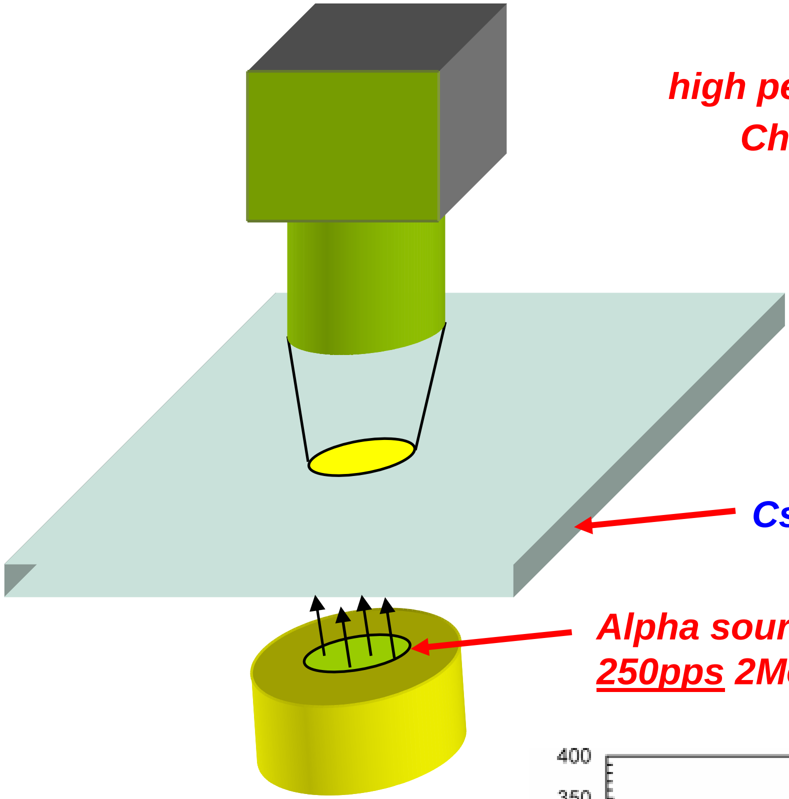
µ-SFOP

The mask slides down, scanning several holes (the CCD lens magnification is low in this run)

we were able to image a beam down to 20µm diameter

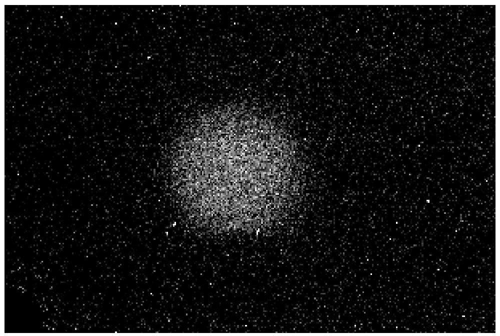
Scintillating screens for very low beam intensity with a cooled CCD still camera

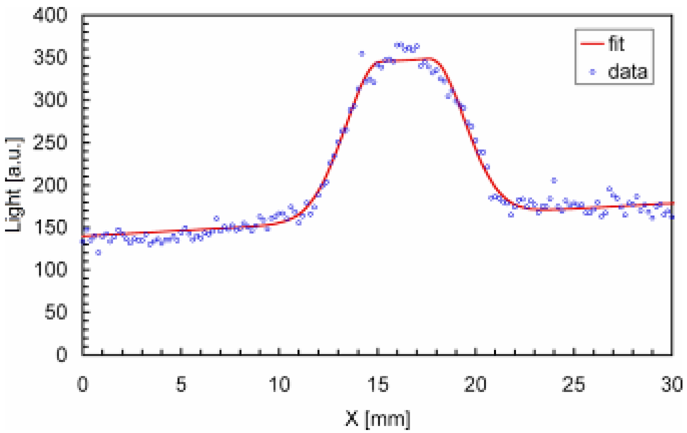
high performance photocamera
Chroma CX3 14-bit CCD

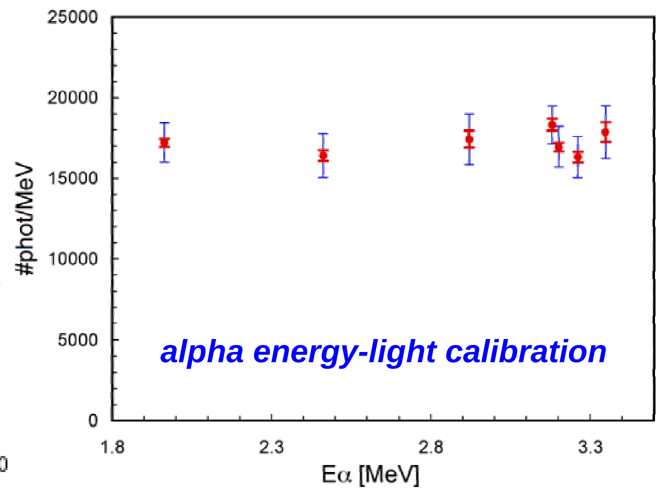


CsI(Tl) scintillator

Alpha source
<u>250pps</u> 2MeV



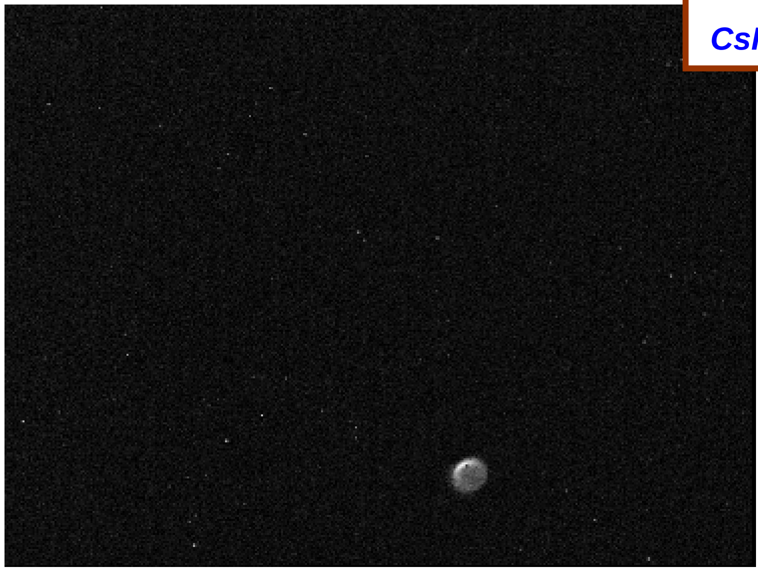


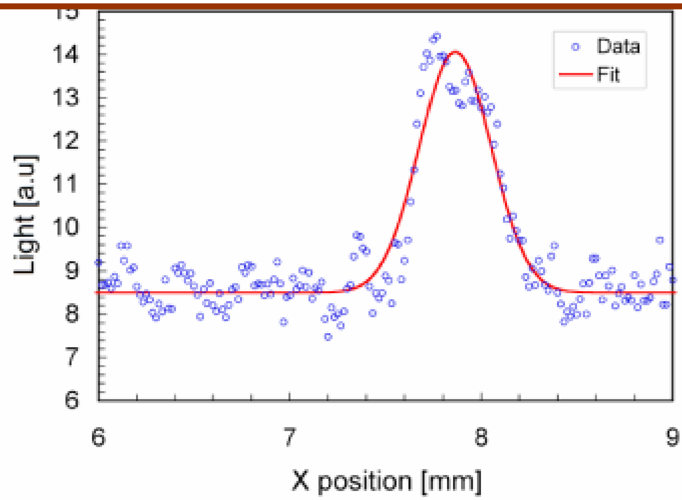


Ultra-thin CsI(Tl) Scintillating screens

test with protons at LNS 180 keV, 5 pA

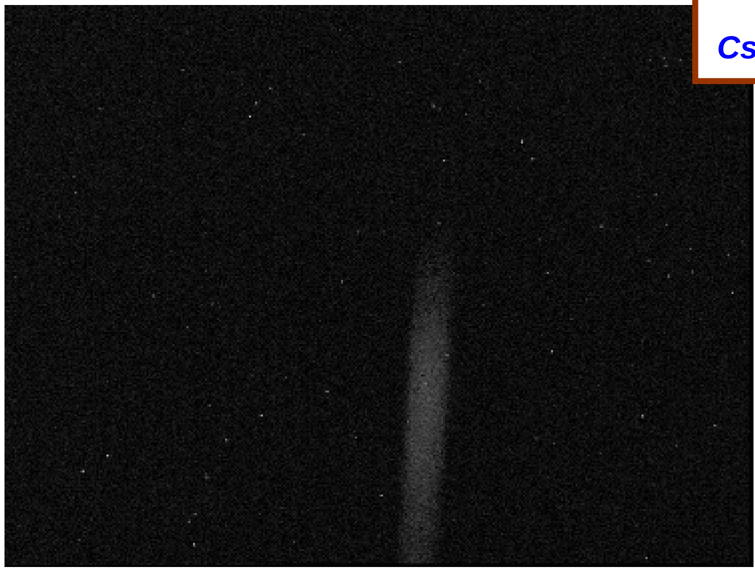
CsI(Tl) ultra-thin scintillator (3 microns) standard video CCD

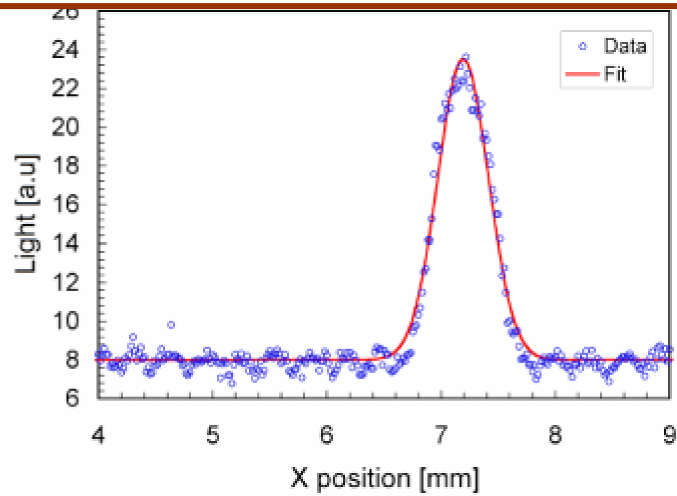




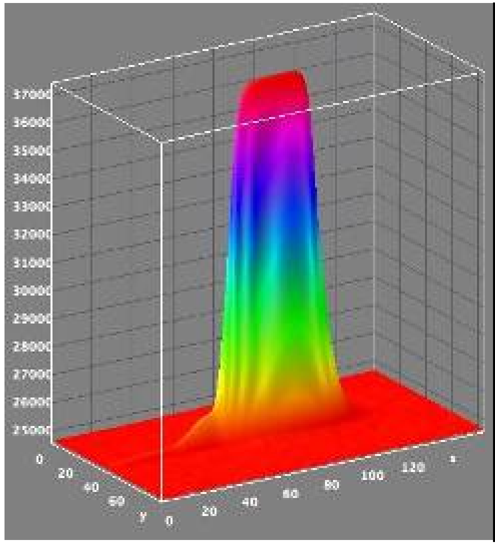
test with protons at LNS 20 keV, 700 pA

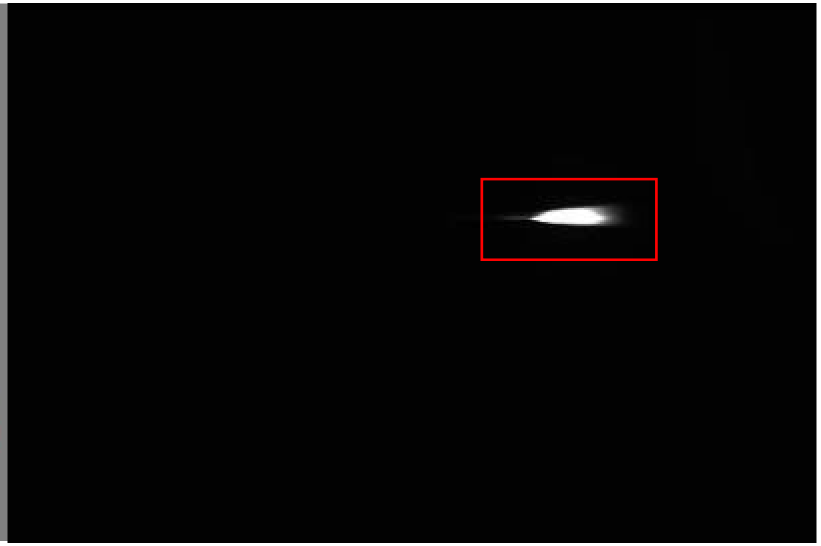
CsI(Tl) ultra-thin scintillator (3 microns) standard video CCD





Scintillating screens for very low beam intensity with a cooled CCD still camera





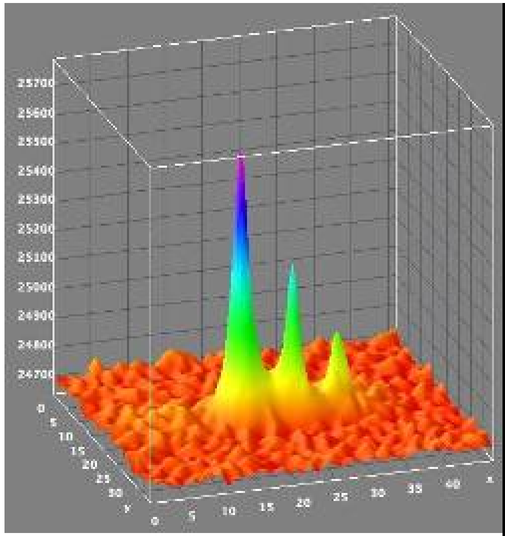
screen = CsI(Tl)

beam = protons

E = 50keV

I ≈ 5pA

$t_{exposure}$ = 60s



screen = CsI (Tl)

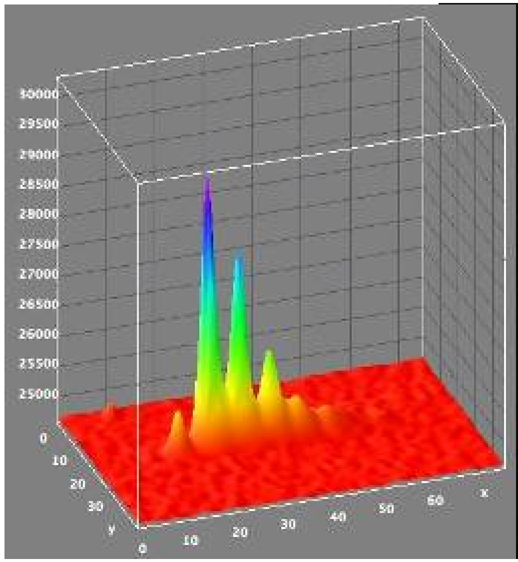
beam = protons

E = 200keV

I ≈ 2.5fA

$t_{exposure}$ = 20s

Scintillating screens for very low beam intensity with a cooled CCD still camera



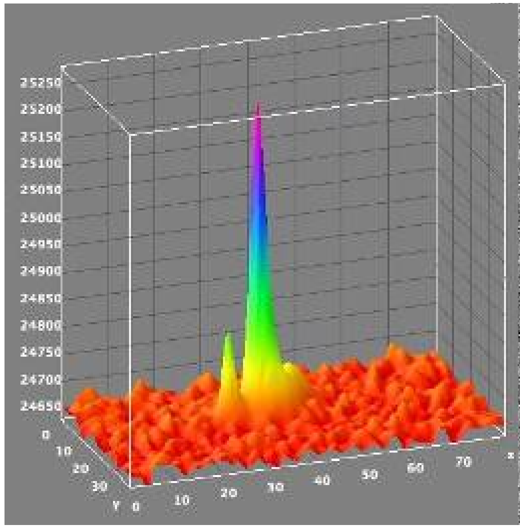
screen = SFOP

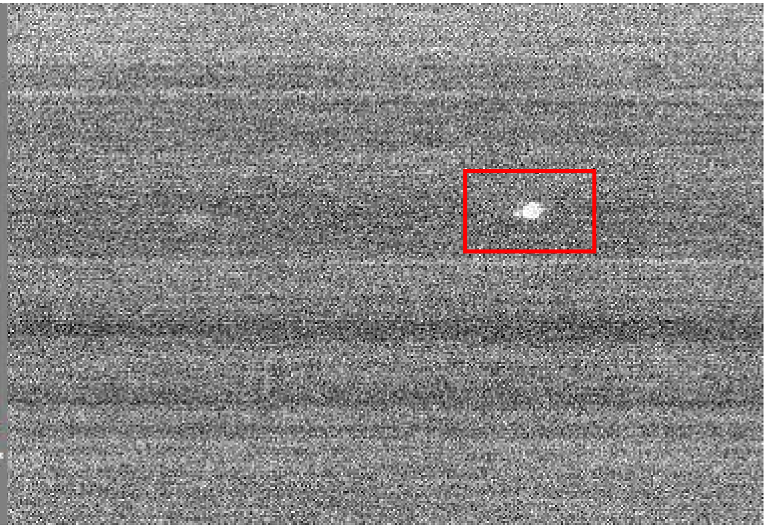
beam = protons

E = 200keV

I ≈ 50fA [5pA/100]

$t_{exposure}$ = 20s





screen = SFOP

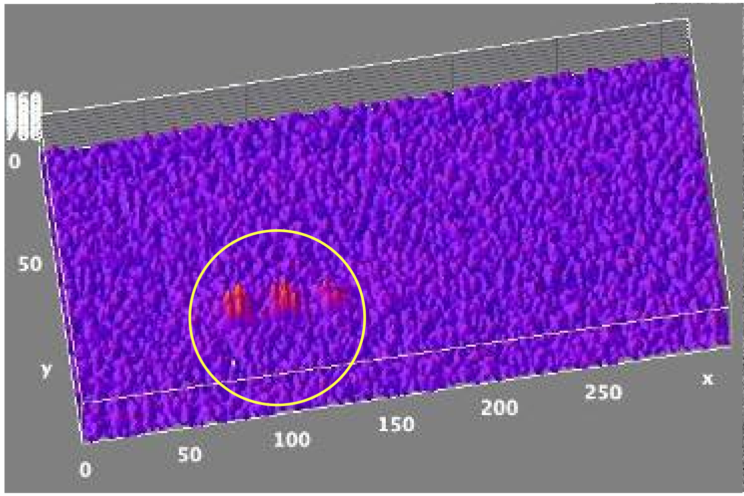
beam = protons

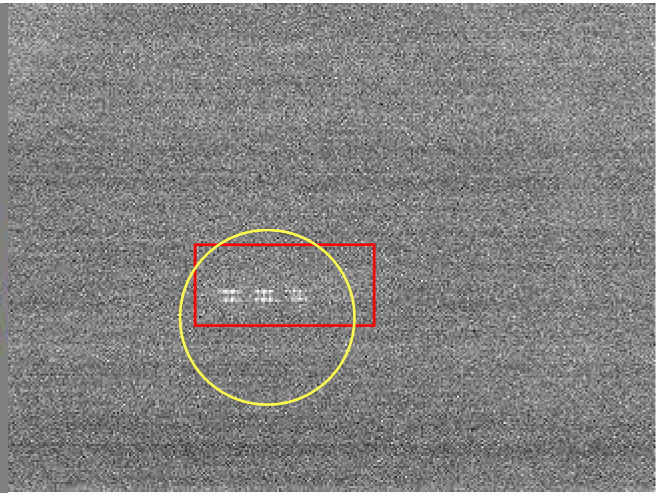
E = 200keV

I ≈ 2.5fA [5pA/2000]

$t_{exposure}$ = 20s

high performance camera 14-bit CCD





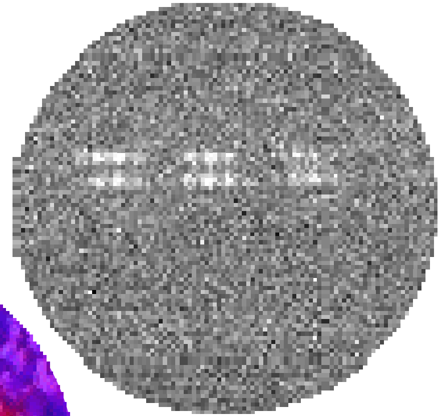
screen = CsI

beam = protons

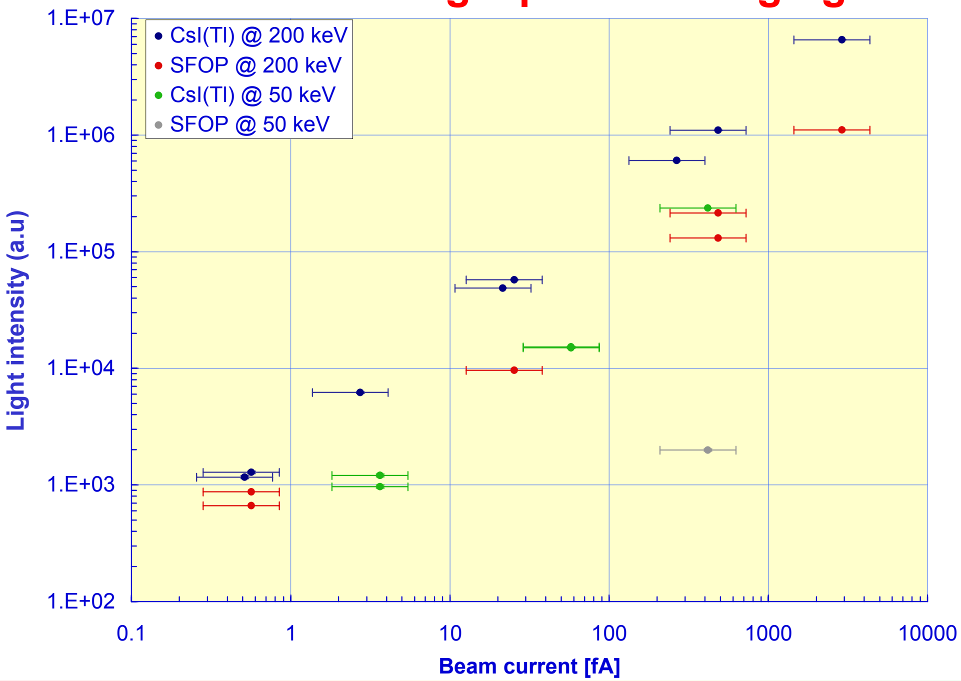
E = 50keV

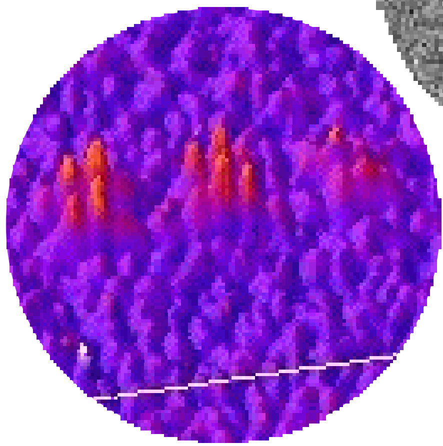
I ≈ not measurable

$t_{exposure}$ = 60s



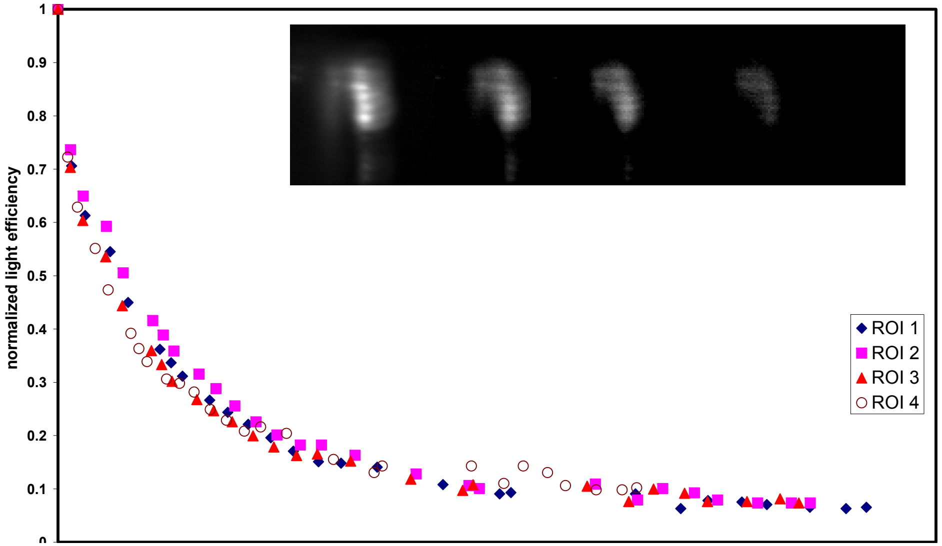
toward single particle imaging....!!!

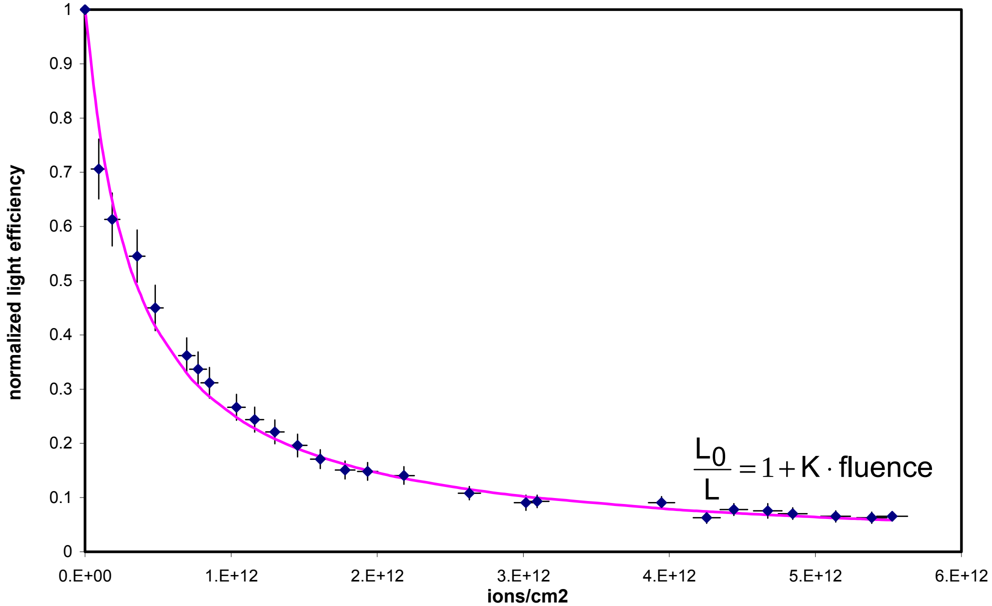




beam attenuated through a fine mesh, pitch ≈ 0.1mm

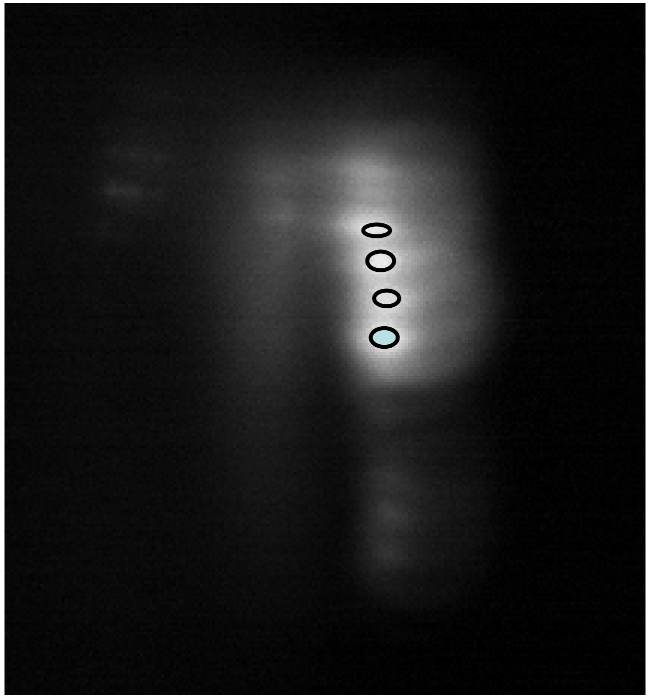
Radiation damage measurement of CsI(Tl)





scintillating light vs. fluence for a 100keV ^{16}O beam

Four regions analyzed



For this fit formula see
A.Quaranta et al., NIM B, 266, 2008, 2723-2728

Conclusions

- different techniques tested/employed at LNS for beam imaging with scintillating screens
- scintillators are a tradeoff solution between robustness, ease-of-use, and cost
- CsI(Tl), doped glass, and plastics (in some cases) offer good performance
  - radiation degradation of performance?
- cheap & compact CCD video cameras show very nice performance
- high performance 14-bit CCD still camera + CsI(Tl) allows top sensitivity

Thank you!