Determination of phase space density distributions of ion beams using photo detachment techniques

1.) Intoduction

2.) Cross sections, neutralisation fraction and yield

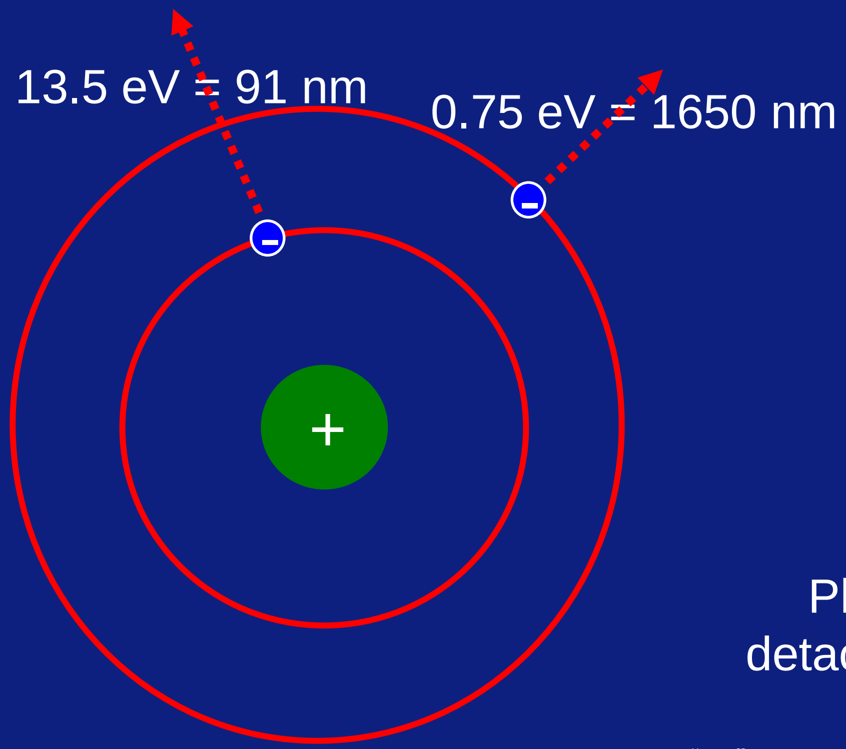
3.) Laser systems

4.) Comparision of yield for different examples

5.) Examples of different experimental set ups

6.) Conclusions

Principle of photo detachment for beam diagnostics



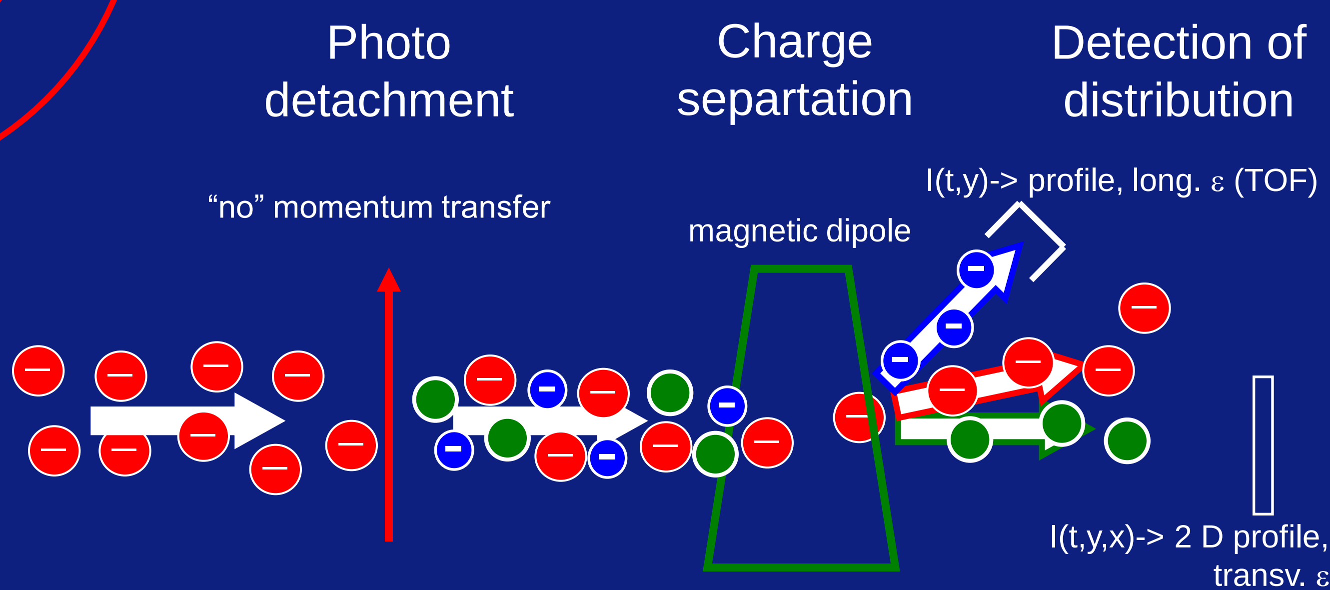


Photo detachment cross sections for H^- beams

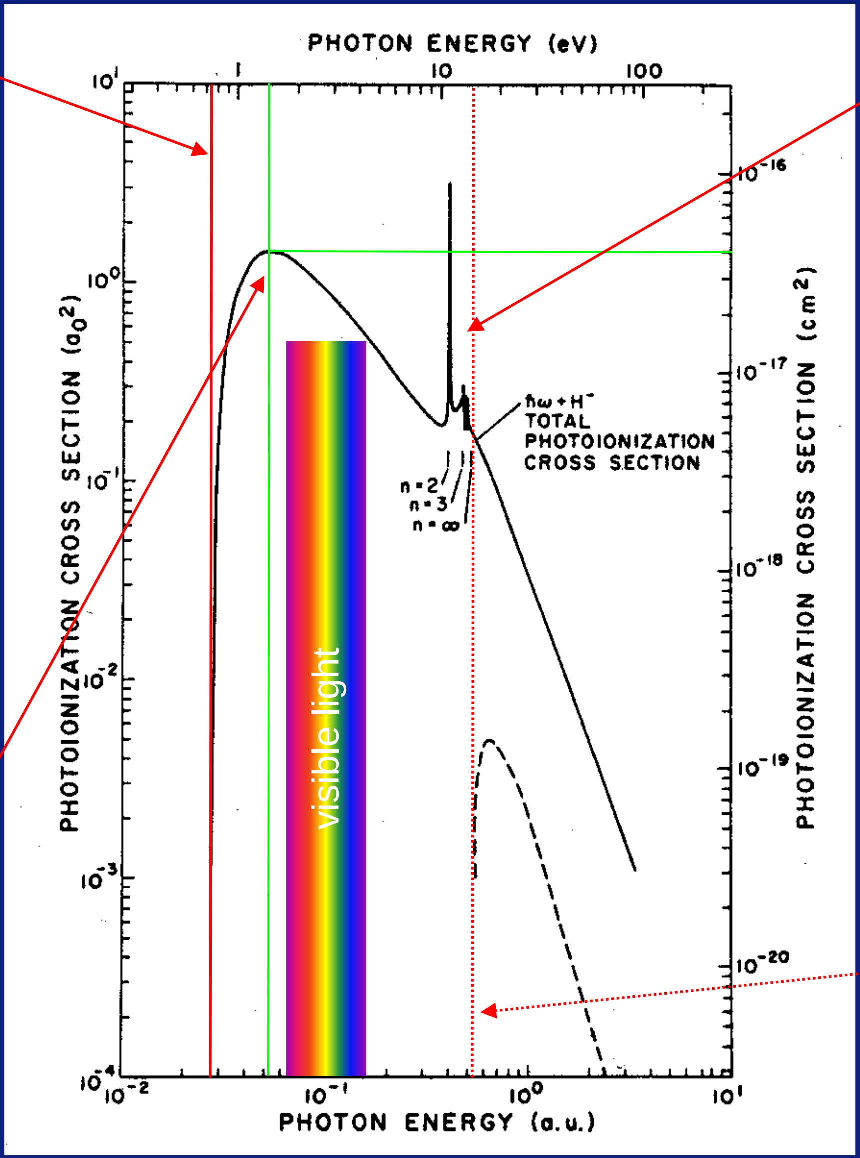
neutralisation energy

$$H^- + h\nu = H^0 + e^-$$

$\approx$ 0.75 eV

Feschbach and Sharp resonances in the range from

10-14 eV(124-88 nm)



Maximum cross section of

$$\sigma \approx 4 \cdot 10^{-21} m^2$$

at $\approx$ 0.75 eV (830 nm)

ionisation energy

$$H^- + h\nu = H^+ + 2e^-$$

$\approx$ 14.4 eV

Calculation of neutralisation fraction and yield 1

(homogeneous density of both beams)

neutralisation fraction:

$$f = 1 - e^{-[\sigma(E)\cdot F\cdot t]}$$

photon flux F:

$$F = \frac{P\cdot\lambda}{h_{Pl}\cdot c}\cdot\frac{1}{h_L\cdot w_L}$$

exposure time t

$$t = \frac{w_L}{v_{ion}}$$

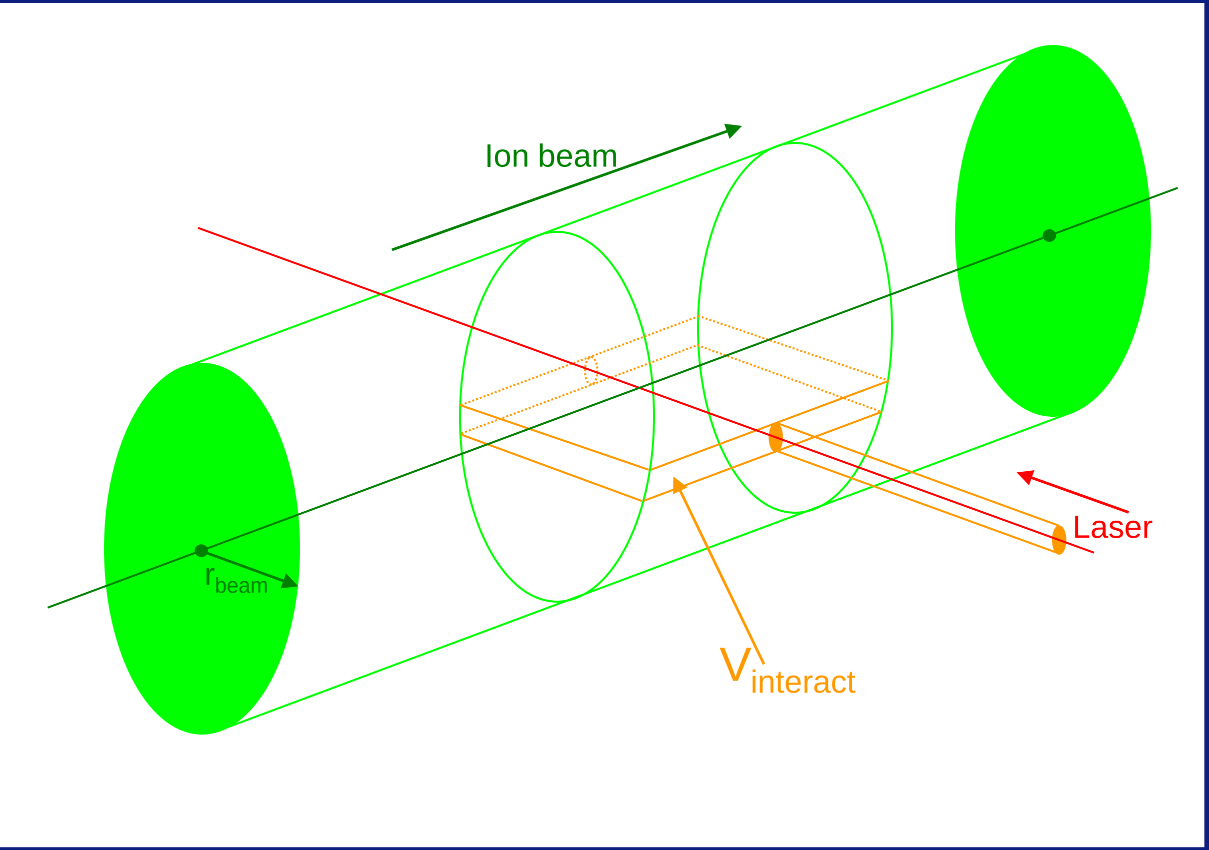
yield N_0

$$N_0 = f\cdot N_{H^-,Vol}$$

$$N_0 = f\cdot\frac{F_{LB}}{F_{IB}}\cdot N_{H^-,total}$$

$$N_0 = f\cdot\frac{2\cdot r_{IB}\cdot h_L}{\pi\cdot r^2{}_{IB}}\cdot N_{H^-,total}$$

$$N_0 = f\cdot\frac{2\cdot h_L}{\pi\cdot r_{IB}}\cdot N_{H^-,total}$$



relativistic Lorentz shift of energy

$$E_{CM} = E_{Lab}\cdot\gamma\cdot[1-\beta\cos\Theta_{Lab}]$$

relativistic flux compression

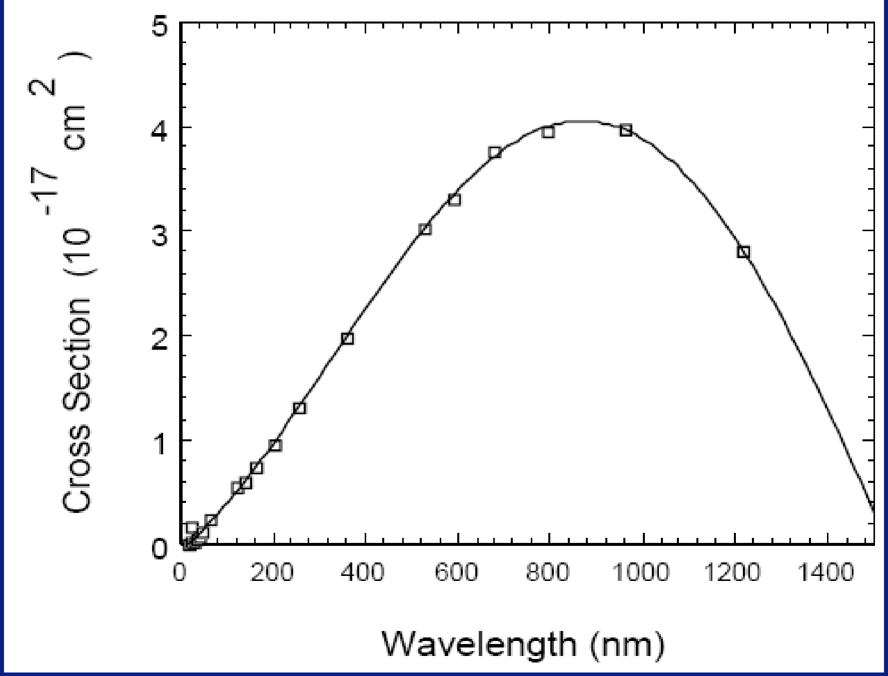
$$F_{CM} = F_{Lab}\cdot\gamma\cdot[1-\beta\cos\Theta_{Lab}]$$

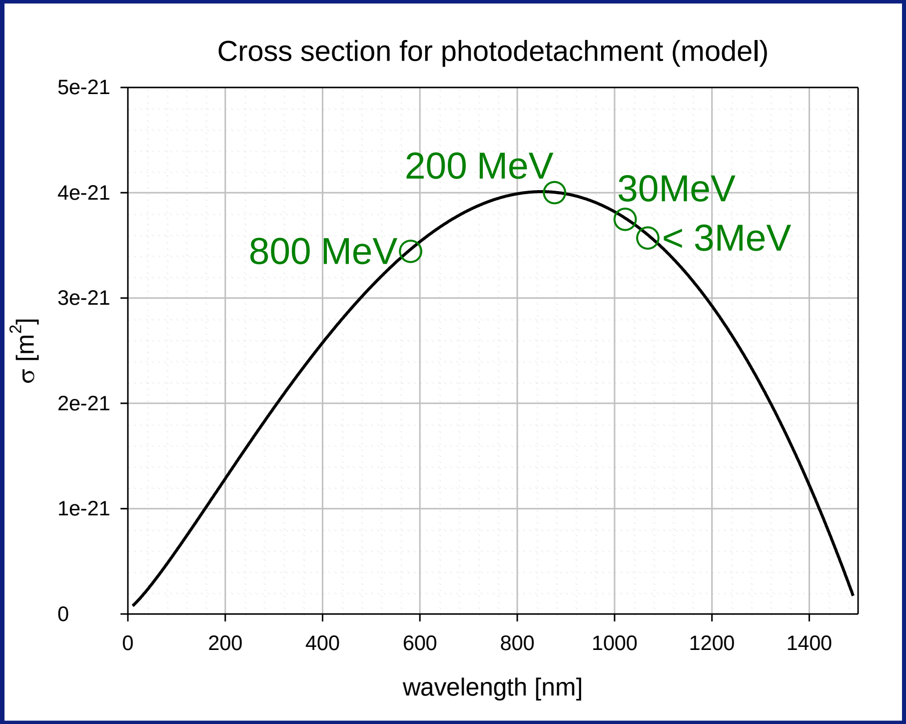
Calculation of neutralisation fraction and yield 2

Modelling of the wavelength dependency

for the determination of the Lorentz shift

on the neutralisation fraction





Calculation of neutralisation fraction and yield 3

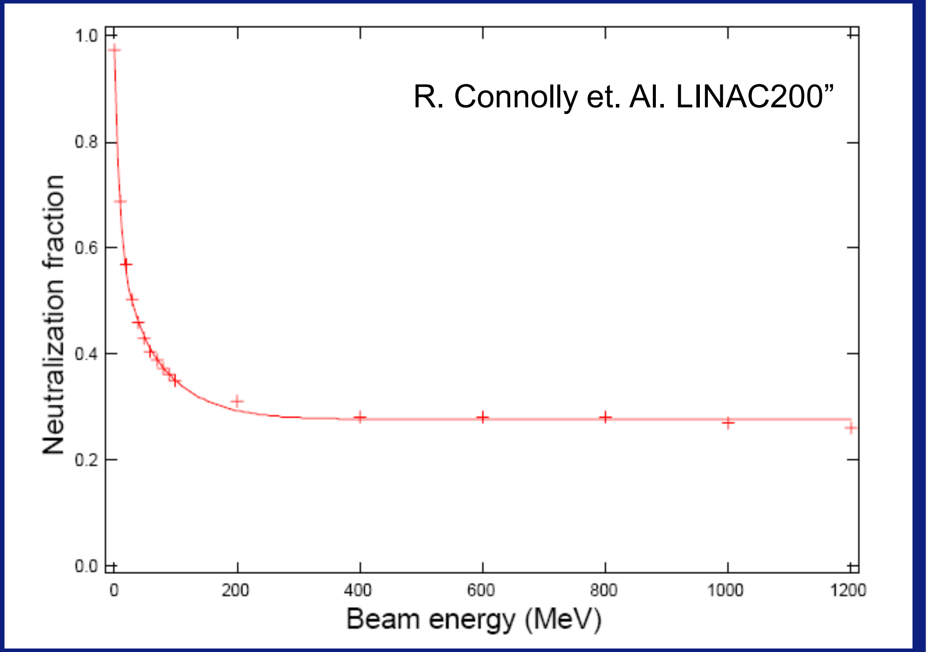
Example : SNS MEBT experiment

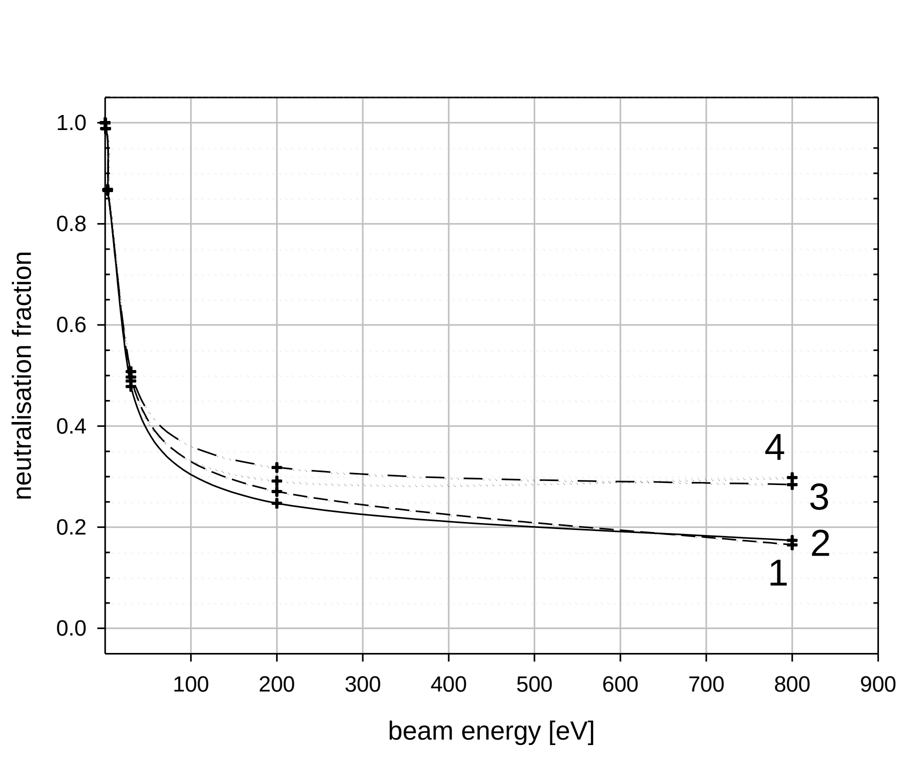
λ=1064 nm

τ=20ns, E=50 mJ => P=2.5 MW

w_l=3mm, h_l=1mm

1) Without relativistic correction
2) Influence of flux compression
3) Influence on Lorentz shift on cross section
4) Including both effects



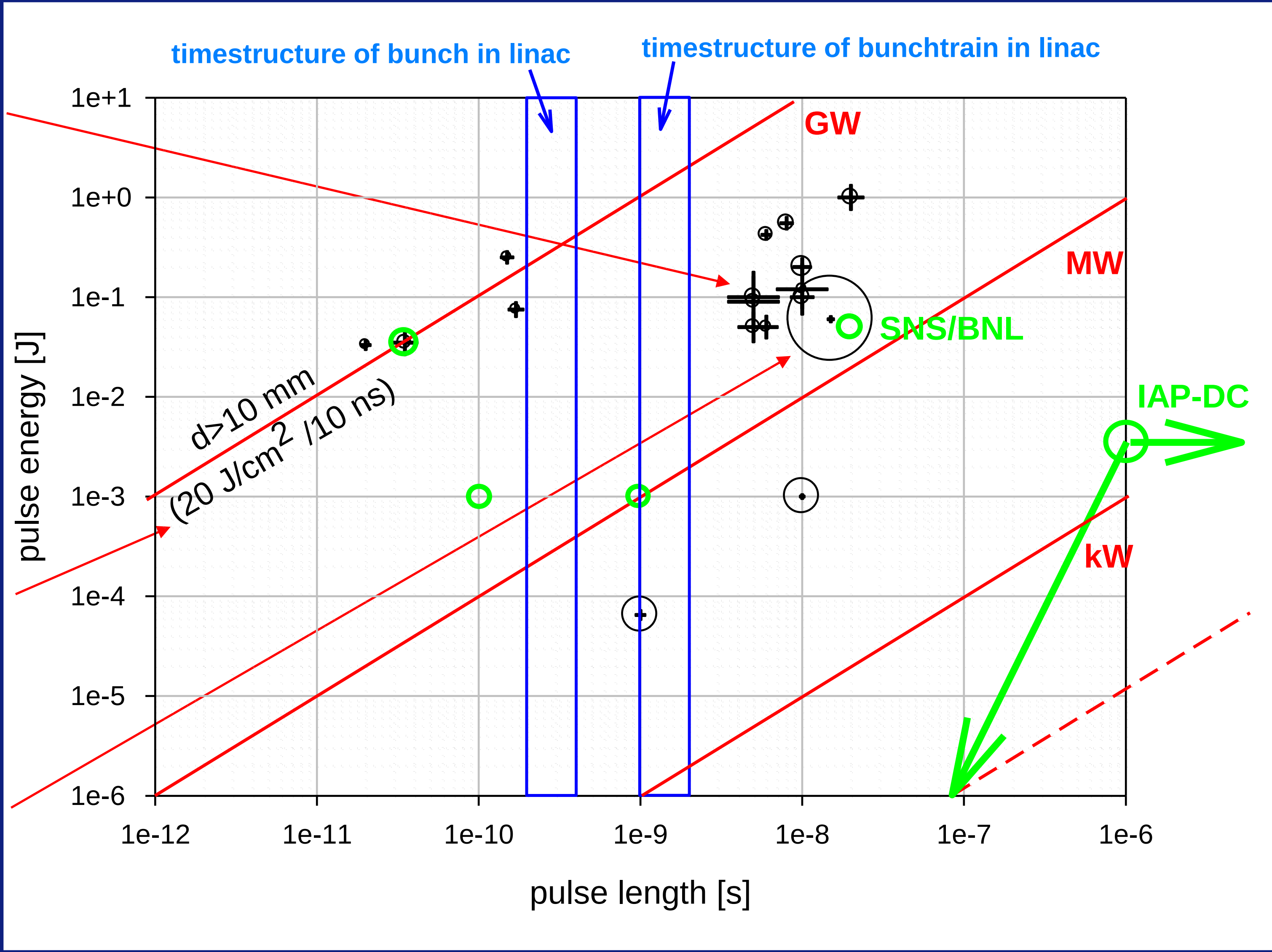


Pulsed Laser systems at 1064 nm (NdYAG)

Cross size according to laser beam emittance (M^2)

destruction threshold for lenses and mirrors

circle area according to repetition rate

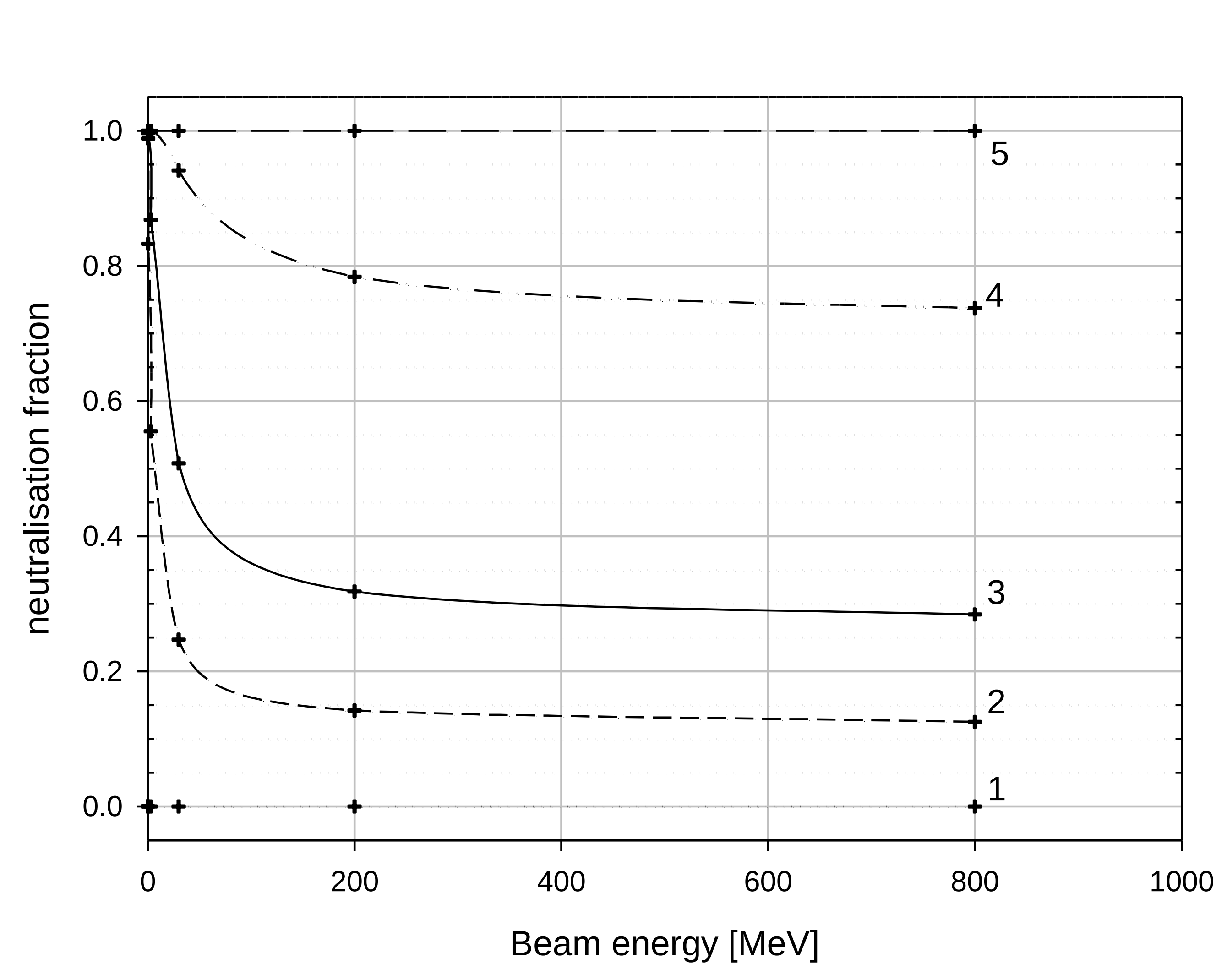


Calculated neutralization fraction as a function of Laser power

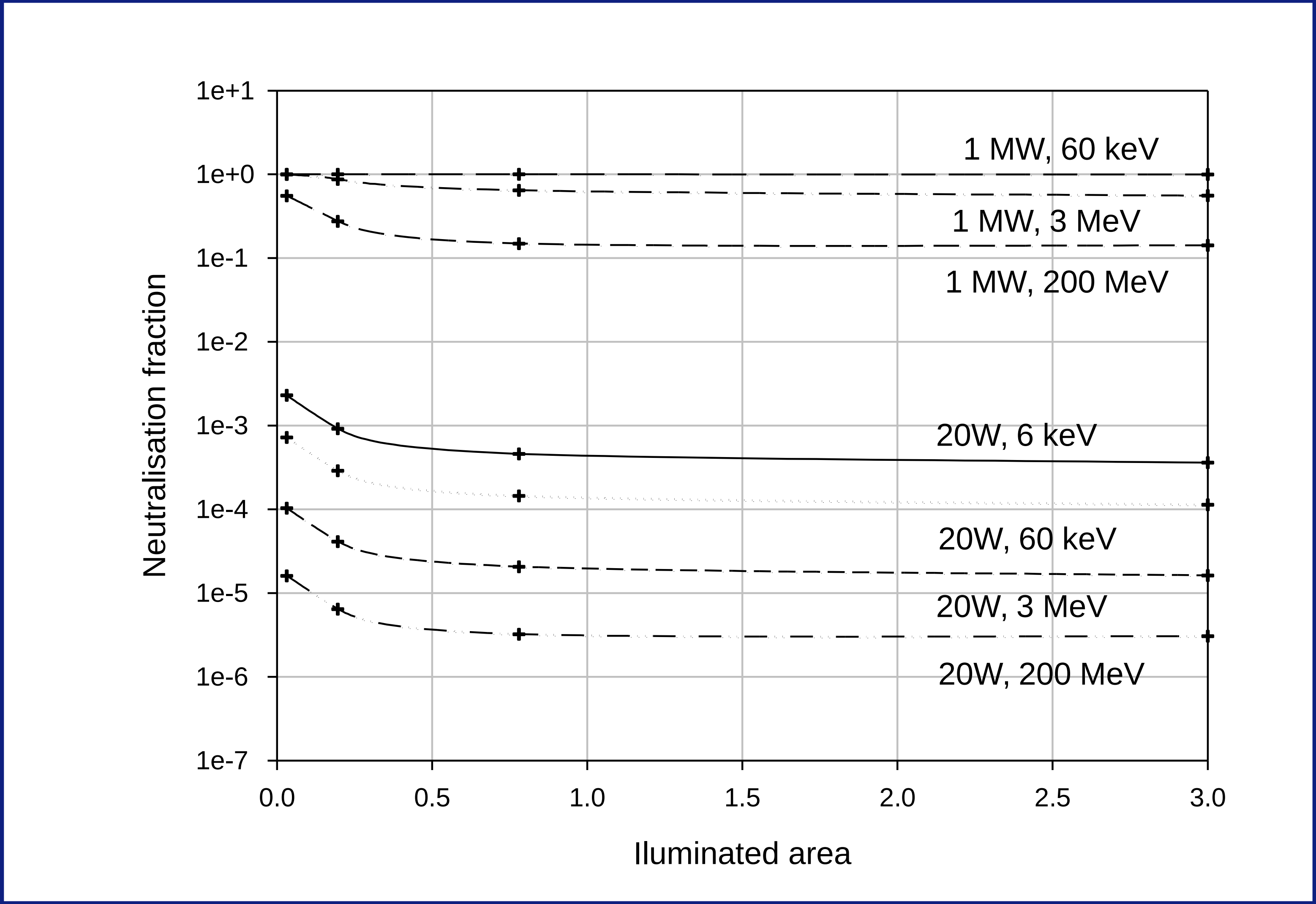
Laser spot size 1 x 3 mm

(US – SNS scenario)

1) IAP – DC Laser 20 W (300 µs / 6 mJ)
2) 1 MW pulsed (1ns / 1 mJ)
3) SNS-BNL 2.5 MW pulsed Laser (20 ns / 50 mJ)
4) 10 MW pulsed (100ps /1 mJ)
5) 1 GW short pulsed Laser (35 ps / 35 mJ)



Influence of different laser beam radii on fraction



Neutralisation yield

6 keV, 0.5 mA, 300 μs , 20 W, r=15mm => 18.6*10^6 per pulse

Independent of laser beam radius !

6 keV, 0.5 mA, 20 ns , 2.5 MW , r=15mm => 0.53 *10^6 per pulse

6 keV, 0.5 mA, 1 ns , 1 MW , r=15mm => 25 *10^3 per pulse

60 keV, 50 mA, 20 ns , 2.5 MW , r=15mm => 53 *10^6 per pulse

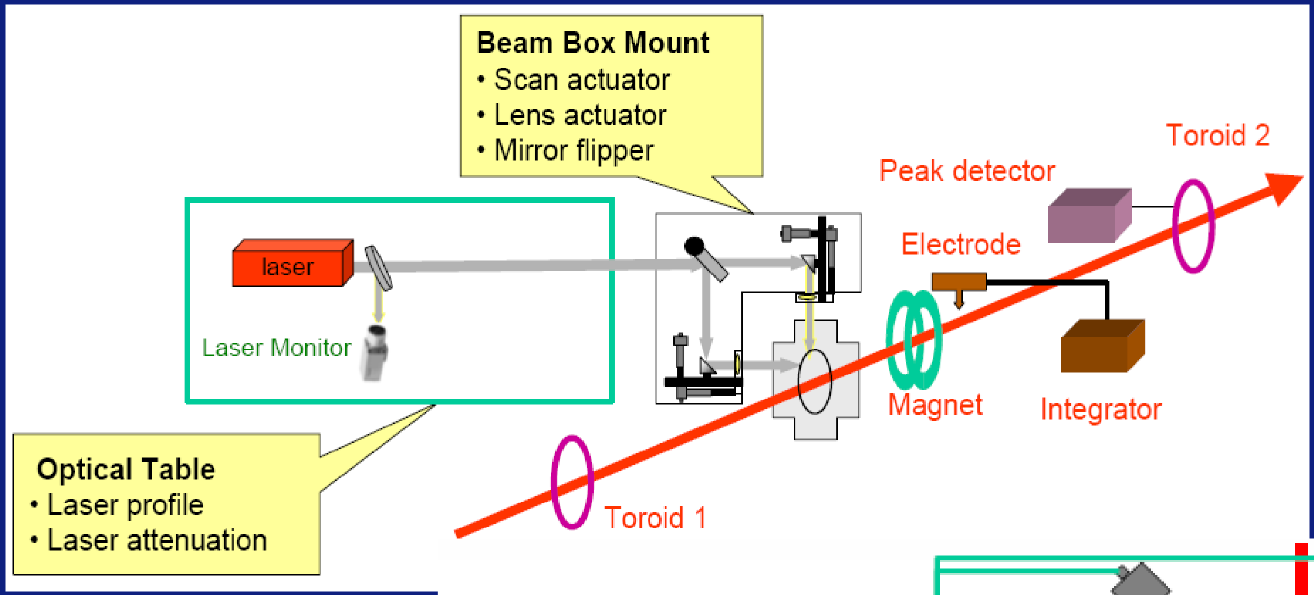
60 keV, 50 mA, 1 ns , 1 MW , r=15mm => 2.6 *10^6 per pulse

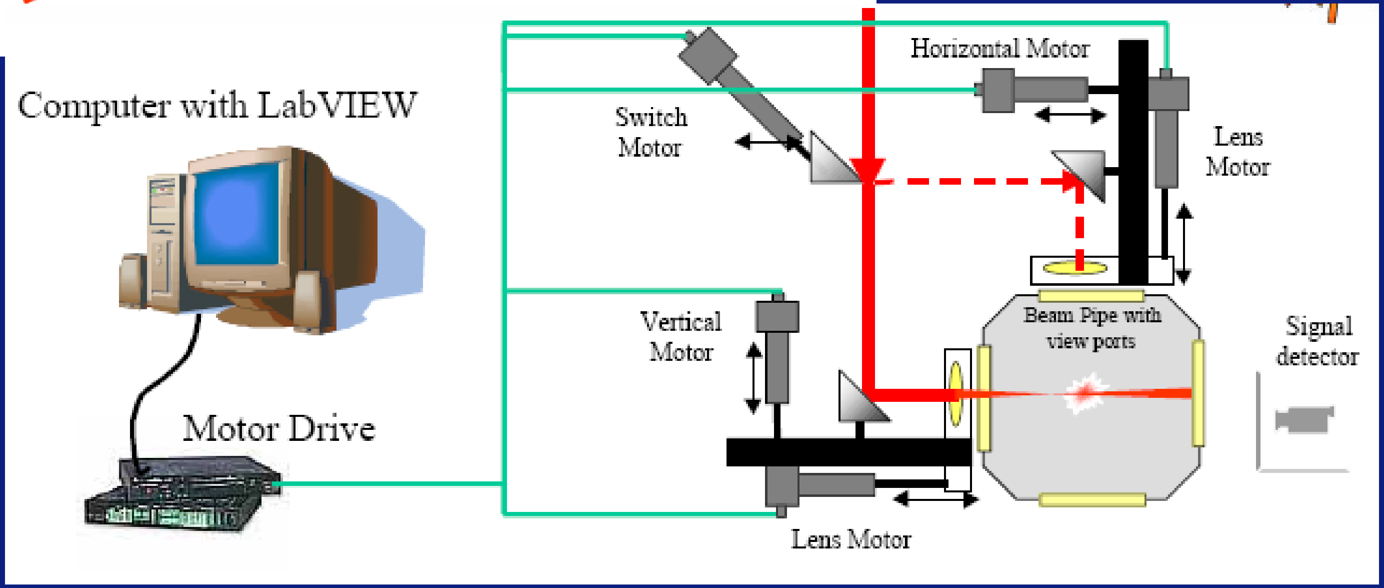
3 MeV, 50 mA, 20 ns , 2.5 MW , r=5mm => 59 *10^6 per shot

3 MeV, 50 mA, 1 ns , 1 MW , r=5mm => 17.3 *10^6 per shot (=100ps/10 MW)

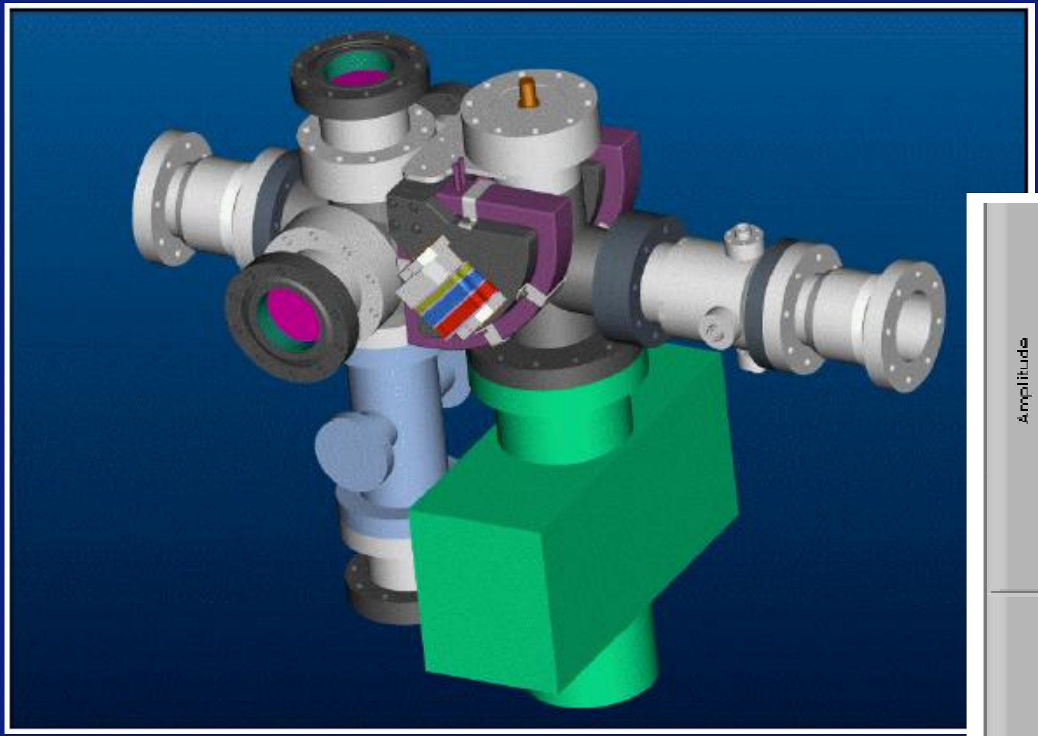
At higher beam energy yield drops app. to half/ one third of these values

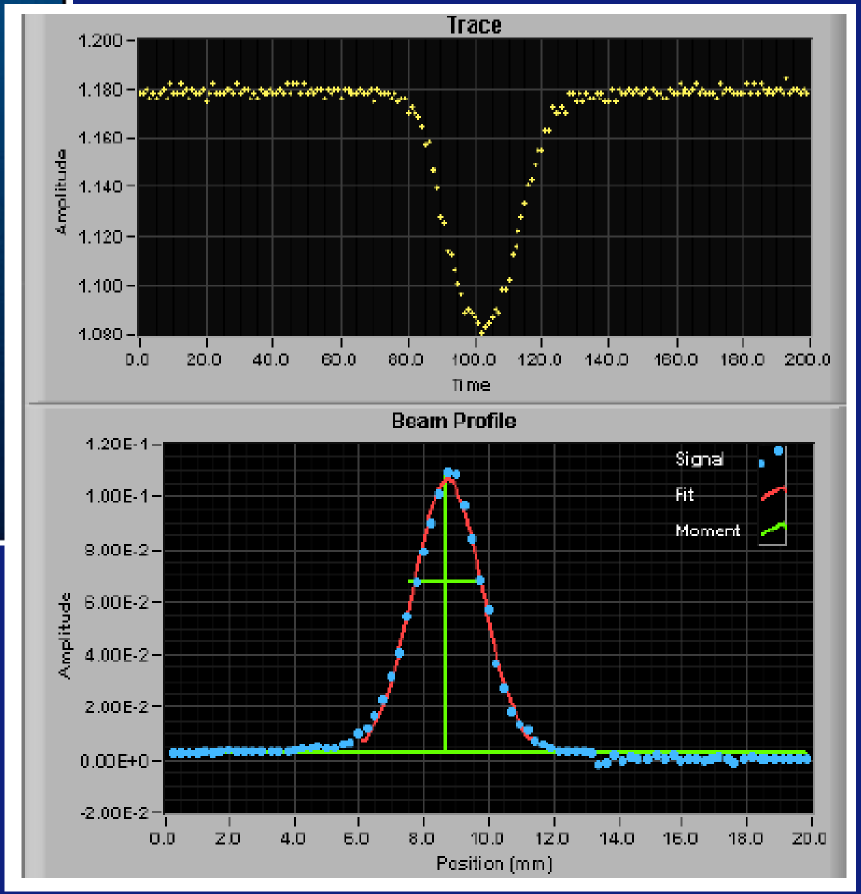
SNS beam profile monitor system 1



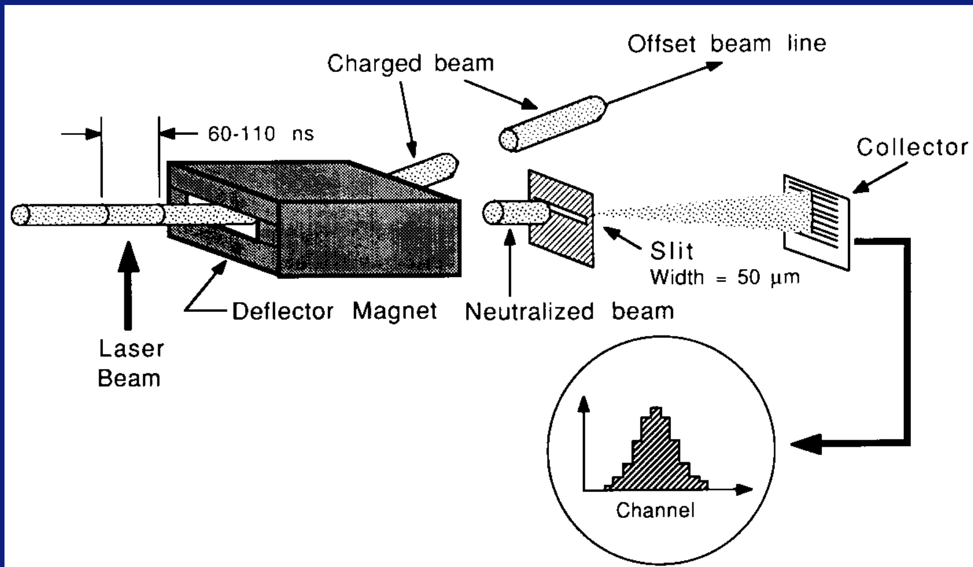


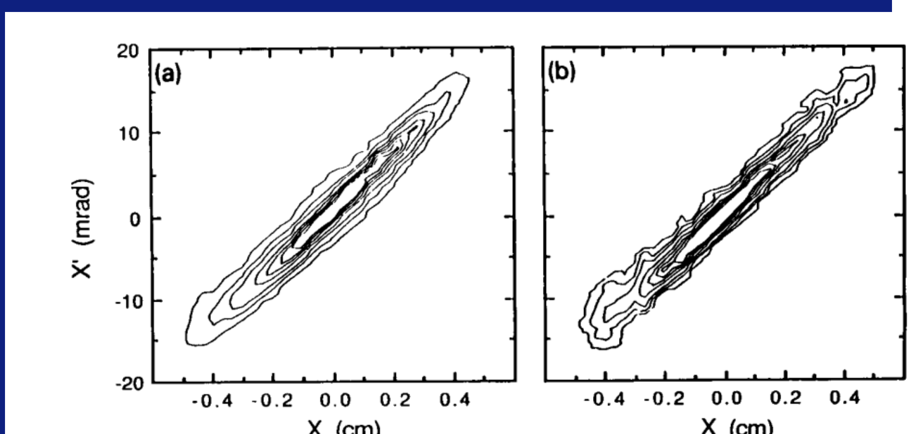
SNS beam profile monitor system 2





Los Alamos LINDA transversal emittance measurement device





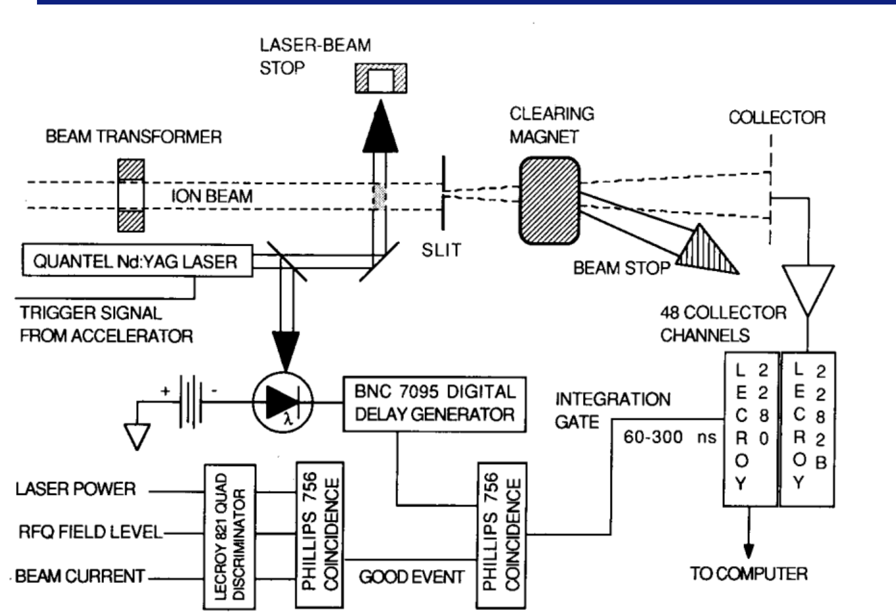
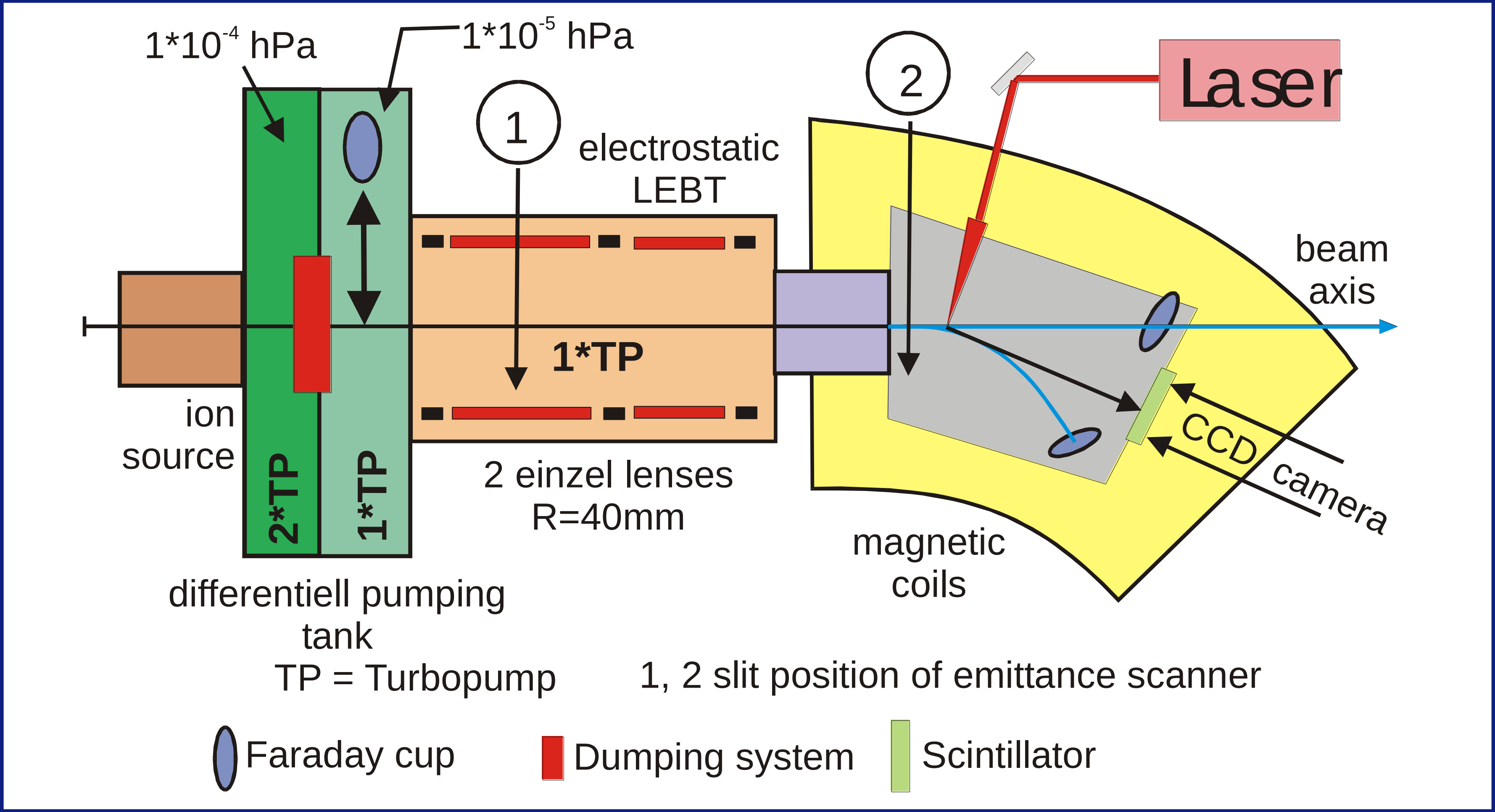


Fig. 3. Block diagram of slit-LINDA test on ATS.

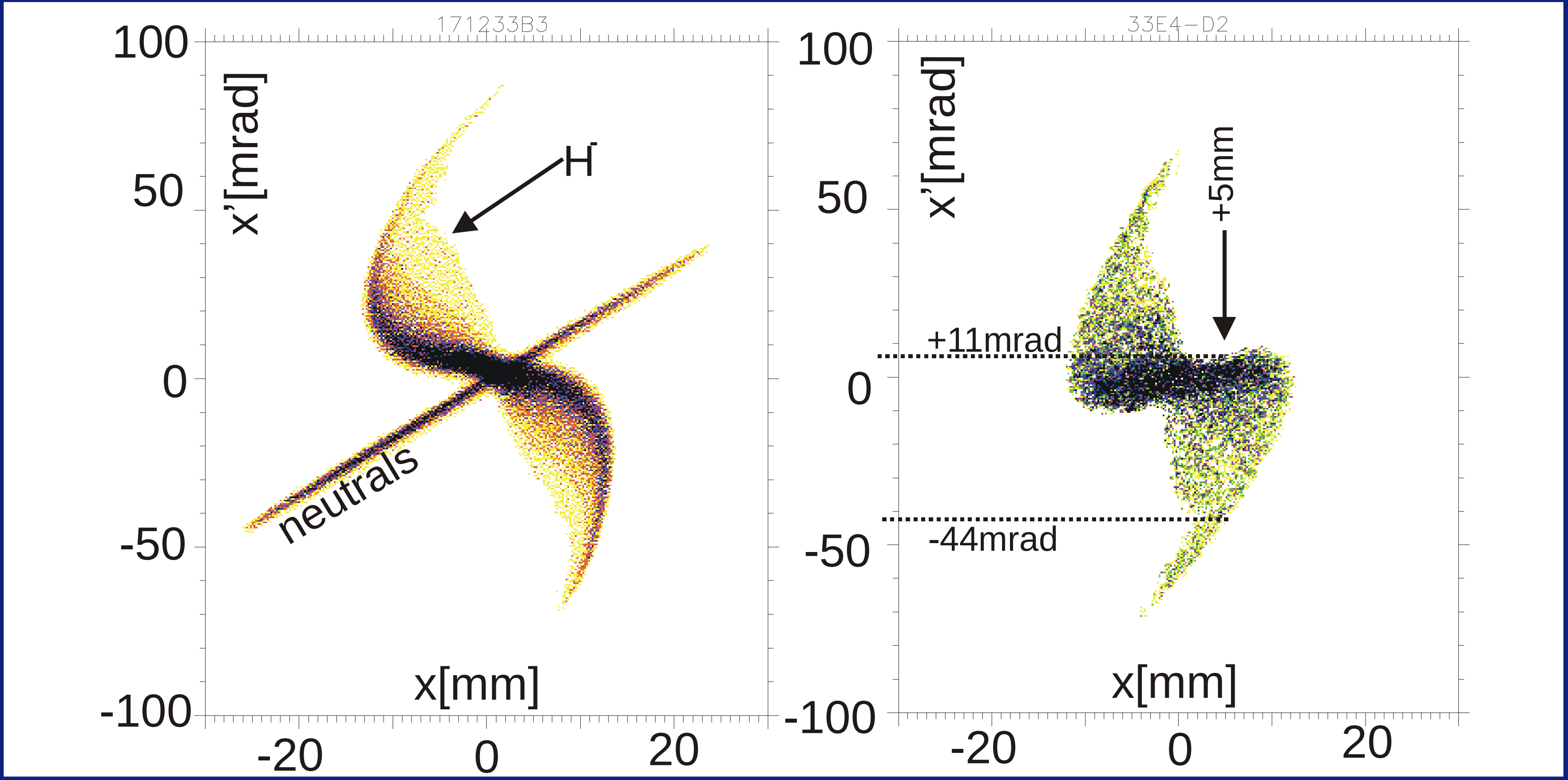
IAP transversal emittance measurement device - experimental set up



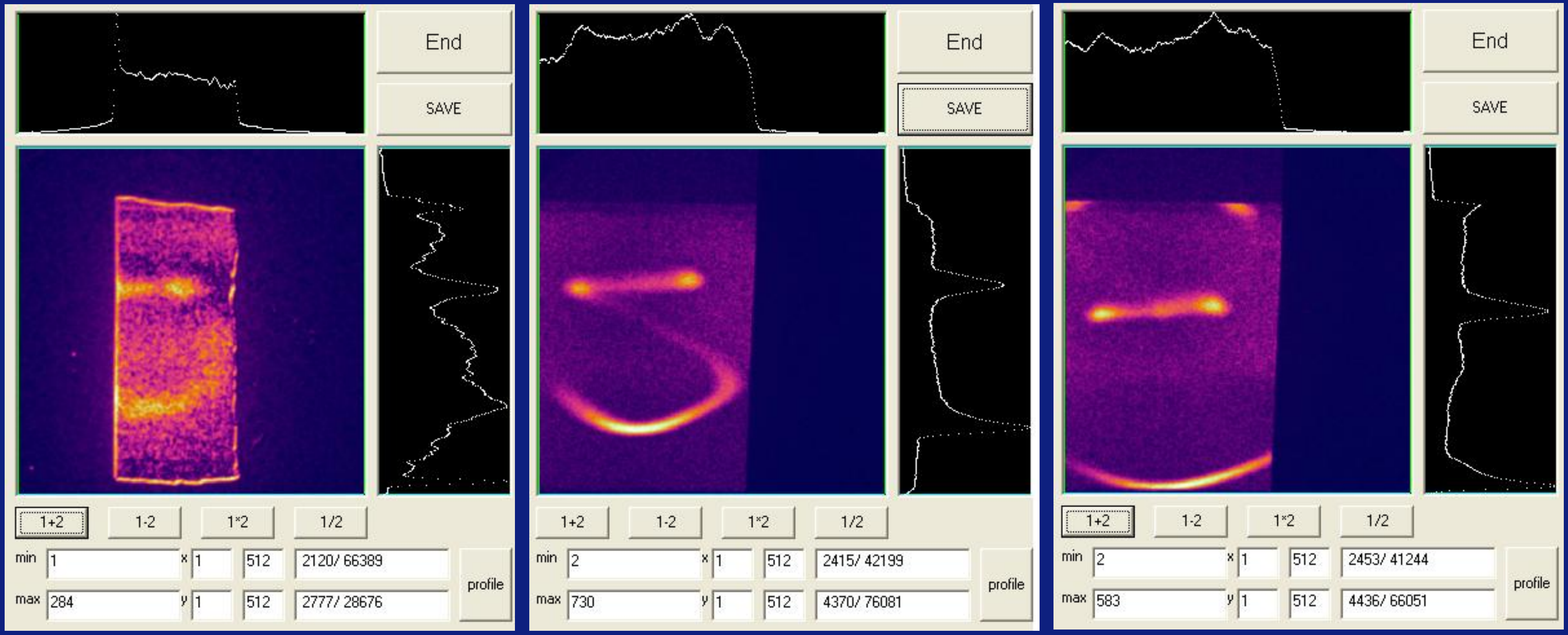
IAP transversal emittance measurement device - conventional emittance measurement

Measurement behind the LEBT app. 110 mm in front of interaction point using an Allison scanner

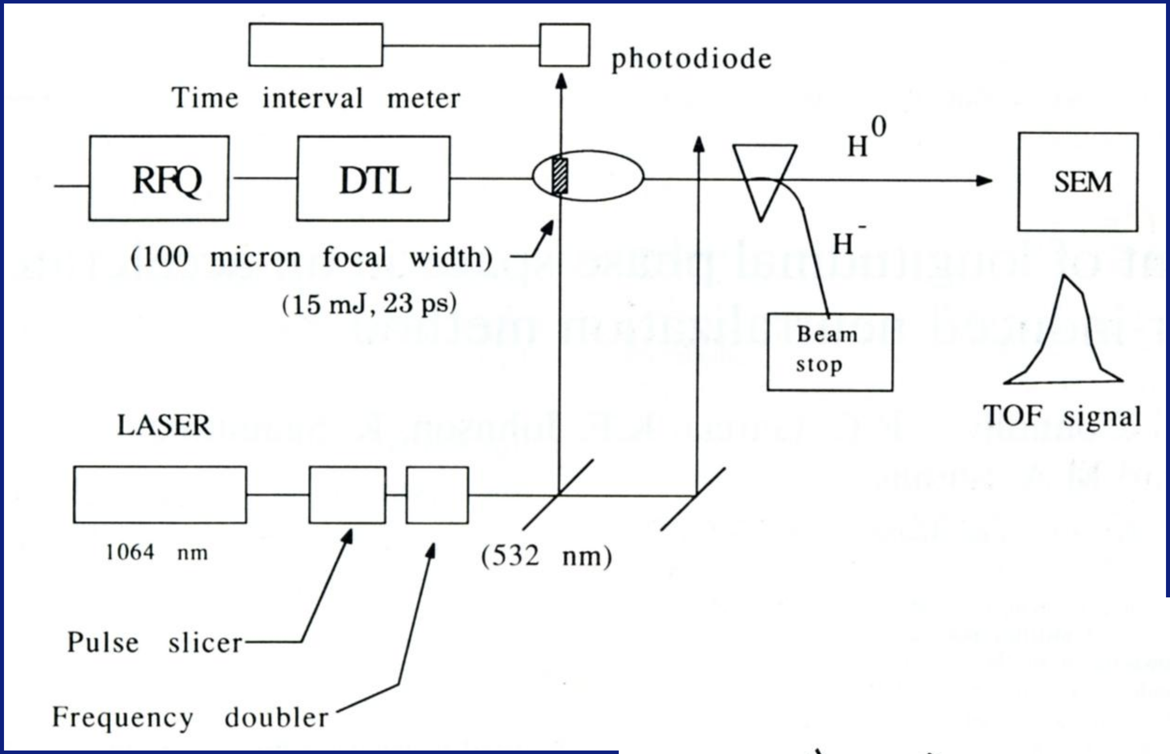
Calculated emittance at interaction point.

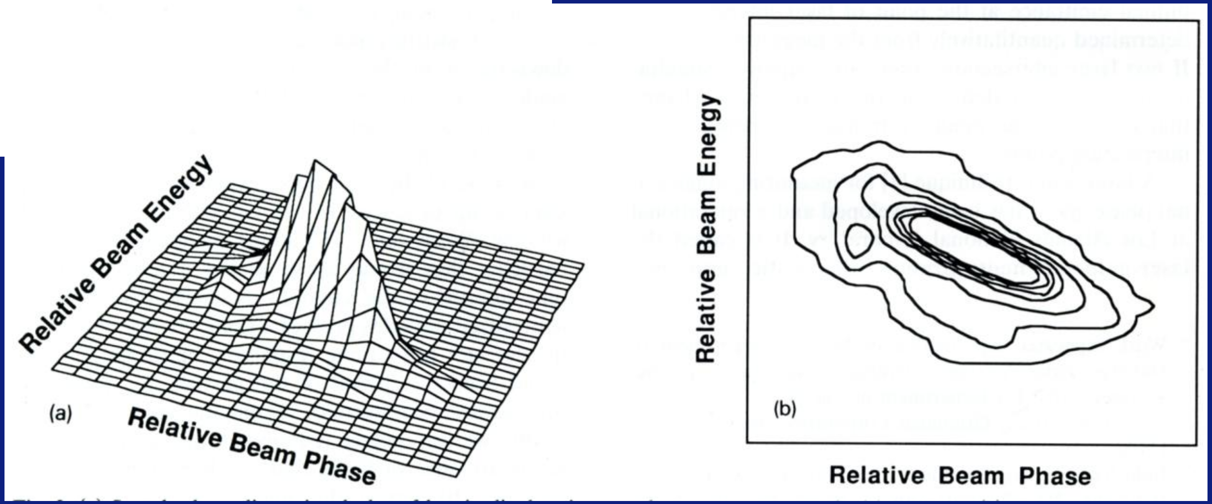


IAP transversal emittance measurement device

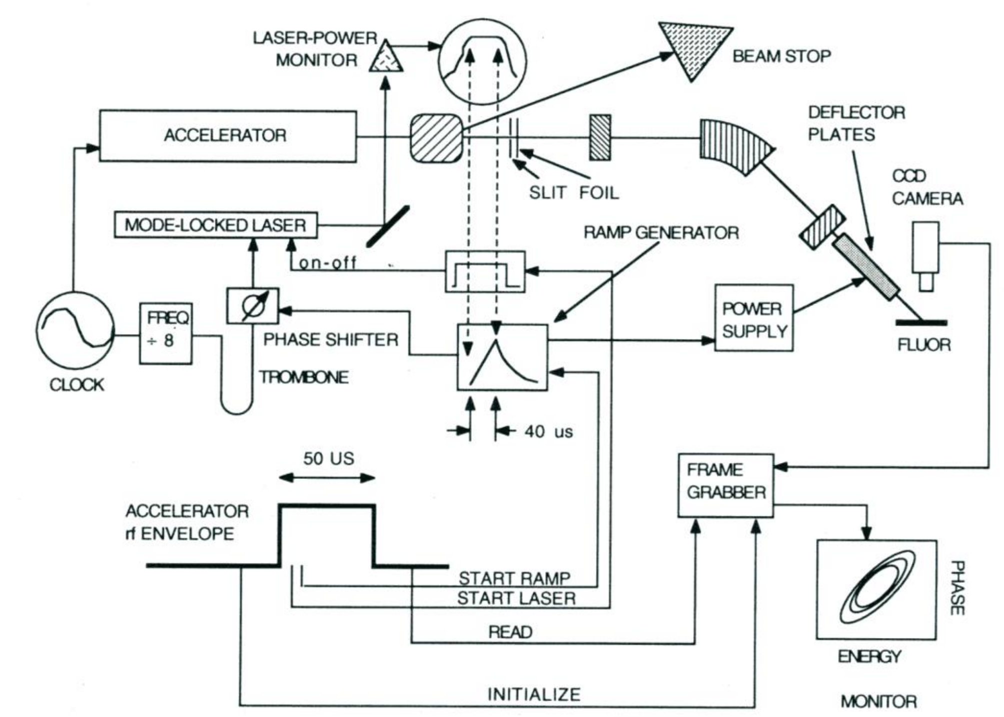


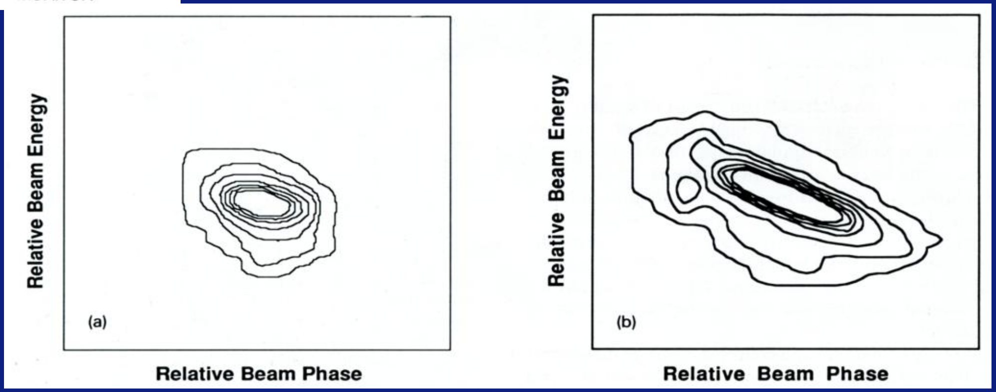
Los Alamos LINDA longitudinal emittance measurement device



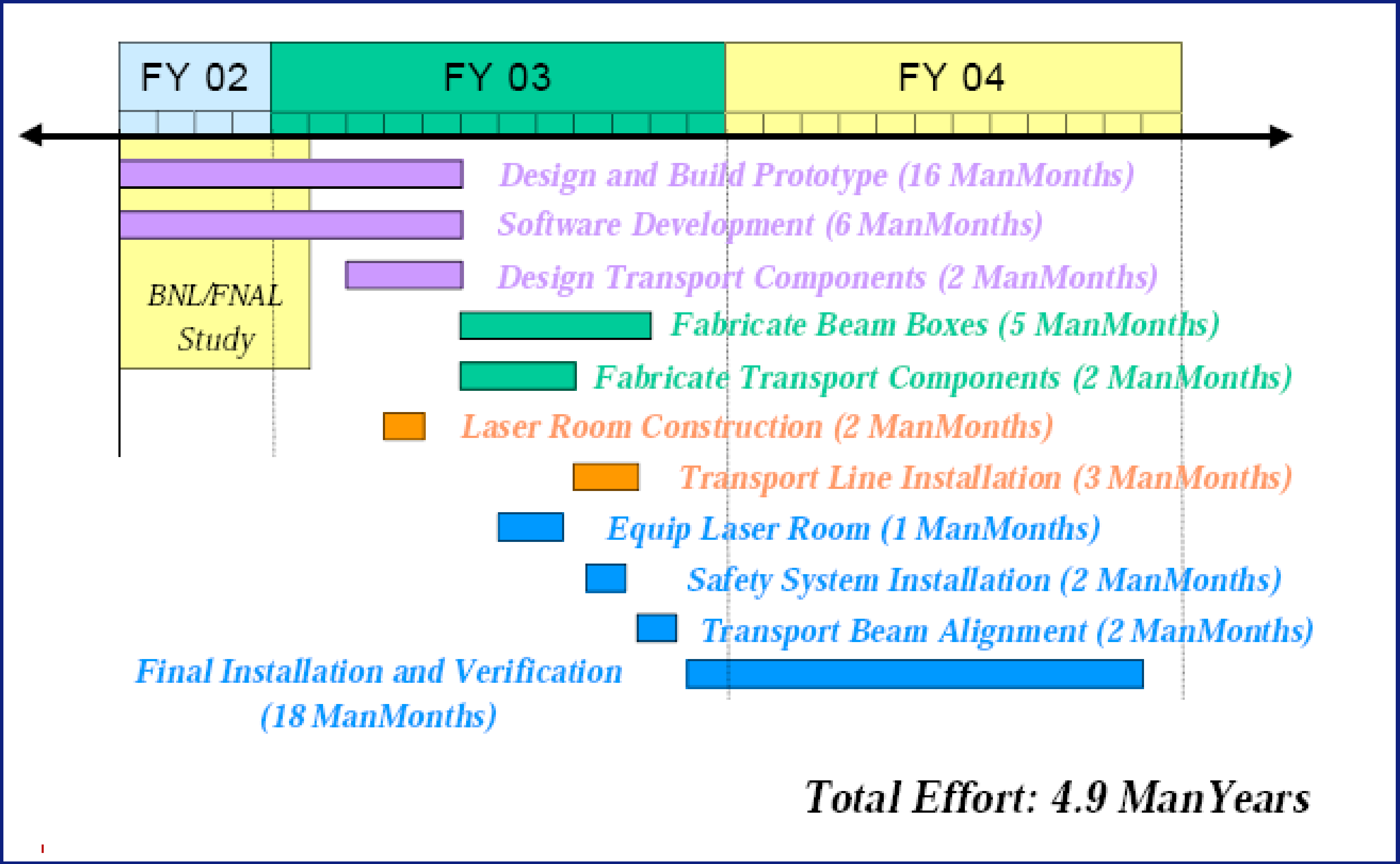


Los Alamos LINDA longitudinal emittance measurement device





SNS schedule – required man power



Conclusions

The choice of the laser system has to be adopted to the pulse structure of the ion beam to achieve a optimum yield.

For the given high beam current a sufficient number of particles per pulse will be detected for any laser system above 1 MW

The particle yield is mostly independent of the laser beam radius
(excluding saturation, influence on resolution of the measurement)

To avoid problems with the optical system for time resolved measurements the laser power should be below 100 MW
(additionally there is only a minor gain from higher power due to saturation effects)

A laser system delivering a 1ns, 5 mJ pulse at 50 Hz seems to be near the optimum for measurements from the IS up to beam injection into the rings (without time resolution apart from the LEBT)

=> The next step will be a cost analyses of the optical system (Laser + mirror + lenses + translation)