Universita' di Padova

Istituto Nazionale Di Fisica Nucleare

SAND2008-4931C

Single Event Effect Assessment and Radiation Monitor with a Ion Photon Emission Microscope

Paolo Rossi[a,b]

[a]Sandia National Laboratories, Department 1111, Albuquerque, NM, USA

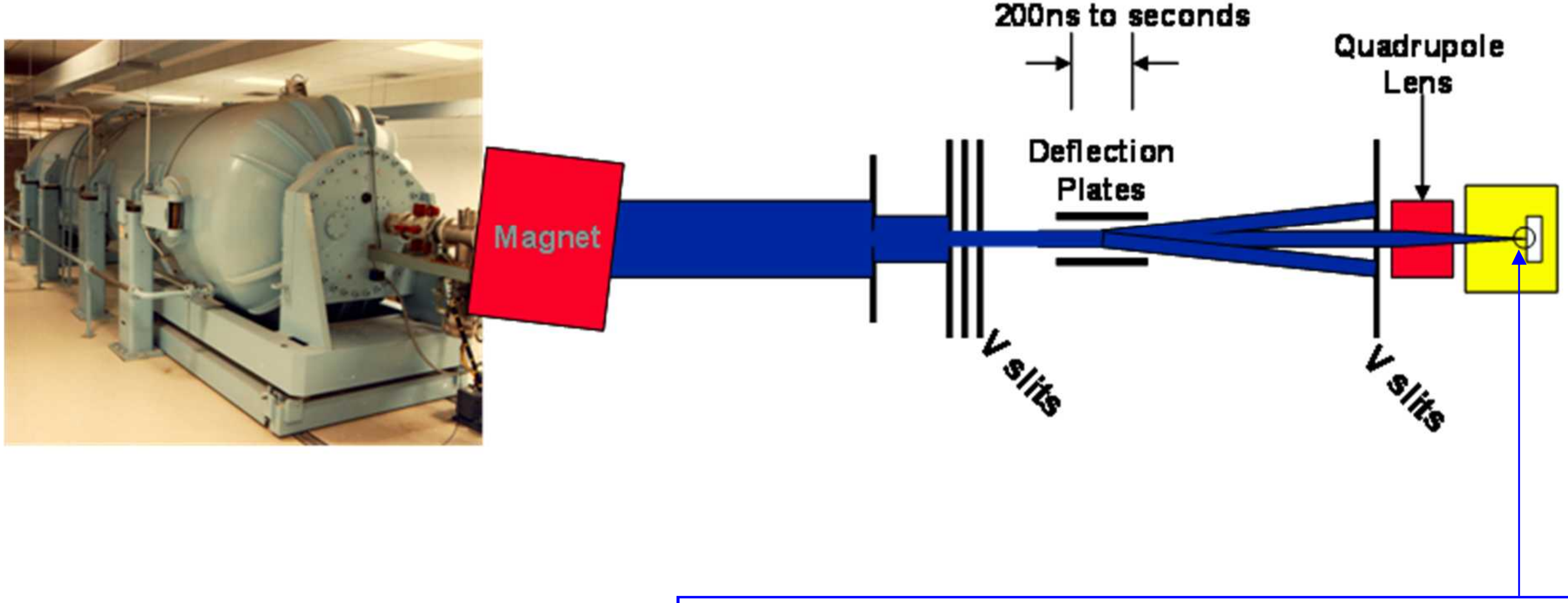
[b]Department of Physics, University of Padua and INFN, ITALY

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Work supported in part by the Italian "Istituto Nazionale di Fisica Nucleare" (INFN).

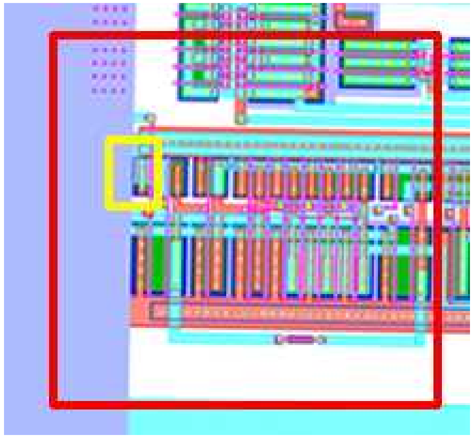
Sandia National Laboratories

Microscopy with Ion Beams for assessing "local" failures (SEE) in a chip subjected to radiation and help improving the design of the same

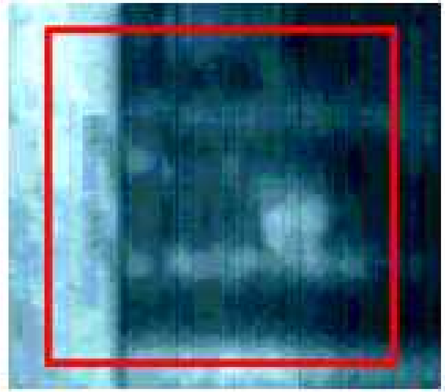


Low intensity beams of high energy ions are focused into a micro-region on a microchip

SEE Imaging at Sandia μone



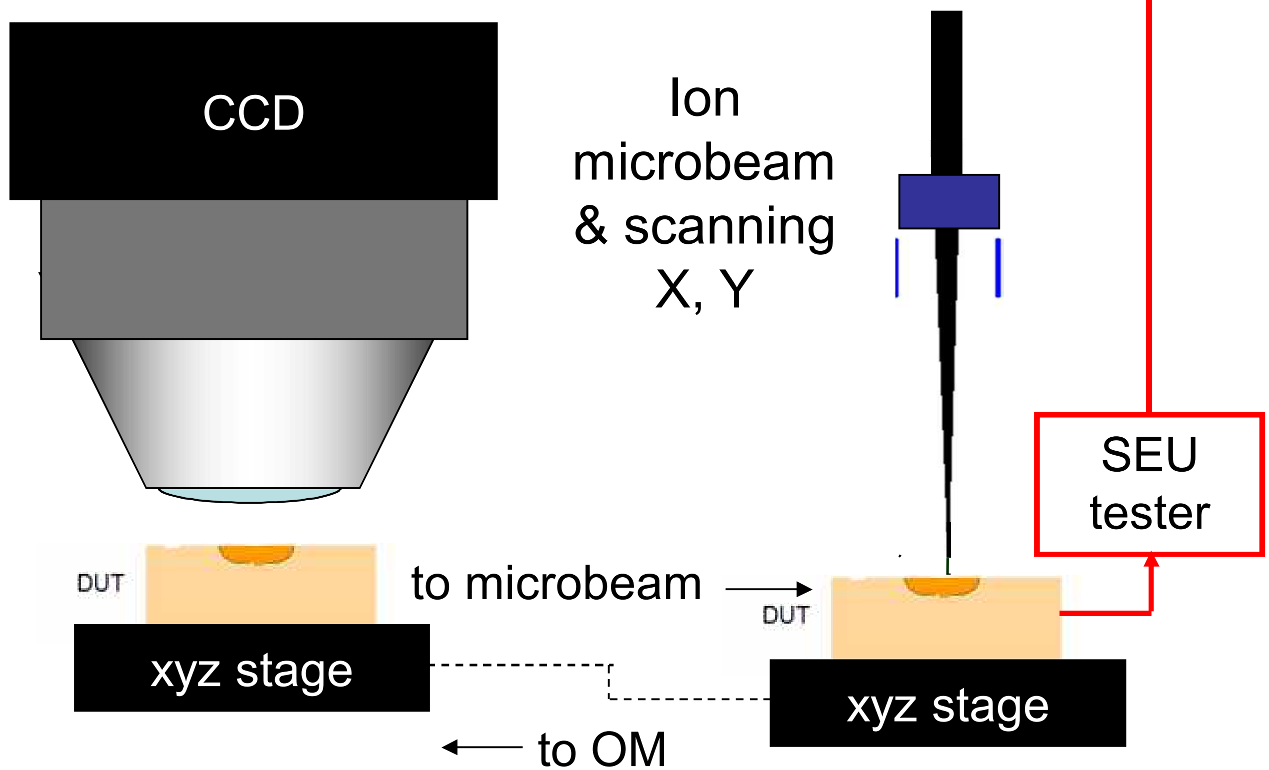
GDSII Navigation

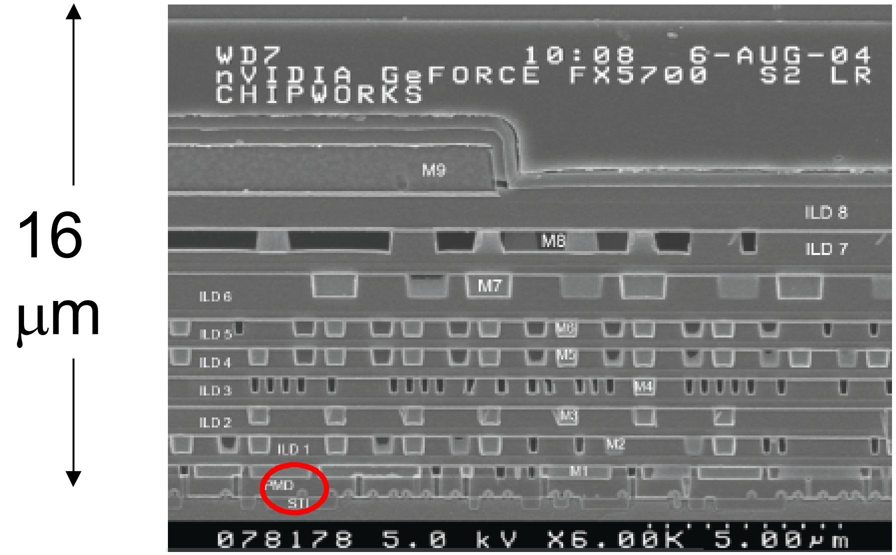


Optical Microscope OM

SEU map

1. GDSII or bmp files loaded
2. Optical Microscope - OM
   - IC brought into focus
   - IC landmarks found – positions tagged
   - GDSII calibrated to xyz stage
3. IC translated to the microbeam
   - Translation vector previously determined
   - Suspect components scanned to
   - Or whole IC scanned – SEE locations tagged
   - IBIC and SEE images taken
4. Position of SEEs ovelayed on OM and GDSII
   - Rad sensitive parts identified

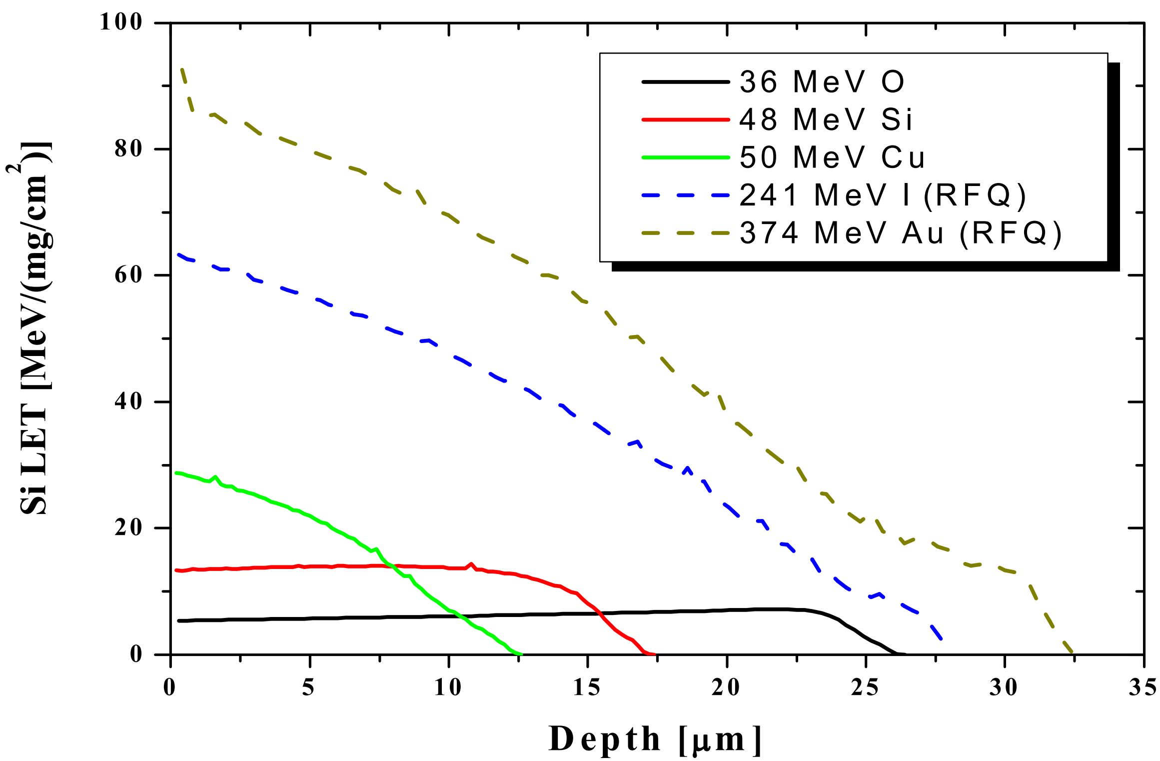




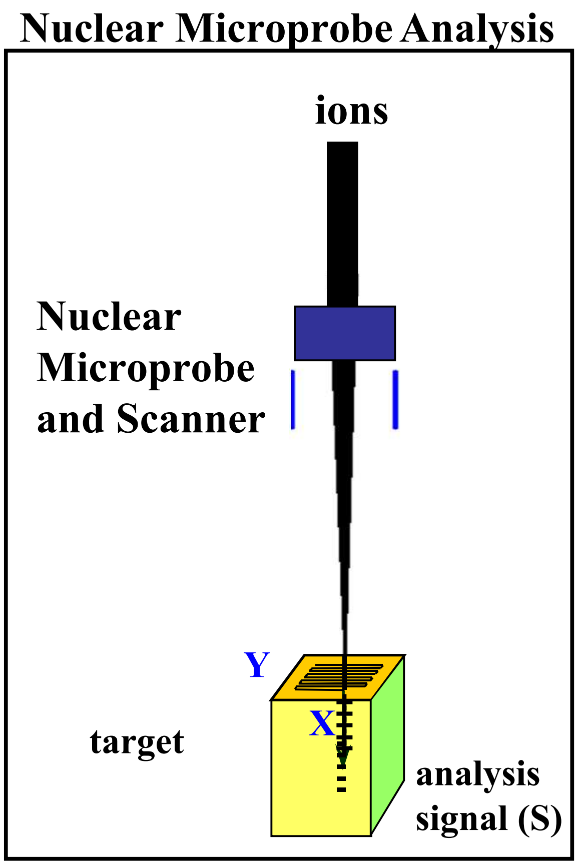
Modern ICs vs. our LET range.

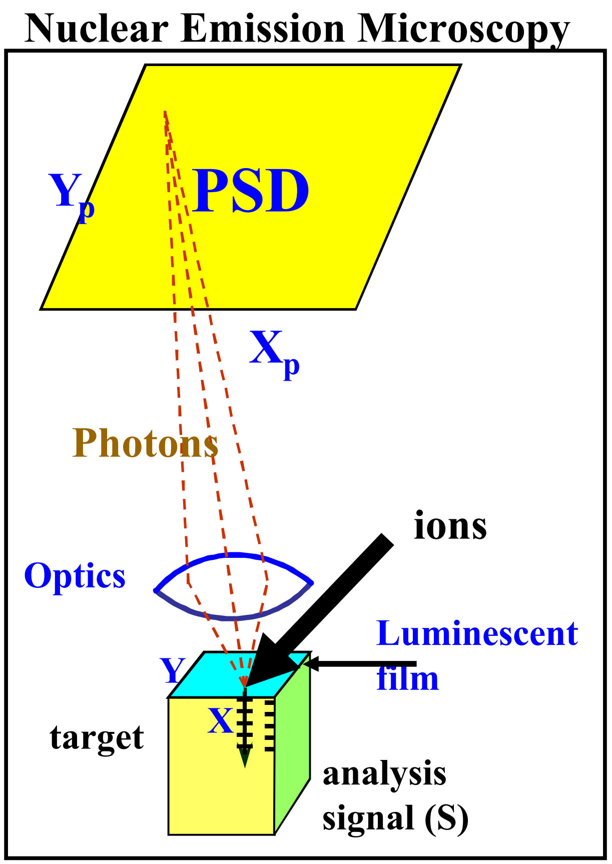
To explore SEE on chips with very thick metallization, interlevel dielectrics and passivation layers, one needs Cyclotron Energies (TAMU, Michigan State, or LBNL 88-inch Cycl.)

How to do Radiation Microscopy at such energies ??



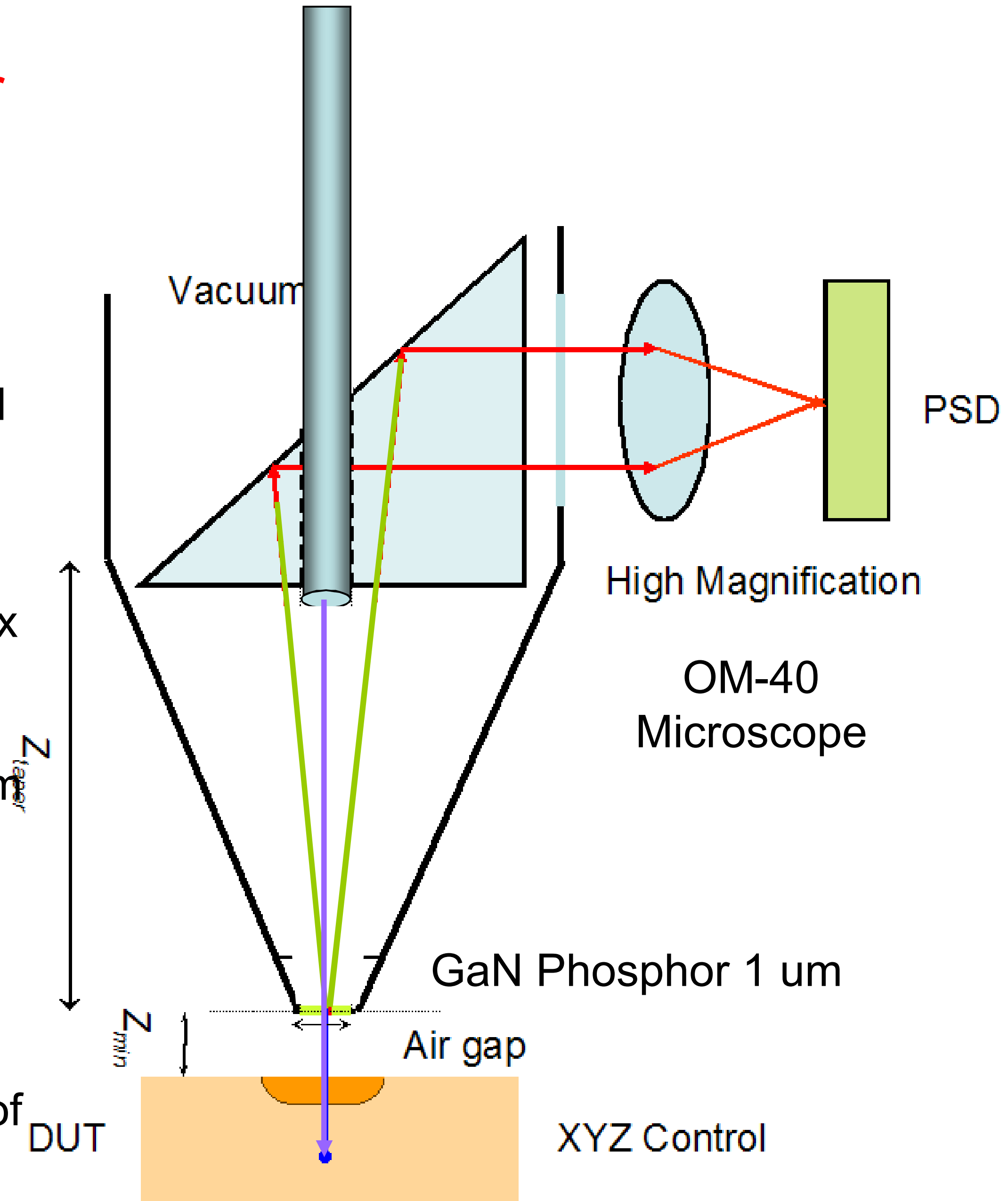
Problem: High Energy Ions are very difficult to focus
Solution: detect instead the impact point!



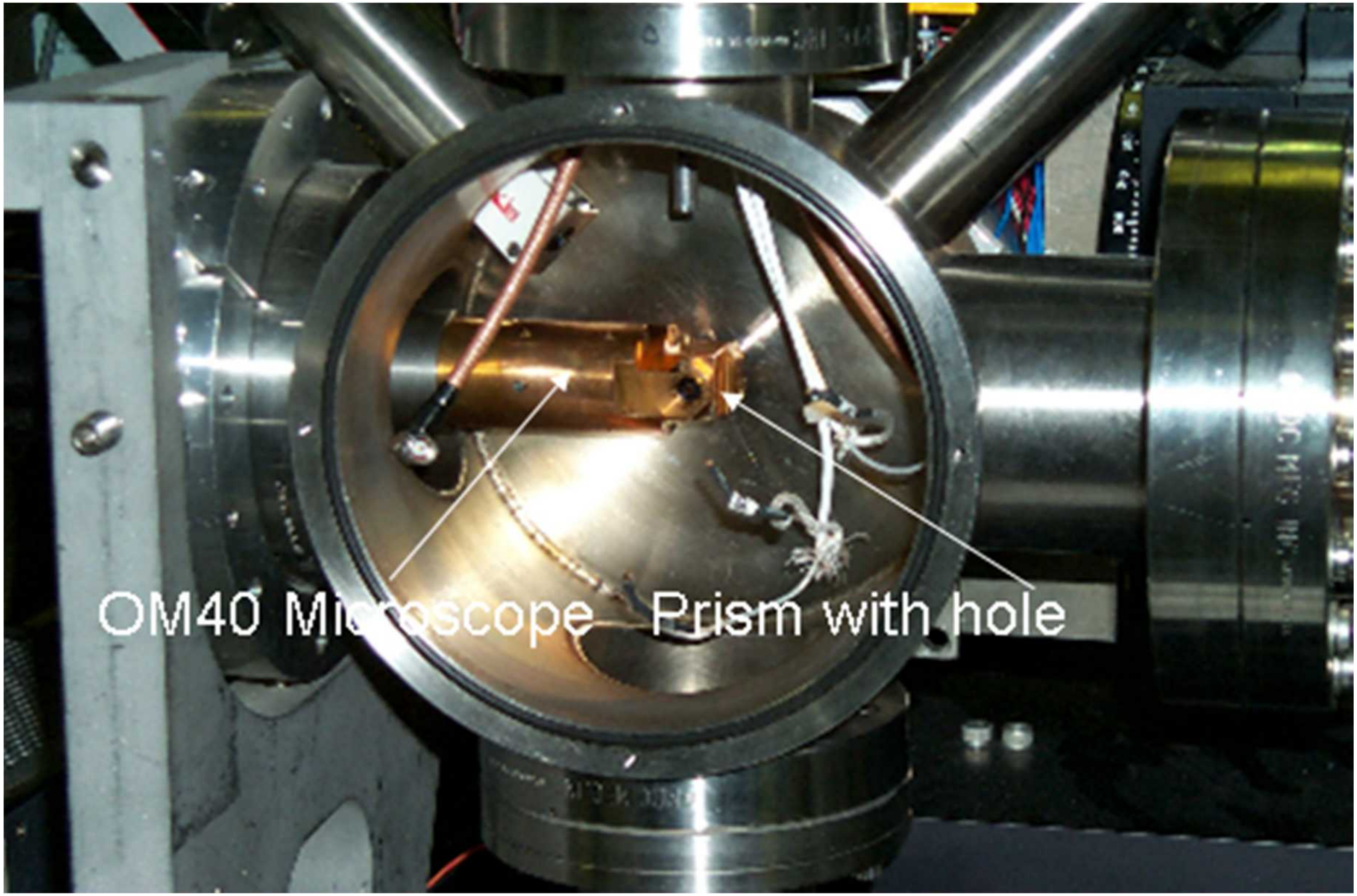


Cyclotron IPEM A Radiation Microscope for SEE testing (>GeV)

1. Beam from Cyclotron exits nozzle thru 1um Al foil
2. Transmitted 6mm in air to 1um GaN phosphor blade
3. Air gap is <100um
4. Angular scattering and beam divergence of 5mrad means parallax angle of beam in air gap is 10mrad.
5. Parallax and exit foil+airgap+Gan scattering effect on resolution is 1um
6. Blooming to be <1um
7. Net resolution of IPEM ~1-2 um
8. XYZ stage calibrated to GDSII file
9. Computer navigation to IC components
10. REM data presented as overlays of optical, GDSII, and SEE images to quickly identify rad sensitive components.

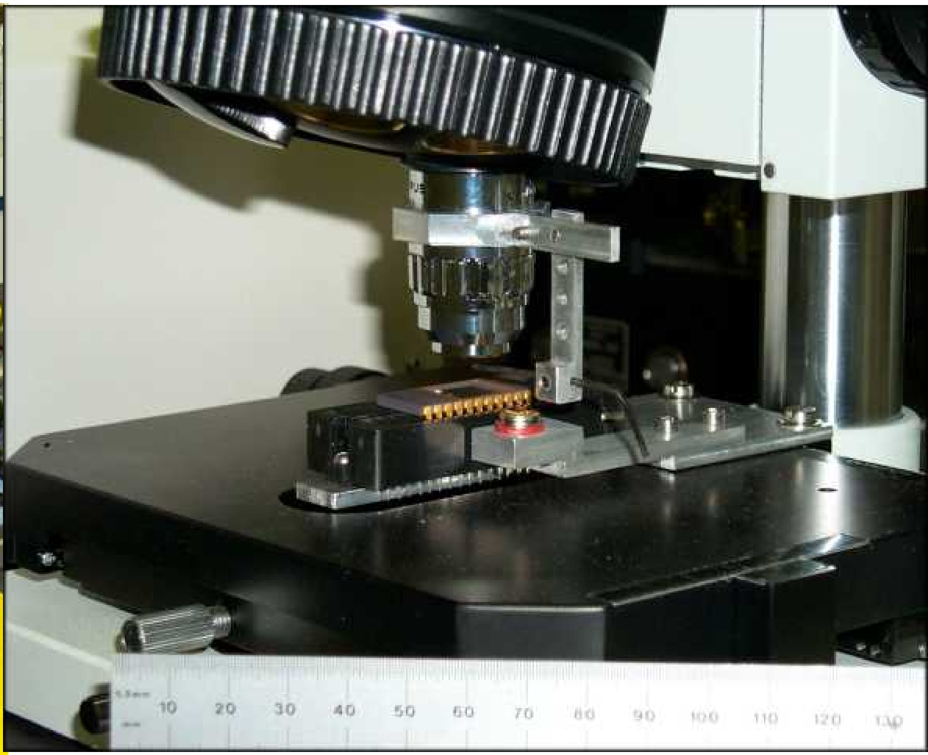


Scattering Chamber and OM40 Microscope



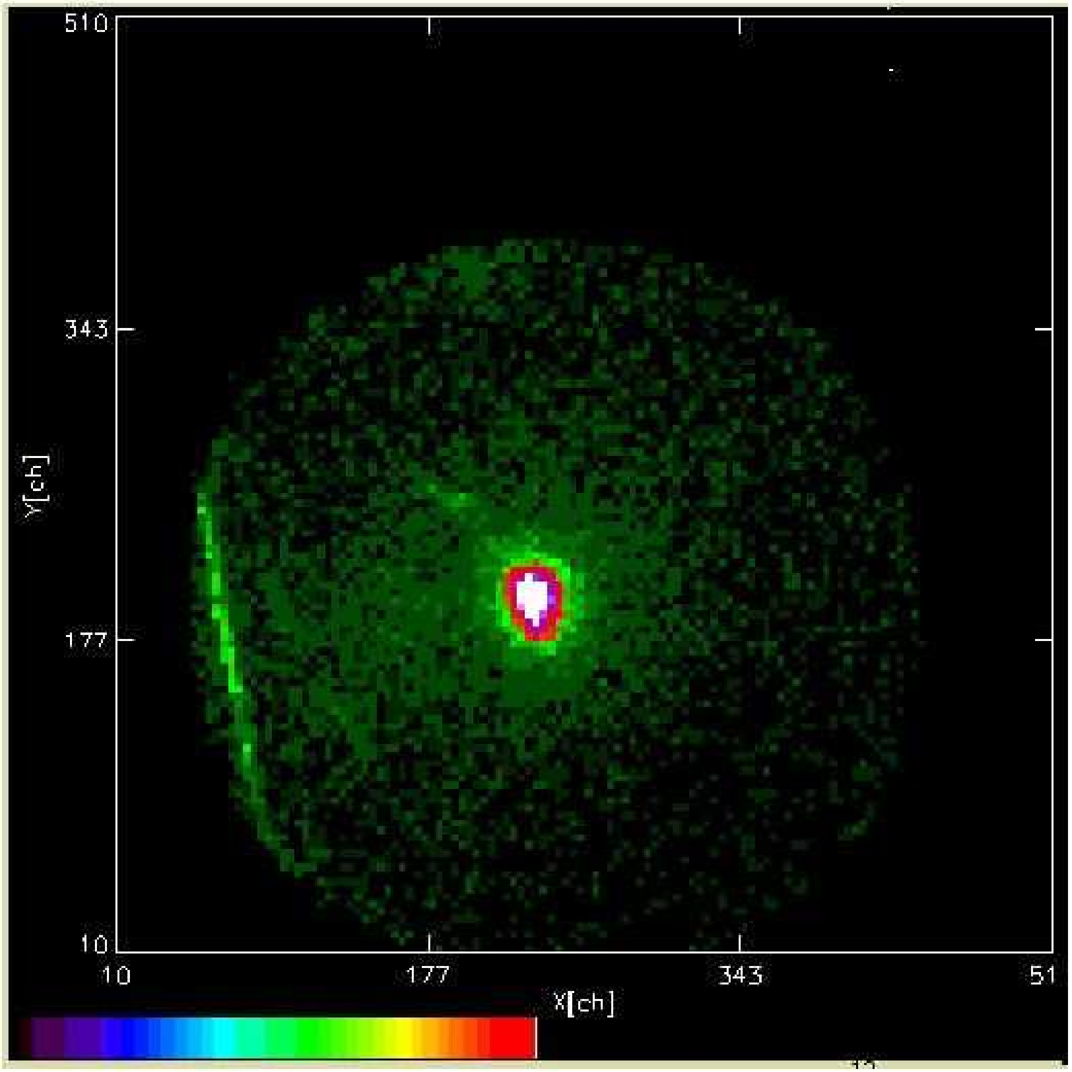
The JEOL OM-40 microscope has a 1.5 mm hole for the beam crossing. The current system is in vacuum, but IPEM can be performed eXternally. Light is conveyed from the OM-40 to the PSD outside the chamber

ALPHA PARTICLE TABLE-TOP IPEM



QUANTAR Mepsicron PSD
on top of the Microscope

POINT SPREAD FUNCTION (C20 MeV)



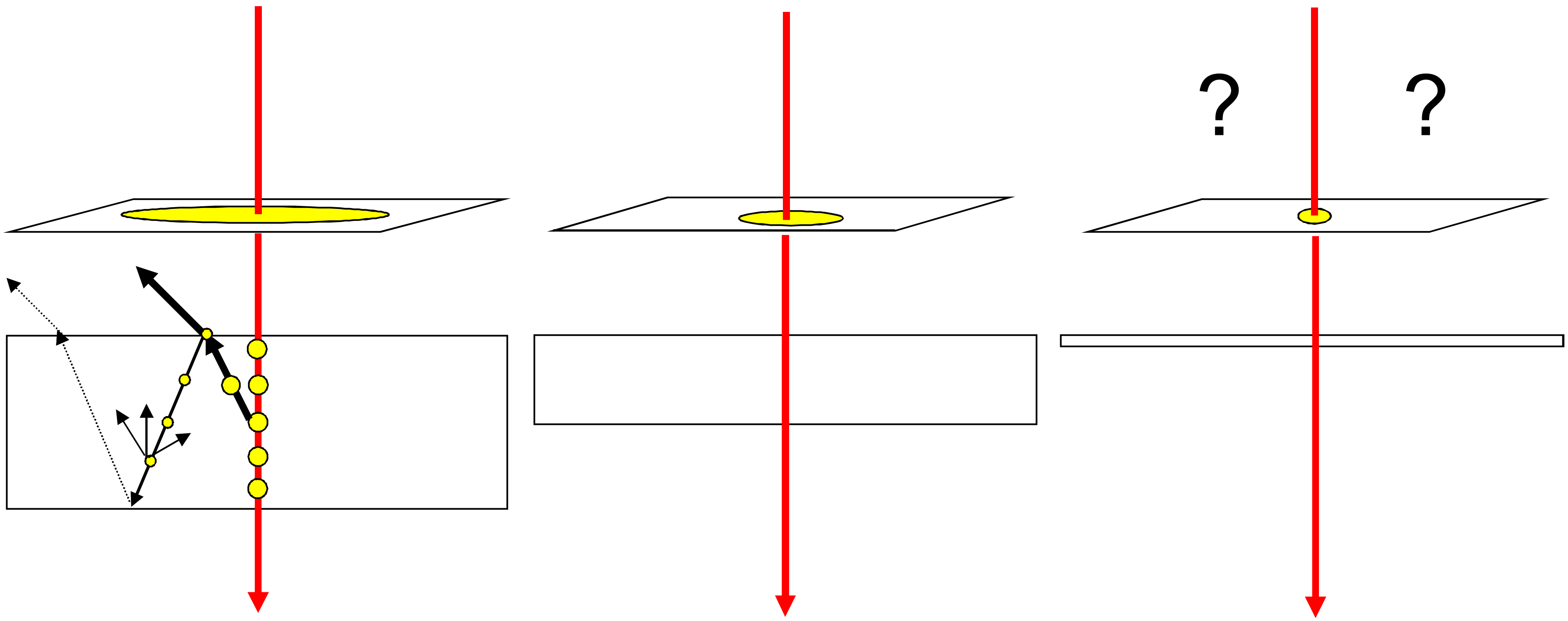
SNL 6MV Tandem
45º line Chamber

Focused microbeam With a spot size of 2-3 μm, impinging a 10 μm BC400 blade

FWHM = 12 μm
TP (Tail %)= 20%

Which Phosphor ?

To avoid the "blooming" the phosphor layer should be as thin as possible provided enough light is produced ->
High yield Phosphors workable into thin films



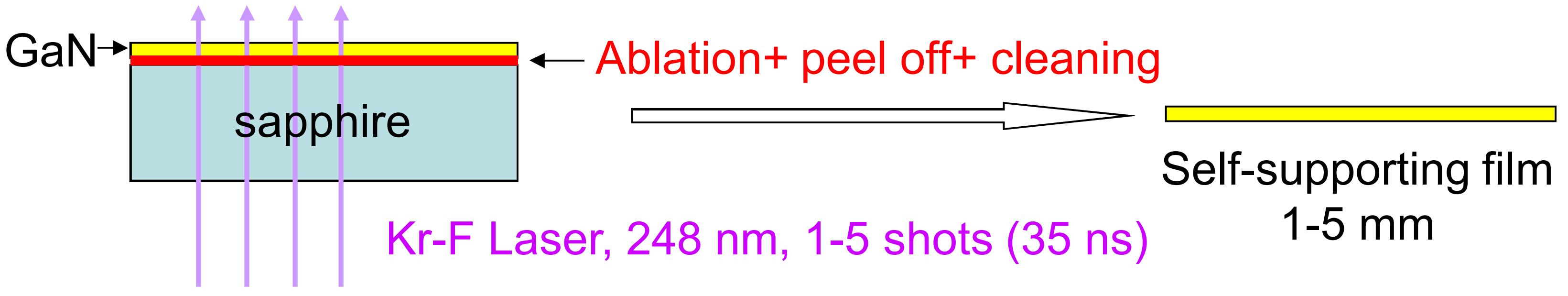
Bicron 400 (10 μm thick)
Resolution FWHM ~10 μm

GaN (5 μm thick)
FWHM ~3-5 μm

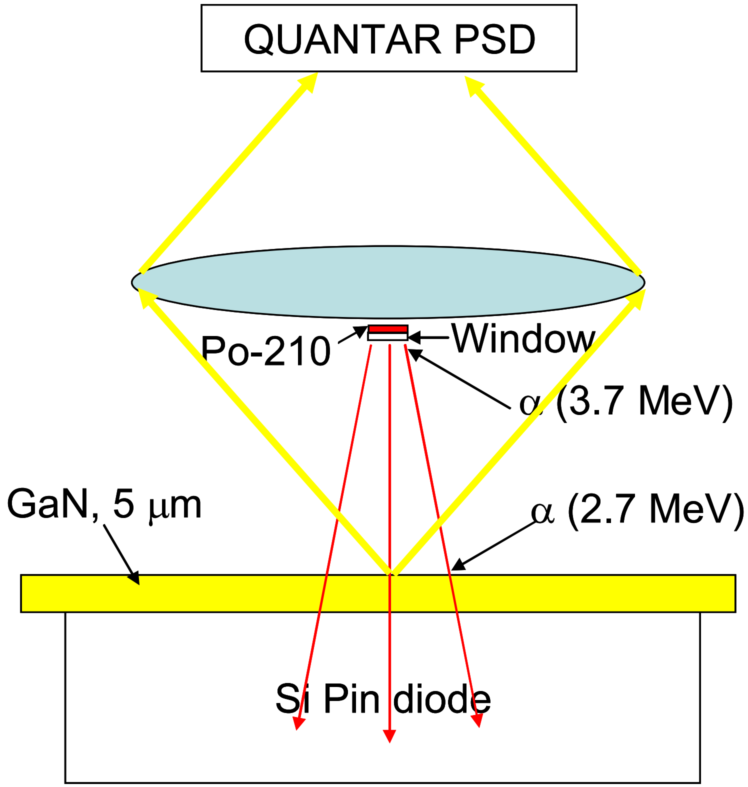
InGaN-QW(1 μm thick)
FWHM ~1 μm

GaN blades preparation

GaN films are routinely grown with MOCVD on sapphire at SNL. Since we needed freestanding foils we developed a method to turn these films to self-supporting foils using laser ablation to detach the films from their sapphire substrates. The films were grown on substrates polished on both sides to facilitate uniform transmission of the Kr-F laser light through the sapphire. Crystal Bond was used to glue the samples face down to a salt substrate to provide mechanical rigidity before and after ablation and to provide a measure of heat sinking. For some samples a holding grid such as a TEM ring was inserted in the glue interface at the front of the GaN layer. Samples were exposed to 1-5 shots of 248 nm, 34 ns laser light, with energy densities in the range of 800-1200 mJ/cm2 over an area of ~4mm2. Adsorption of the laser light induces rapid thermal decomposition at the interface, producing Ga and N2 gas and de-bonding the film from the sapphire. After exposure, the salt was dissolved away in water and the Crystal Bond removed with acetone. The resulting GaN films were cleaned in dilute HCl to remove residual Ga metal at the back interface. This method produced high quality self-supporting films down to 1 mm thickness and now it used to routinely produce these films.



Evaluation of the phosphors' performance with the table-top IPEM



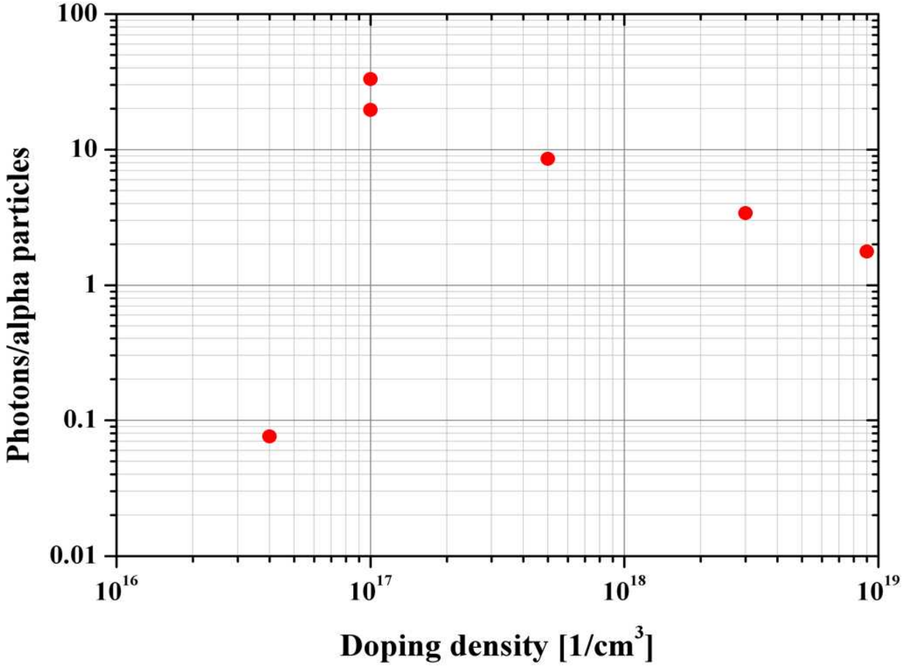
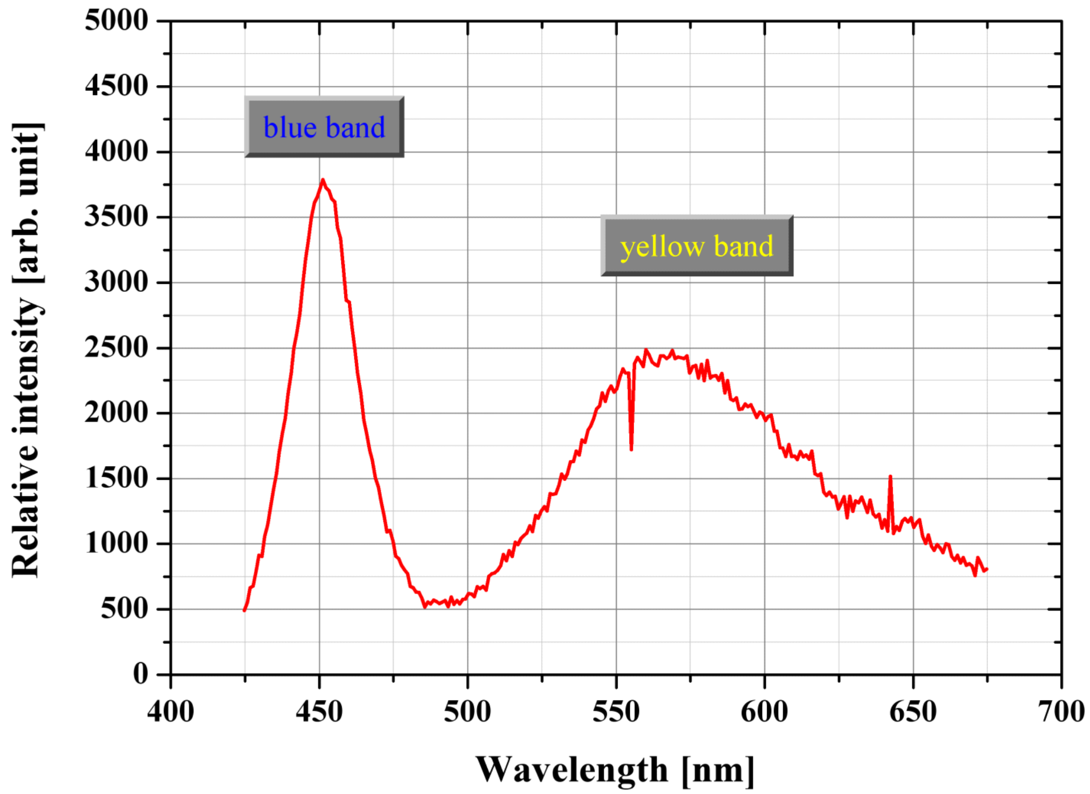


Figure 1

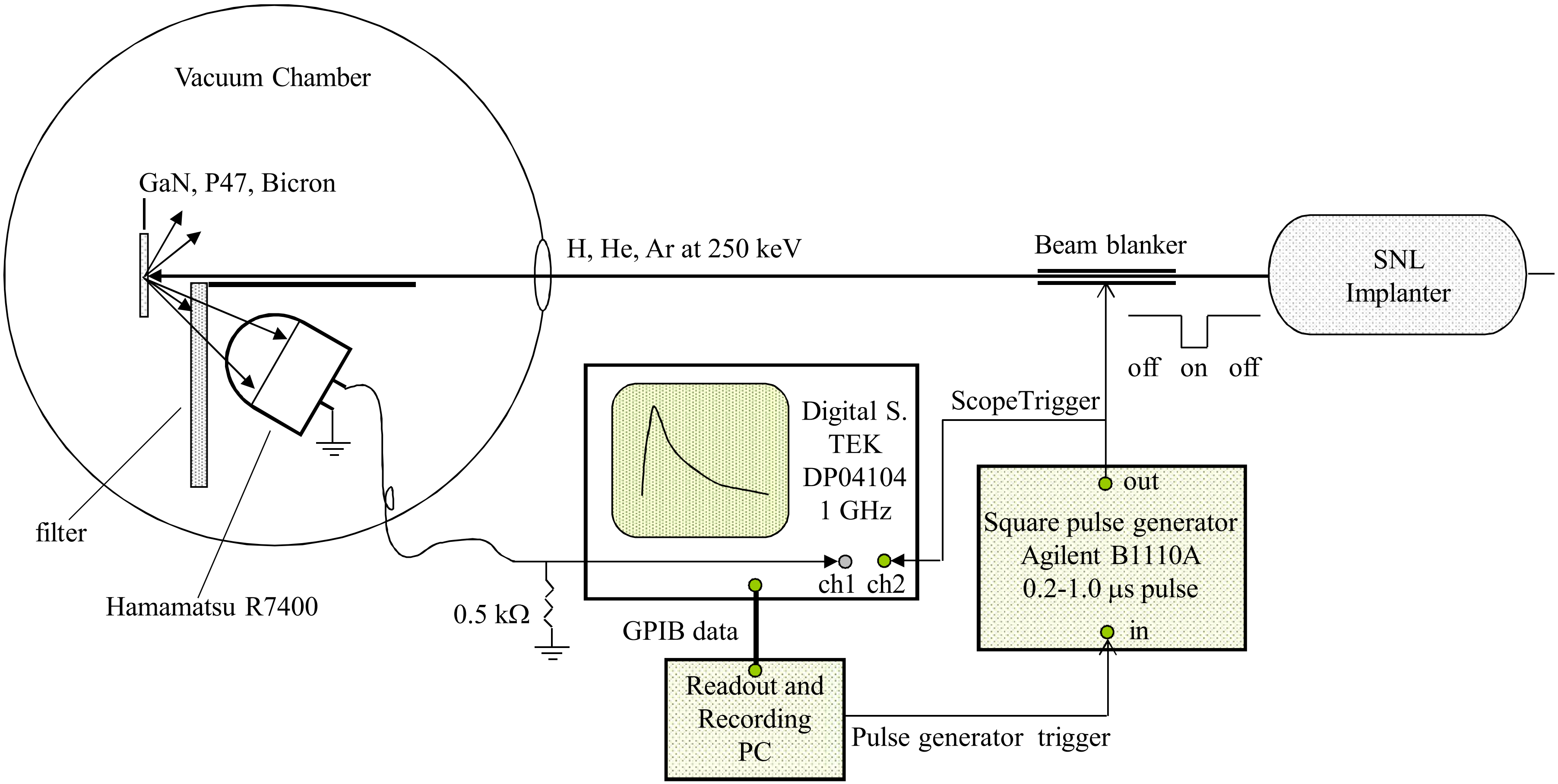
The p-type GaN has negligible visible ion-luminescence (IL) emission while the n-type GaN IL increases with decreasing doping level and peaks around 10^{17} atoms/cm^3 then drops down steeply. We also found that the light lifetime has roughly an inverse behavior.

GaN spectra

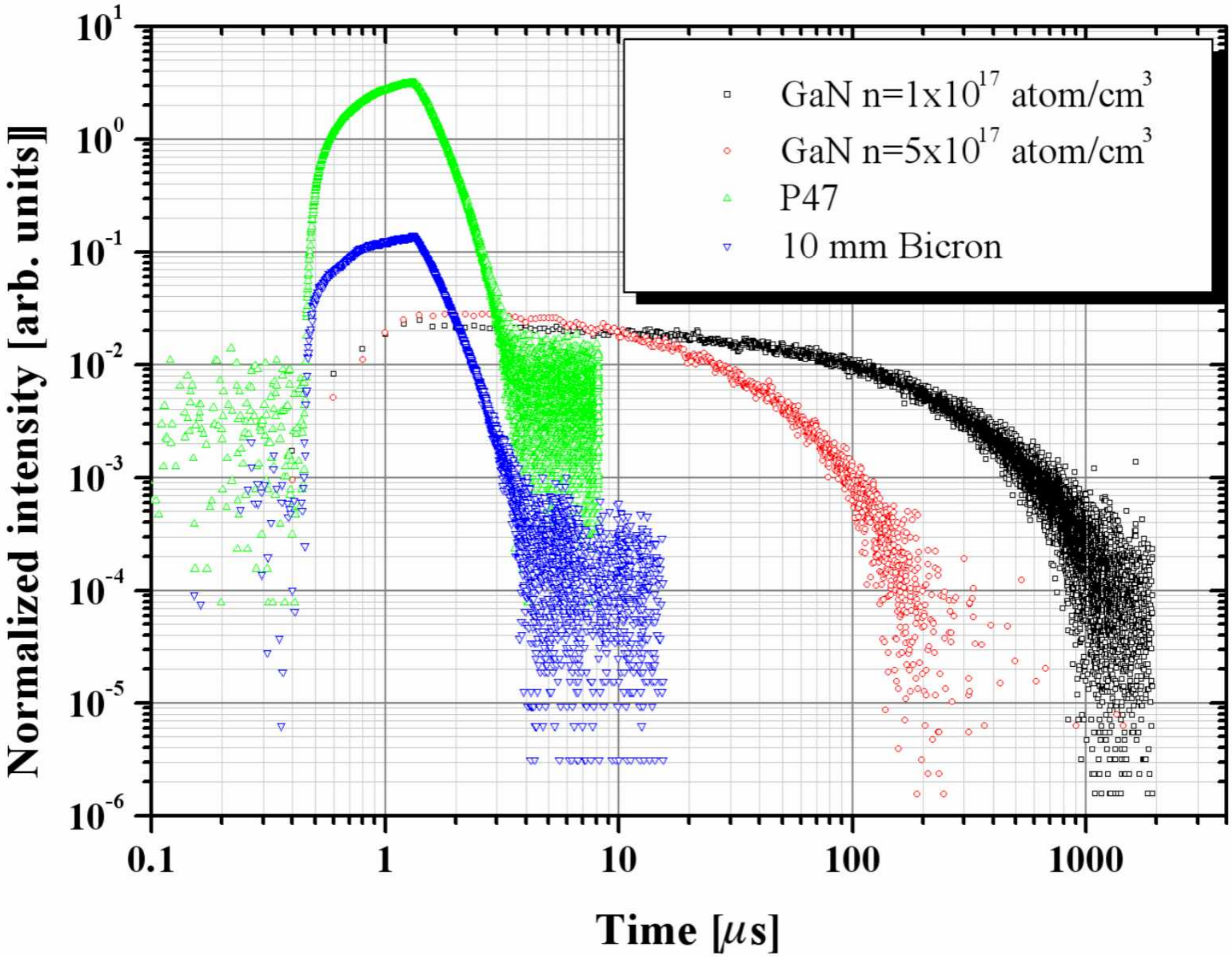


the n-type GaN and InGaN have emission bands centered at 360-UV (GaN), 450-blue (InGaN), and 560-yellow nm. In particular, the UV and blue bands, due to bandgap transitions, have a very short lifetime but reduced intensities. It is the yield of the yellow band that we found to change with the doping concentration (Figure 1) and that may become extremely high.

Light Yield, Spectrum and Life Time measurements at the implanter



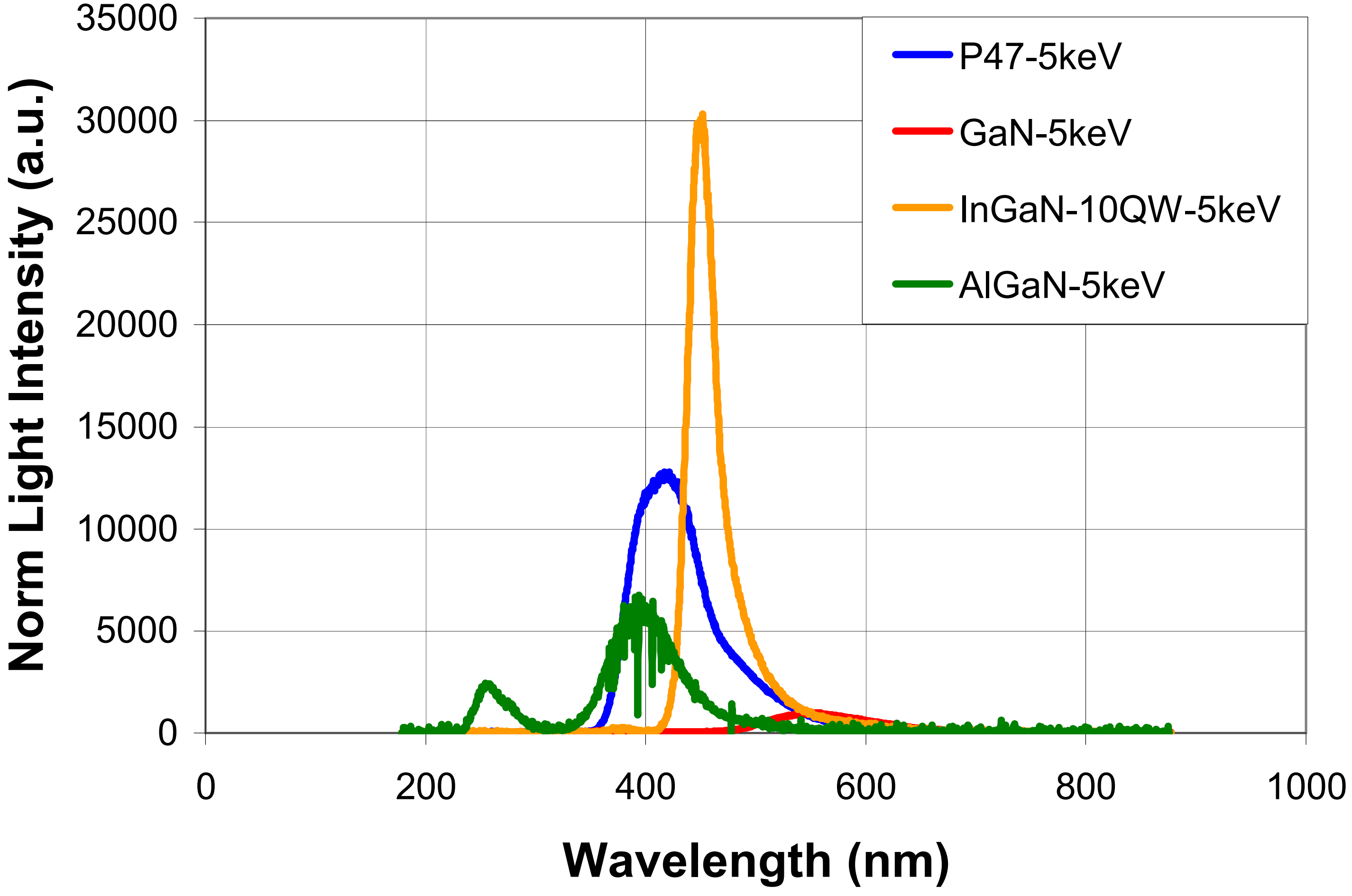
Waveforms



τ(GaN-n=e17)~200 μs, τ(GaN-n=5e17)=30 μs, τ(P47)~50 ns, τ(Bicron)~2 ns

5 keV electrons (Flat Panels) Cathode-Luminescence

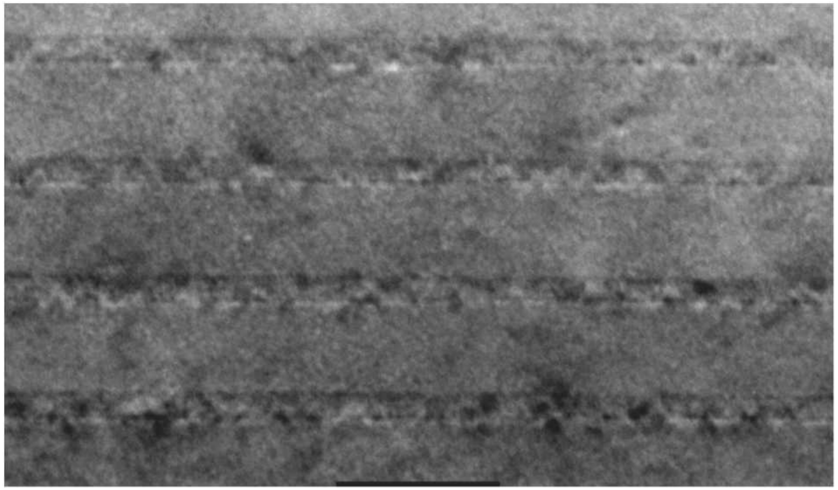
CL Yield: P47=1, GaN=0.12, InGaN=1.11, AlGaN=0.51

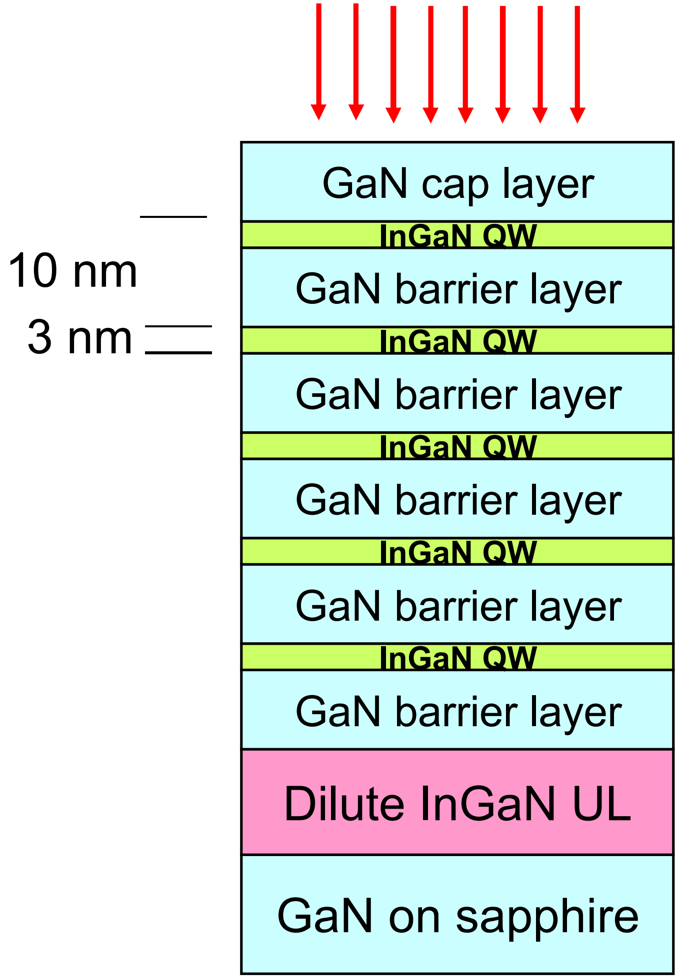


InGaN Quantum Wells for electron detection

D. D. Koleske, S. R. Lee, A. J. Fischer,M. H. Crawford, D. M. Follstaedt, K. C. Cross, N. A. Missert and G. Thaler, Sandia National Laboratories

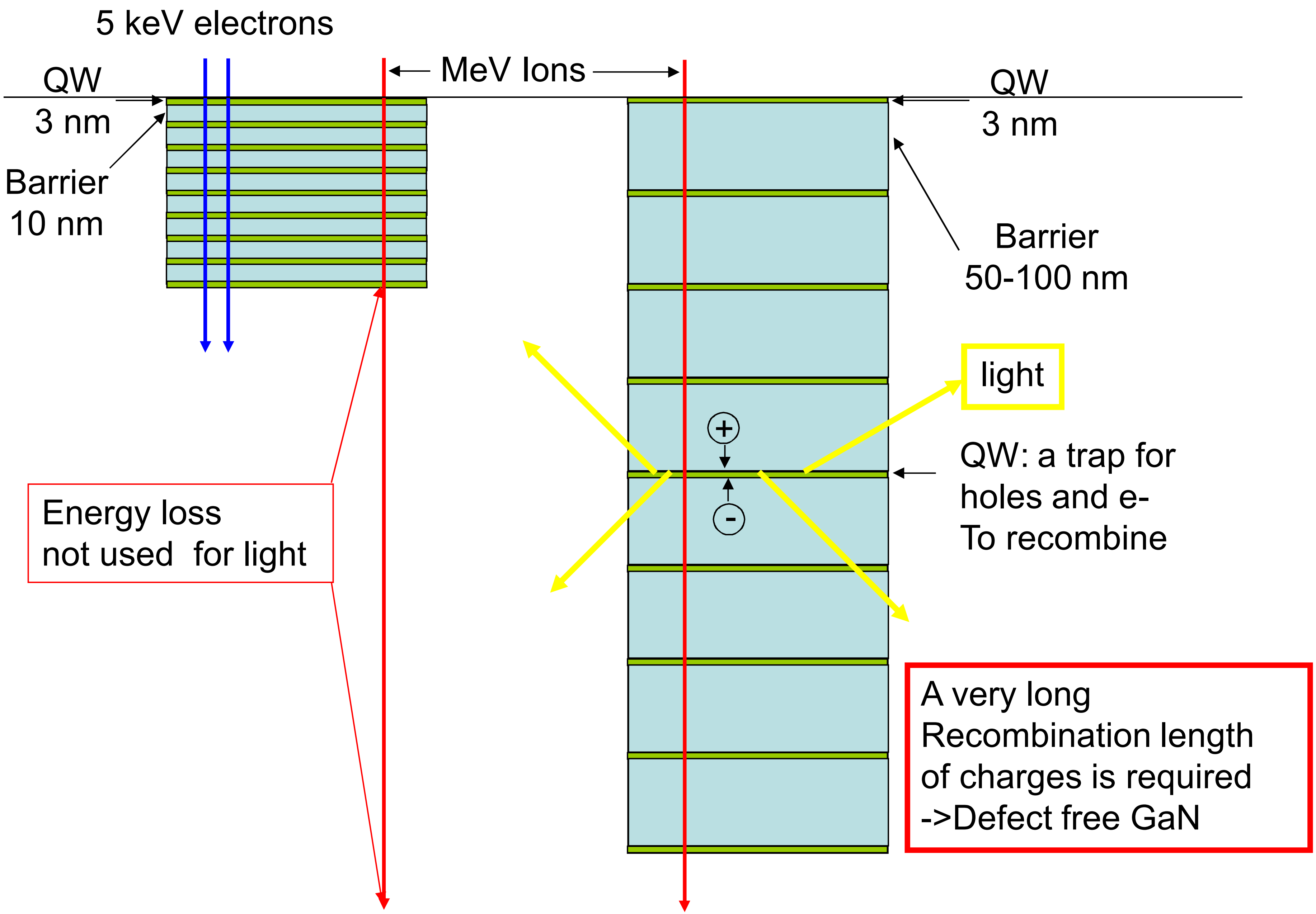
Multi-wafer rotating-disk MOCVD





Each of the MQW structures has:
Indium content = 15.1 ± 0.7 %
QW thickness = 26.3 ± 3.4 Å
Barrier thickness = 94.6 ± 6.2 Å
UL indium content = 1.4 ± 0.3 %
PL wavelength = 457 ± 6 nm

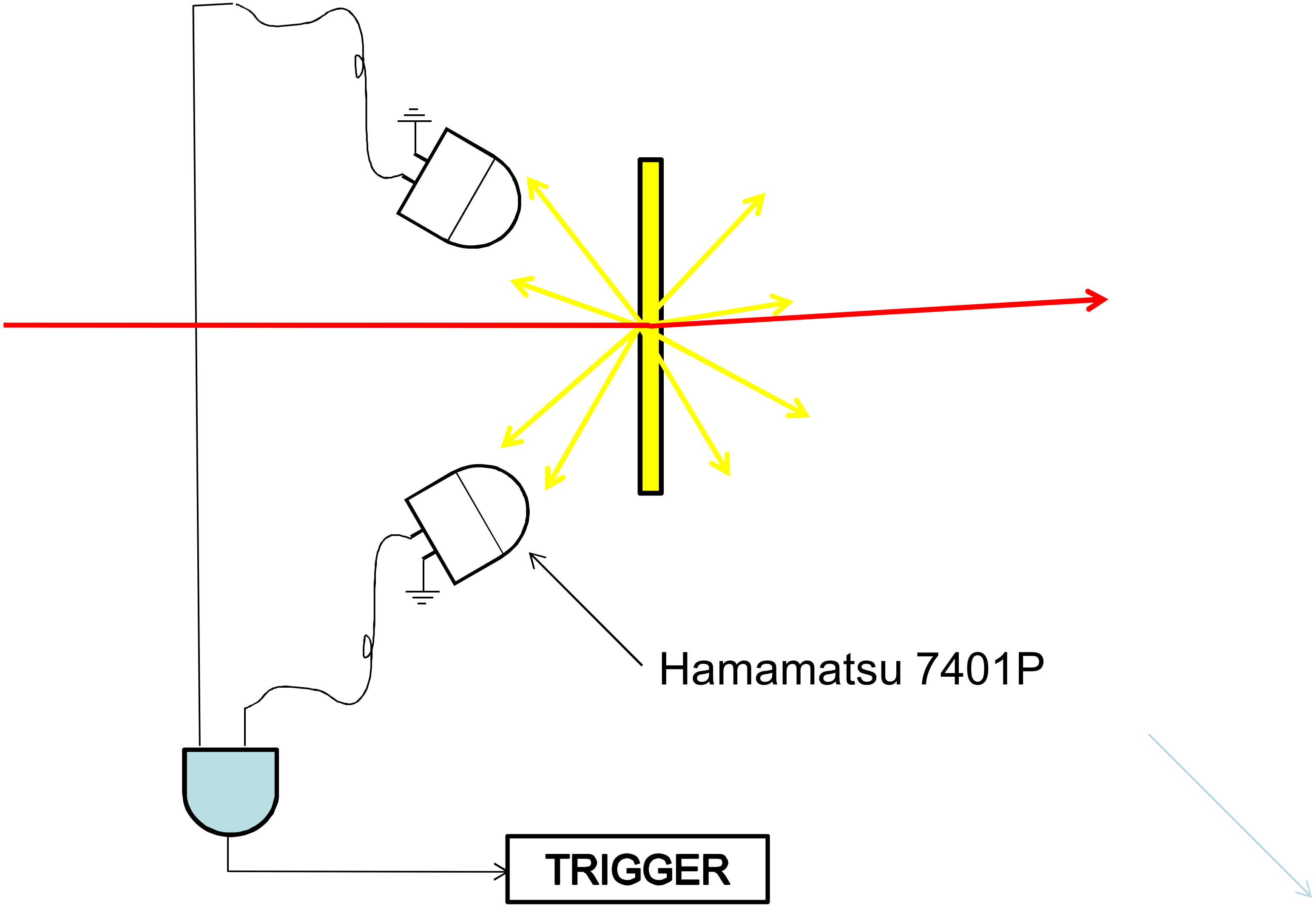
Quantum Wells for Ions Detection: a project



Cyclotron IPEM Conclusion

IPEM may become the best tool
for **MICROCHIPS SEE MAPPING**
at **CYCLOTRON ENERGIES**
for the next decade,
provided its spatial resolution is suitably improved by employing efficient and “quick” phosphors

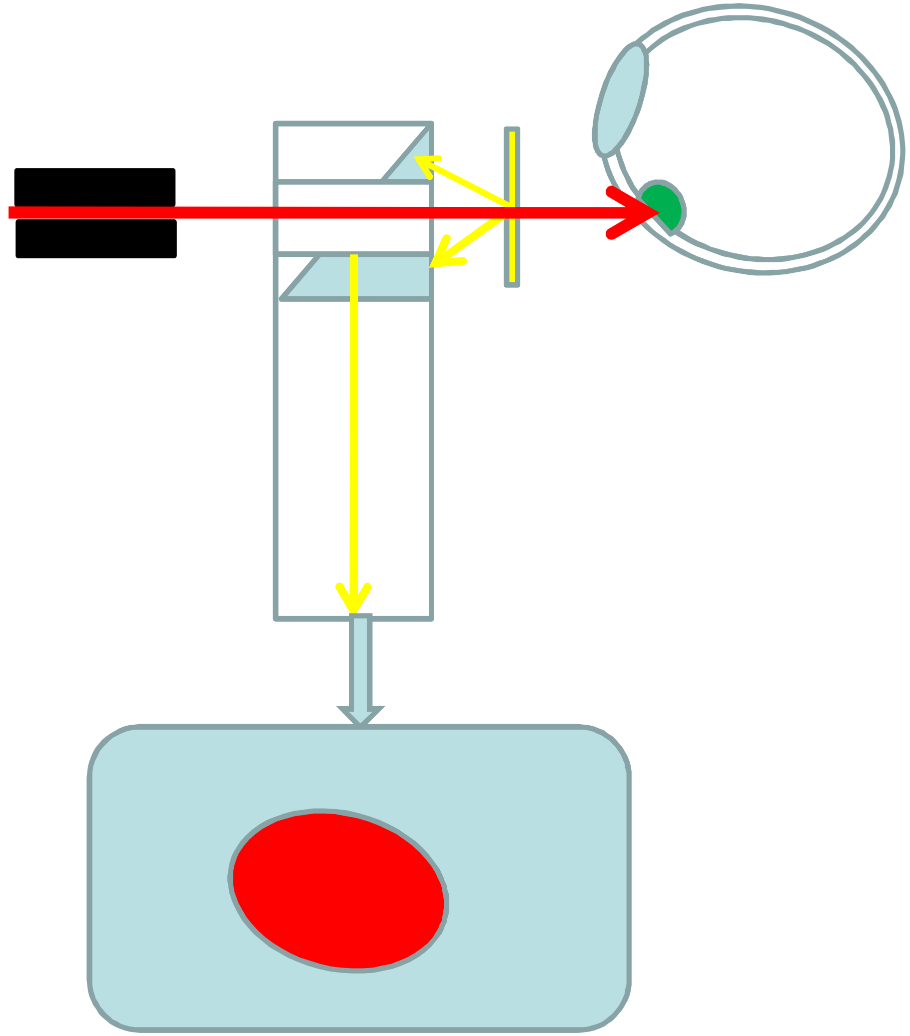
Trigger



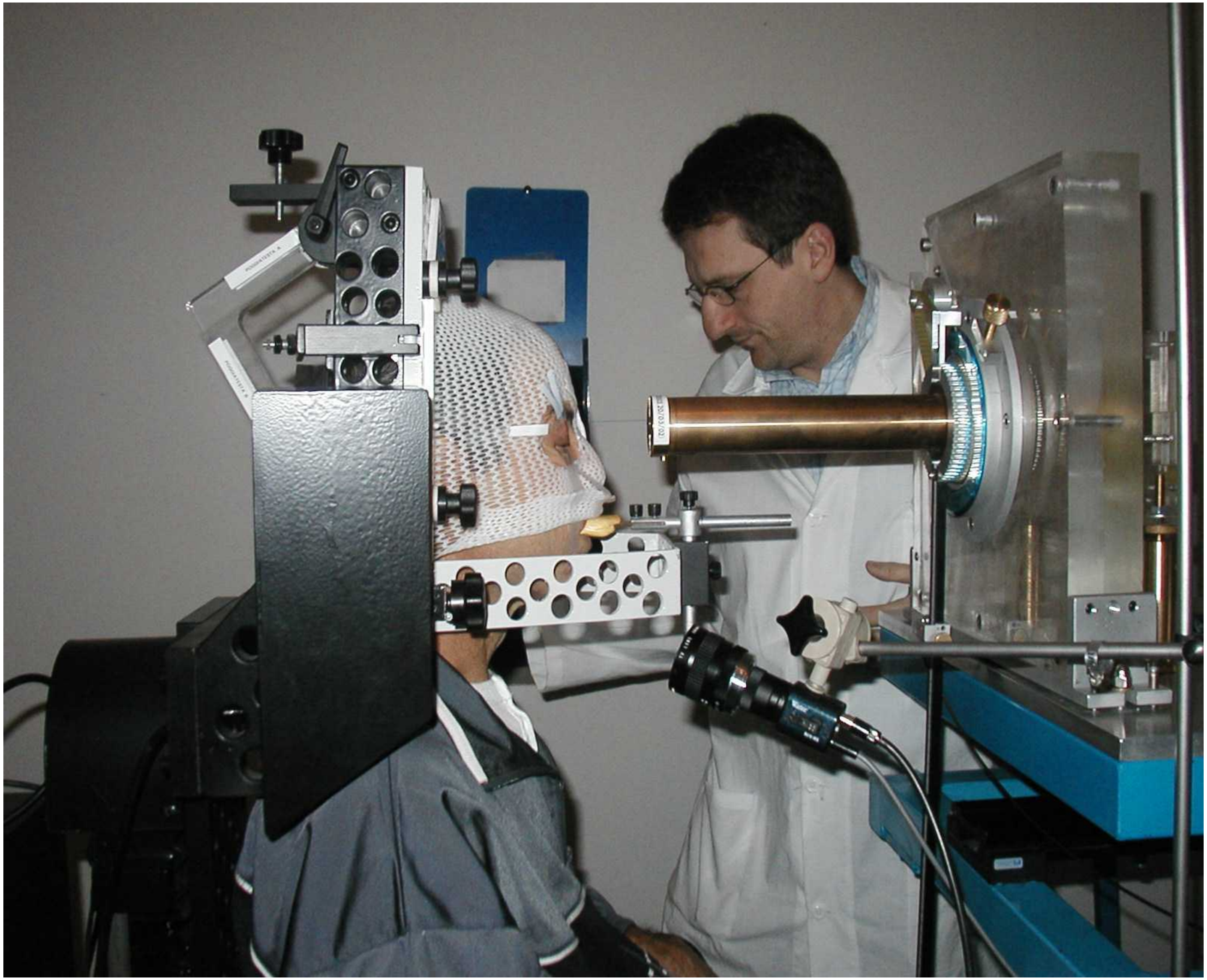
Monitor

In the hadron radiotherapy of a small delicate area, like the eye in uveal and iris melanoma, one needs to accurately monitor the dose being delivered to any pixel of the field, instant by instant, to avoid damages to the patient.

In these applications a "continuous monitor" is required, and the detector should not stop or even degrade too much the beam.



CATANA (Centro di Adroterapia e Applicazioni Nucleari Avanzate)



HVALA LIJEPA

Thank you very much

Molte Grazie