Researches on Laser Wake Acceleration at LFRC： Progress and Problems

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Outline

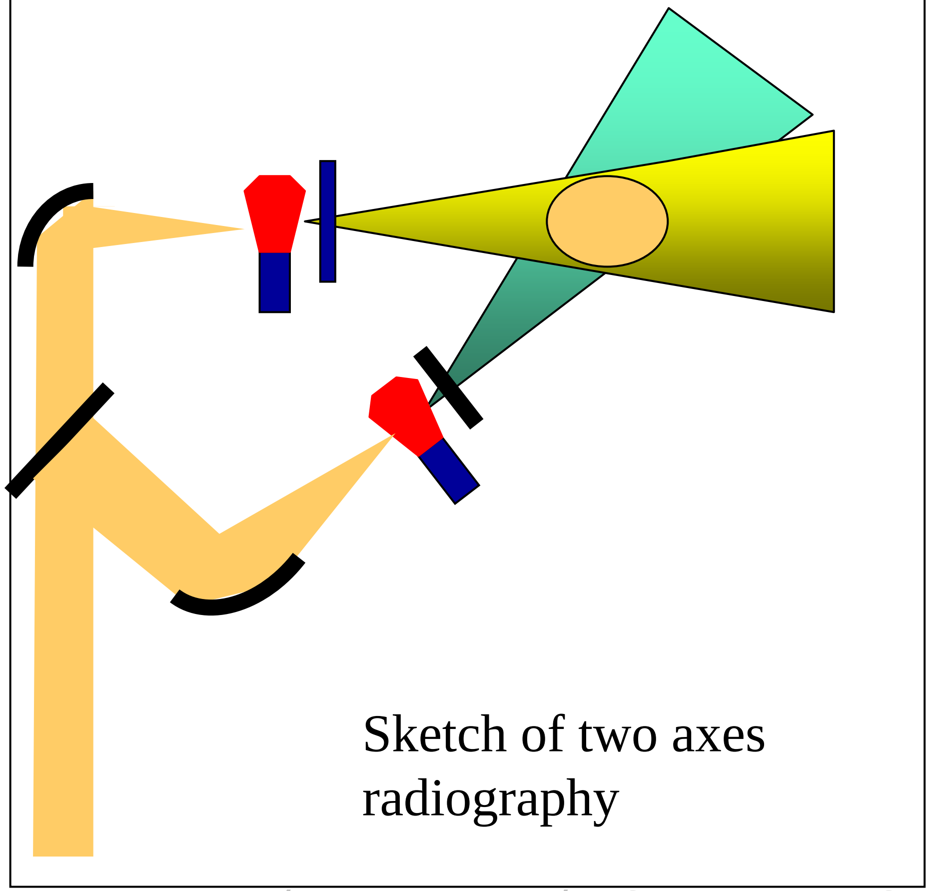
- Introduction
- Electron Acceleration Experiments
  - 10mm long gas jet experiments
  - 5mm long gas jet experiments
  - 2.7mm long gas jet experiments
- Summary

Introduction

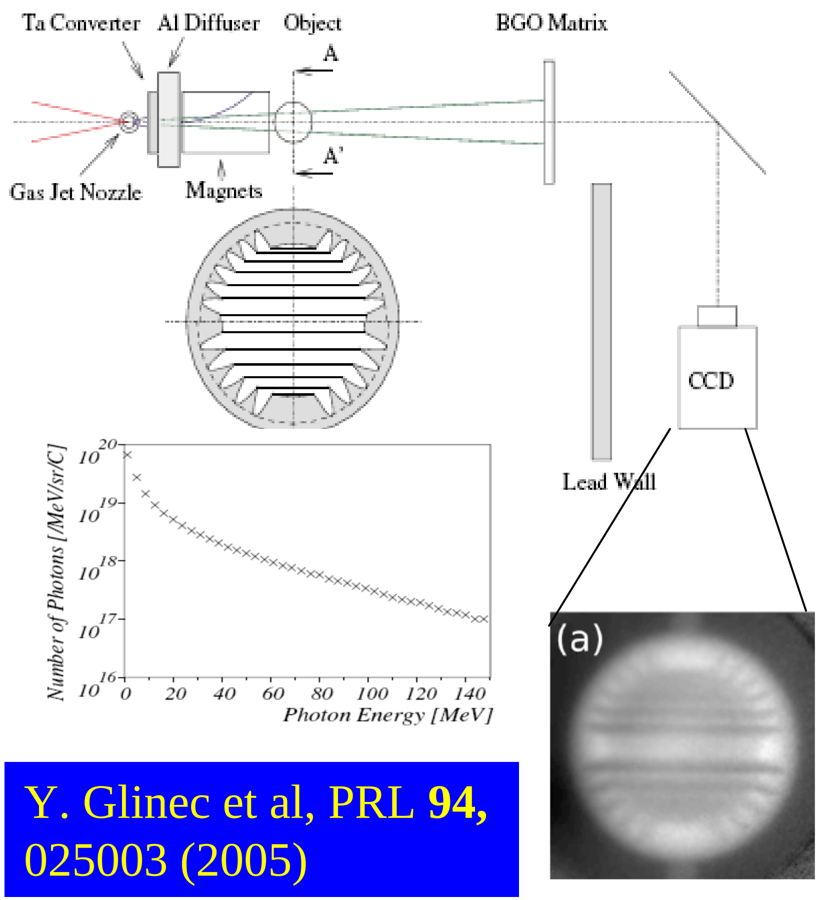
- **Laser wake accelerators are very promising energetic electron sources for several potential applications:**
  - **Gamma ray sources for radiography and photo-nuclear reaction**
  - **FEL**
  - **Injector for synchrotron**
  - **……**
- **There are different demands for these potential applications:**
  - **Large e-number and tens MeV for γ-ray source**
  - **High beam quality and larger than GeV for FEL**
  - **Tens GeV or TeV for high energy physics**

Introduction

Gamma ray radiography based on laser wake accelerators are more compact and easy to multi-axes and multi-frames comparing with traditional accelerators.



Sketch of two axes radiography



Y. Glinec et al, PRL **94,** 025003 (2005)

Introduction

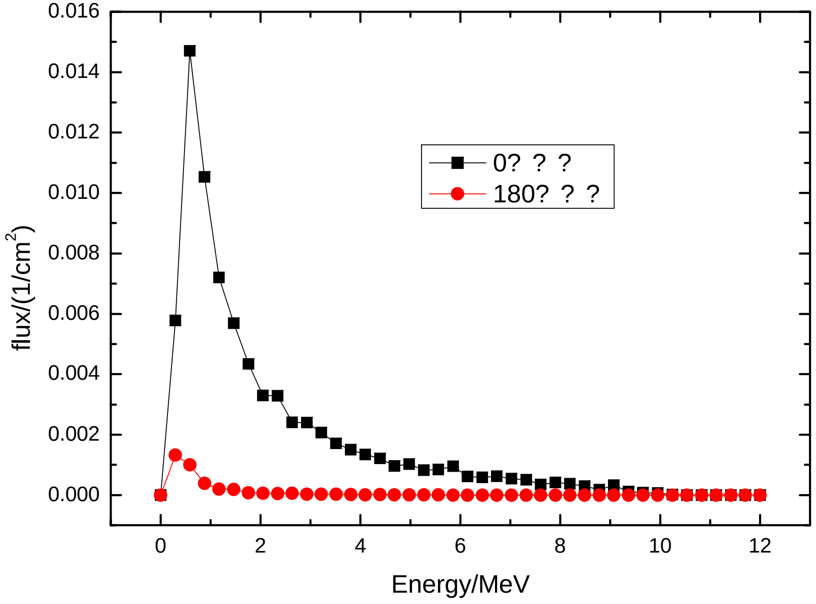
■ **What kinds of electron beams we need for Gamma radiography?**

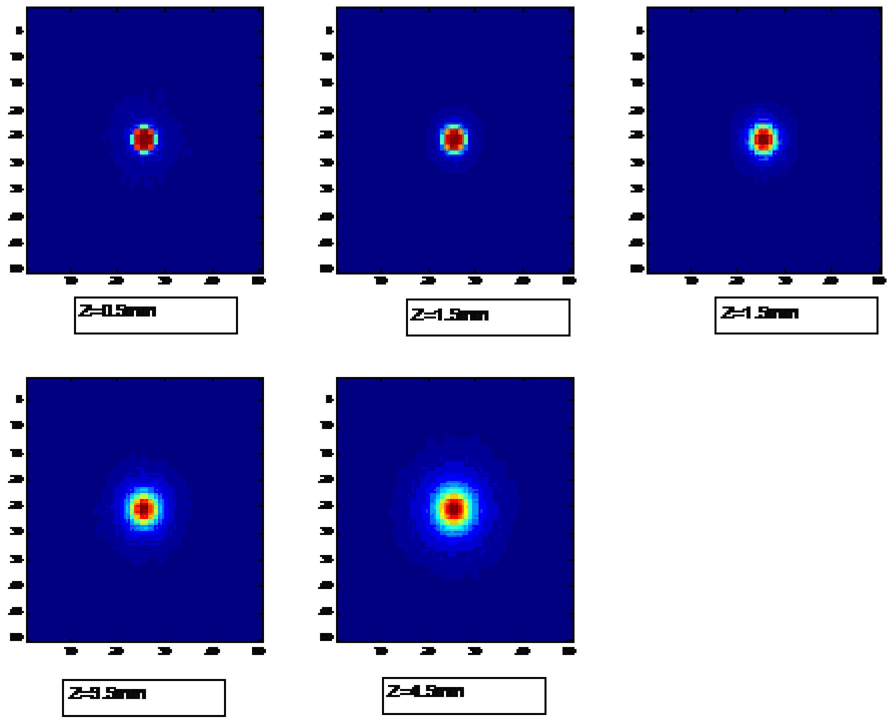
✓Considering the S/N of 1%, we need 10^4 photons (according to statistic law N^{-2})on one pixel and one picture constituted of 1000×1000pixels, total 10^{10} photons are needed. If the detecting efficiency and accepting angle are included, at least, 10^{11-12} is reasonable.

✓If we want to probe matter of 100-200g/cm² in HEDP experiments, several MeV γ-ray photons are needed.

Thus, Tens MeV electron beam with 10^{10-11} electrons(1nC~10nC) is capable of this application!

Gamma ray from electron beam interation with high-Z targets (MC simulations)





γ Spectrum as 10MeV e-beam interacting with 2-mm Ta target

Tomography of e-beam in Ta target

Introduction

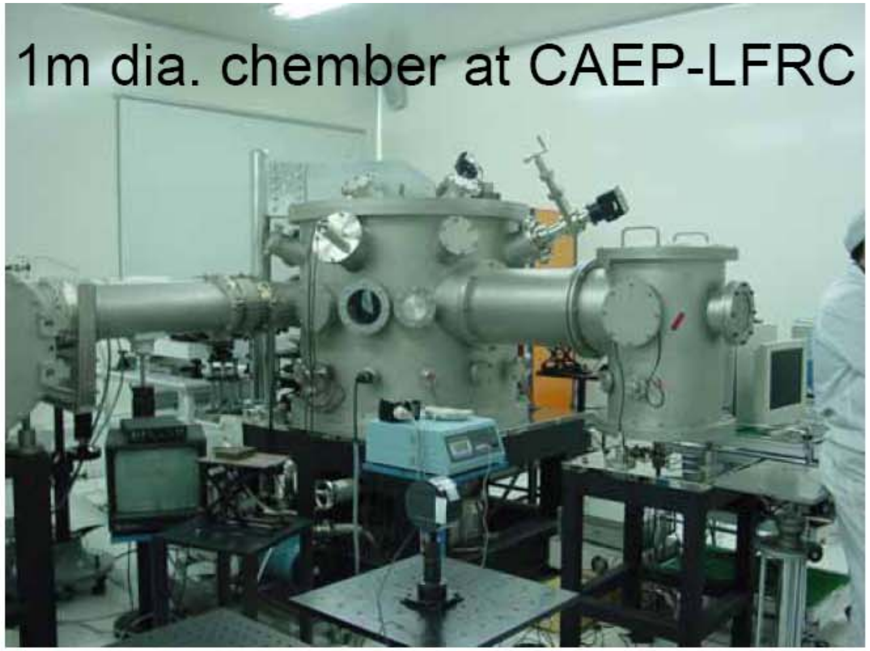
- **How to get tens MeV electrons with larger than 1nC charge number?**
  - **Larger gas density and short gas jet column**
  - **Increasing laser energy**
  - **Increasing contrast ratio**

$$\Delta E\left[GeV\right]\approx 1.7\left(\frac{P(TW)}{100}\right)^{1/3}\left(\frac{10^{18}}{n_p(cm^{-3})}\right)^{2/3}\left(\frac{0.8}{\lambda_0(\mu m)}\right)^{4/3}$$

$$N_b\approx\frac{3}{2k_0 r_e}\sqrt{\frac{P}{P_c}}$$

$$P_c=17.4(n_c/n_e)$$

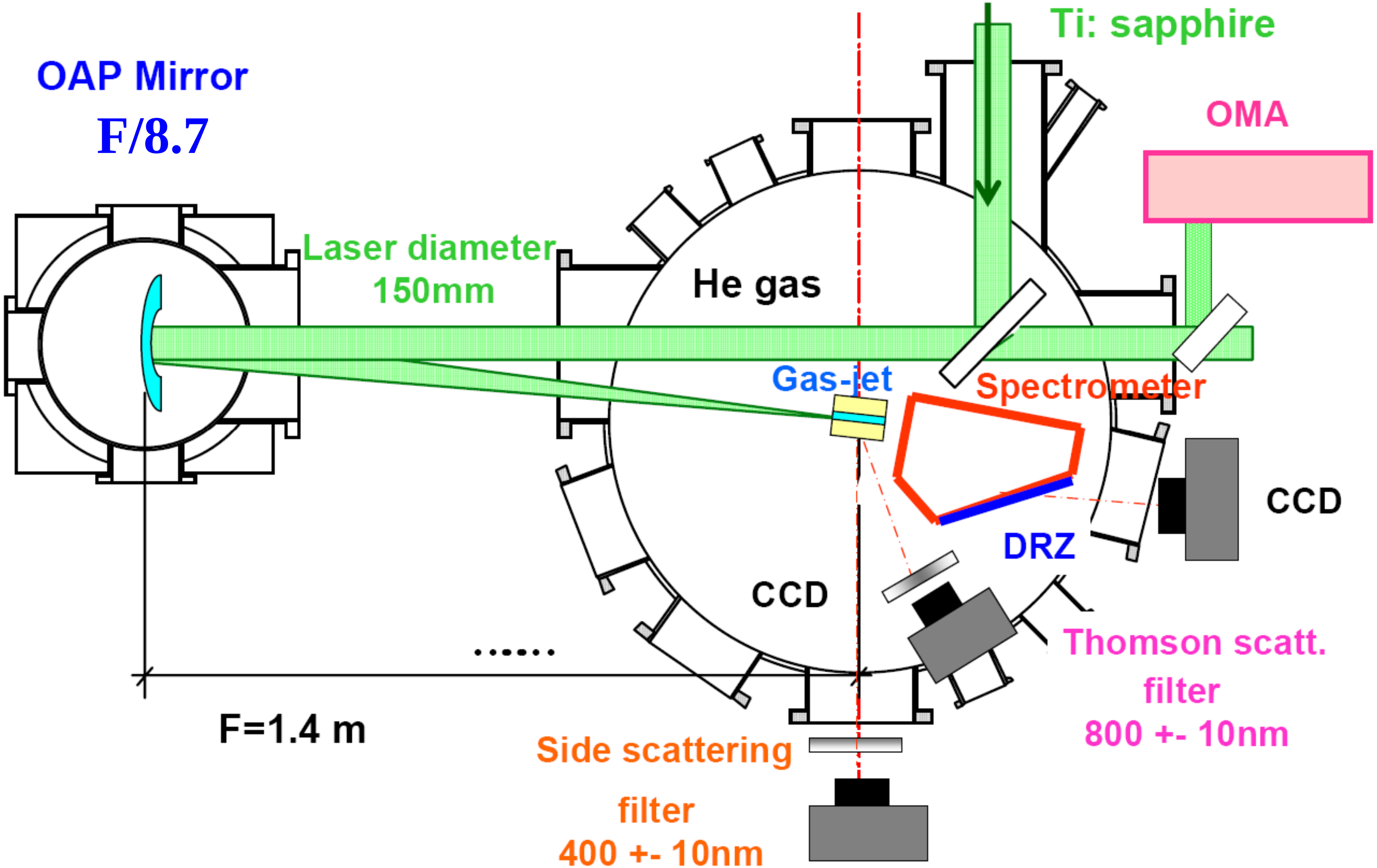
SILEX-I (Super Intense Laser for Experiments on the Extremes)



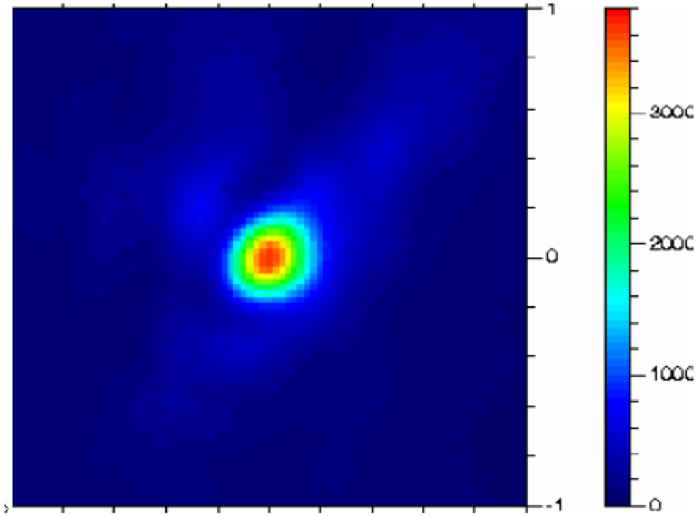
Maximum energy	9J
Pulse duration	30fs
Maximum power	300TW
Contrast ratio	>10^5

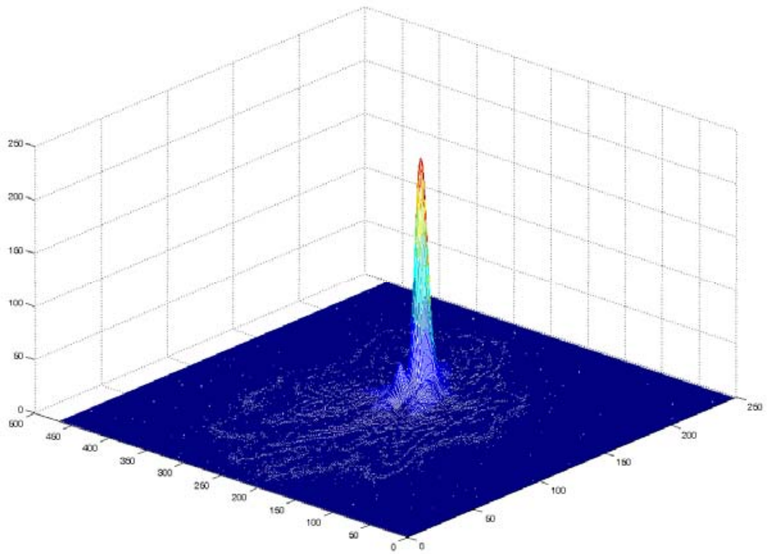
Beam diameter	Φ160mm
Focusing OAP	F/8.7
Focus spot	15μm (FWHM)

Experiment Setup in SILEX-I



The profile of laser focusing spot



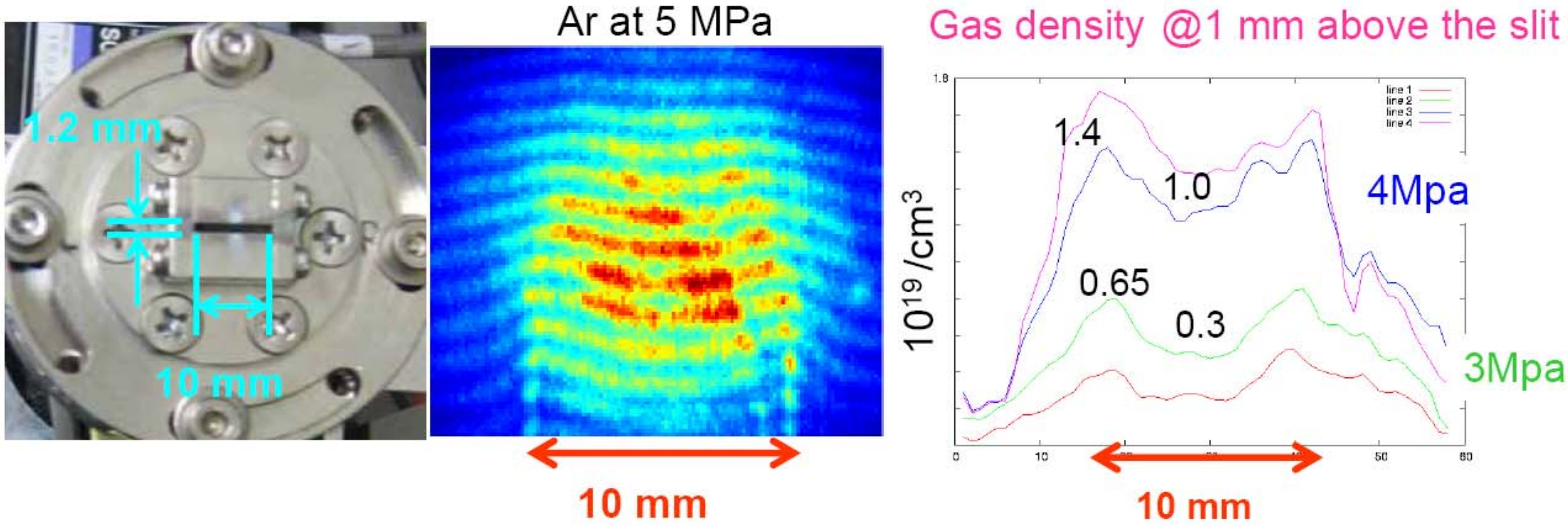


Φ=15μm (FWHM) with F/8.7 OAP

Φ=30μm ($1/e^2$) containing 30% energies

$I=8.5\times10^{18}W/cm^2$ for 200TW， $a_0\sim2$

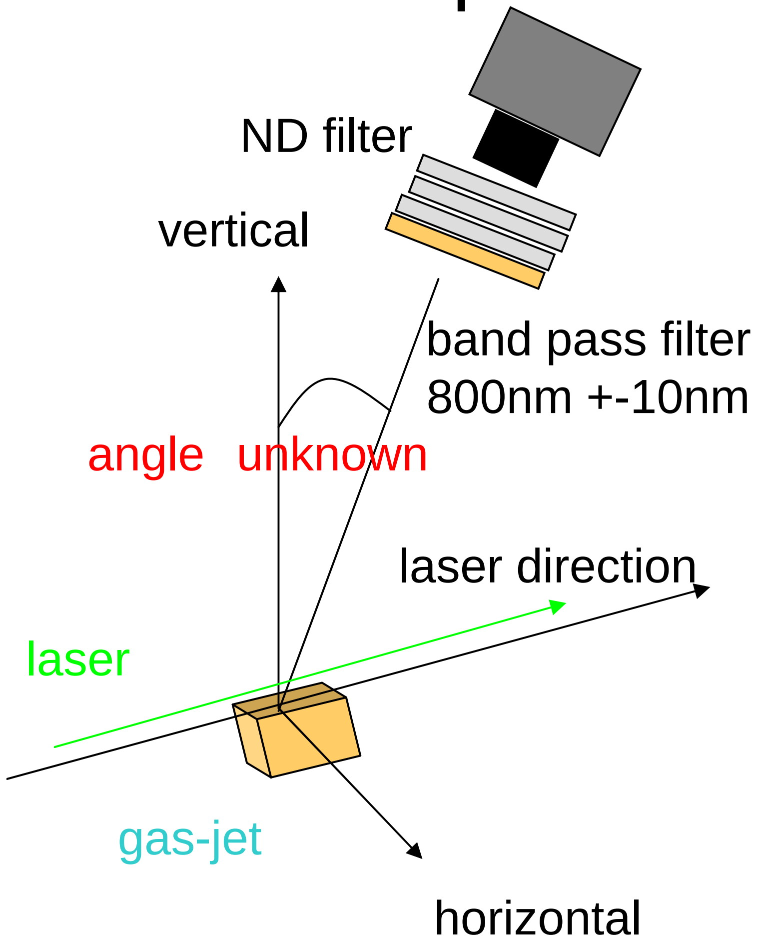
Rectangular nozzle situation



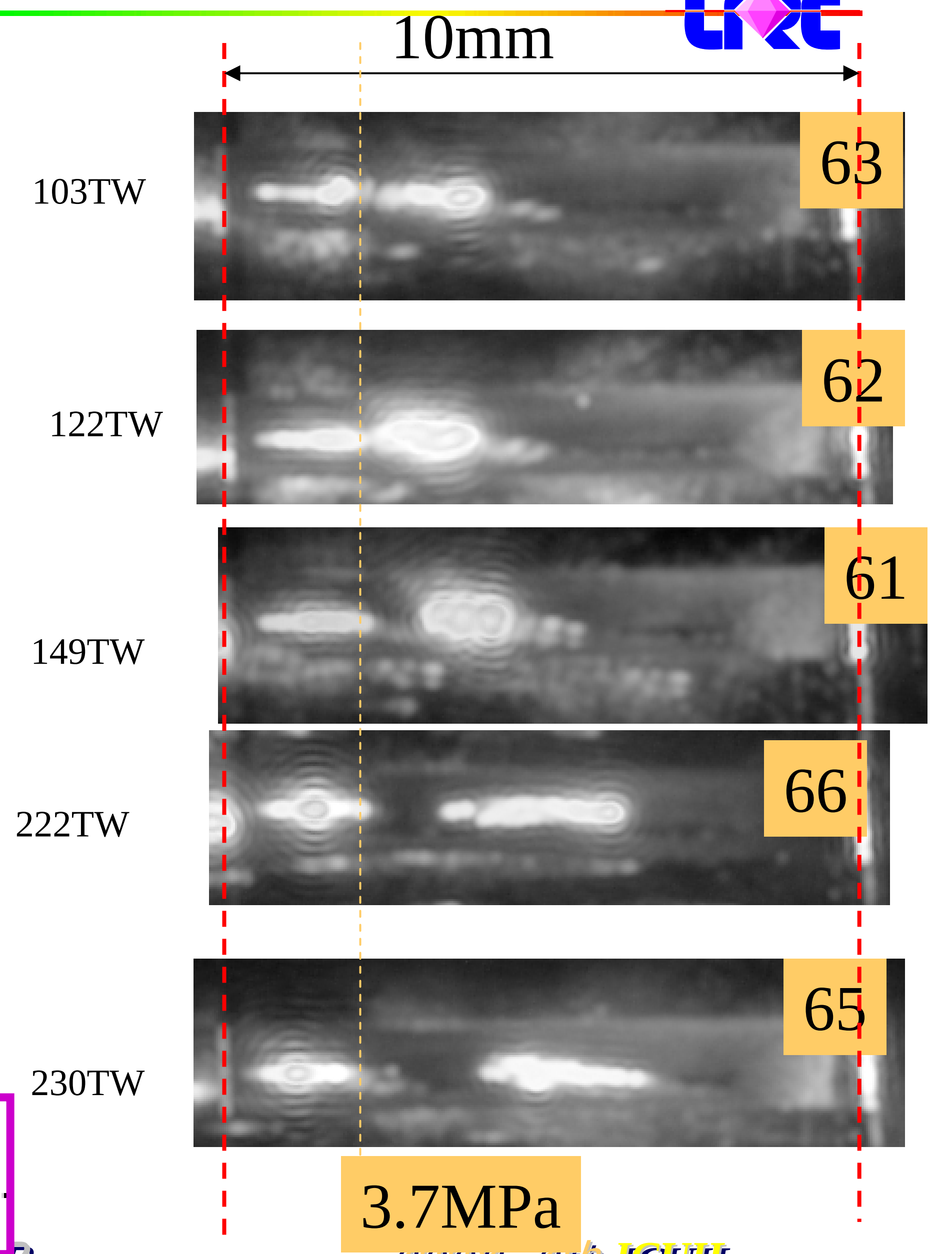
Rectangular Shape Gas Nozzle

Thomson scattering image

set-up



$$\frac{d\mathscr{E}_T}{dV} = n_e e_T = 11.8\,\tau_0 I_{18}(z,r)\,n_{19}(z,r).$$



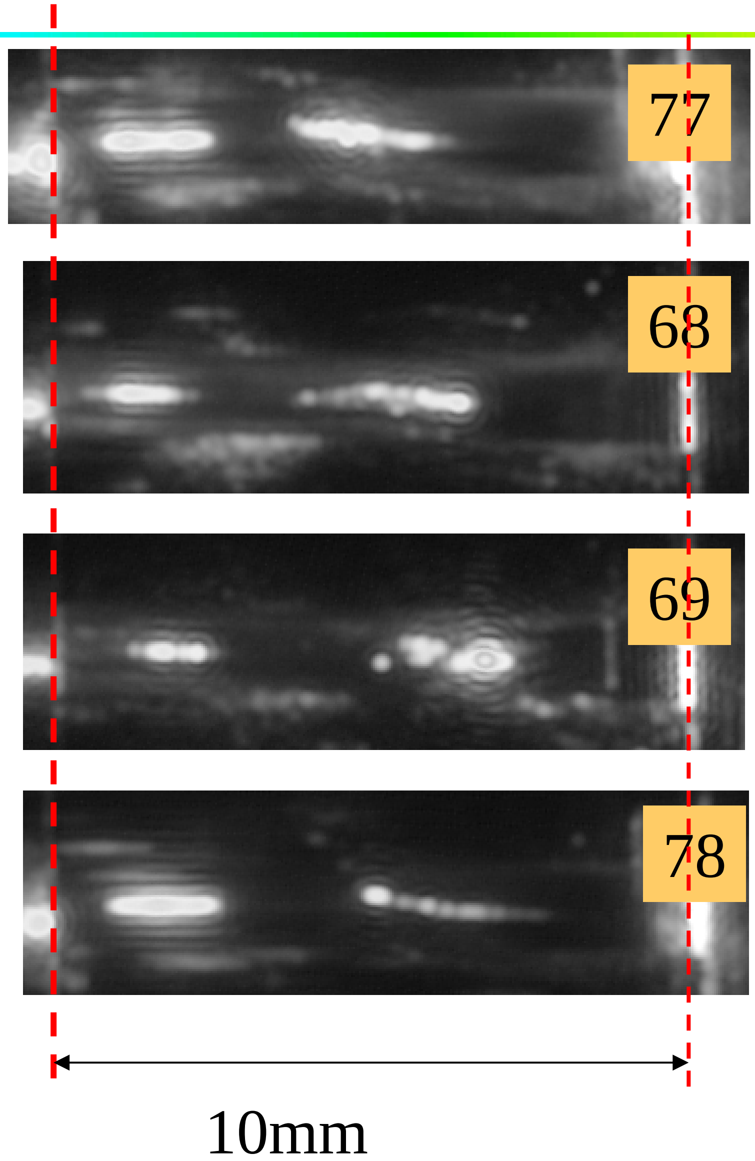
228TW
2.34MPa

246TW
2.28MPa

228TW
1.89MPa

236TW

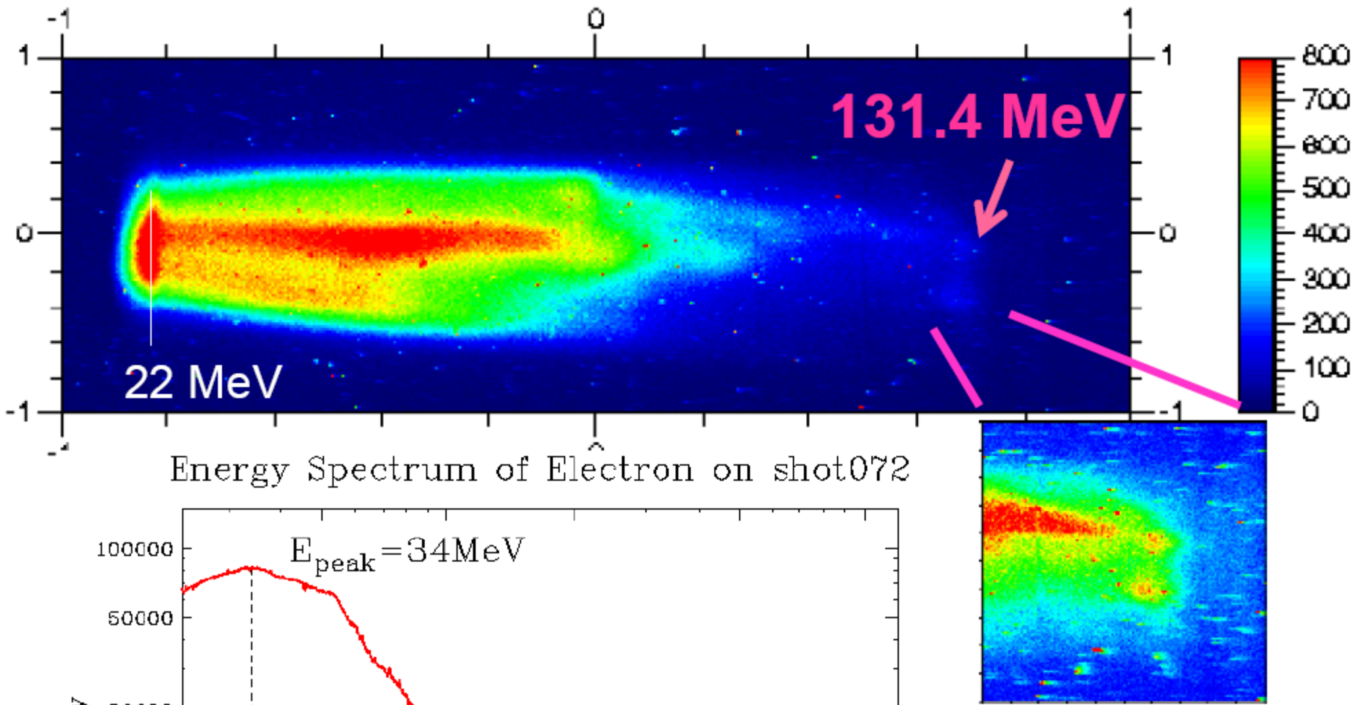
1.71MPa

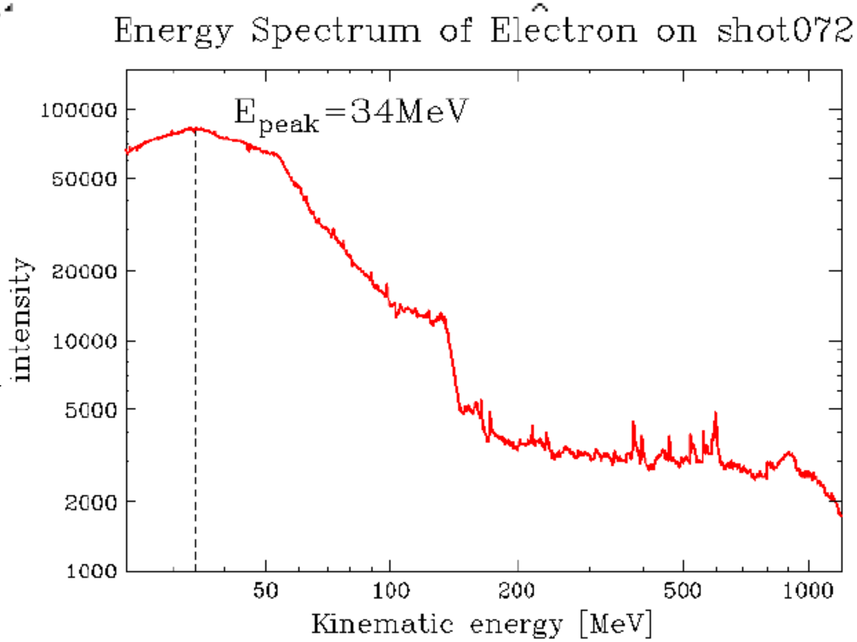


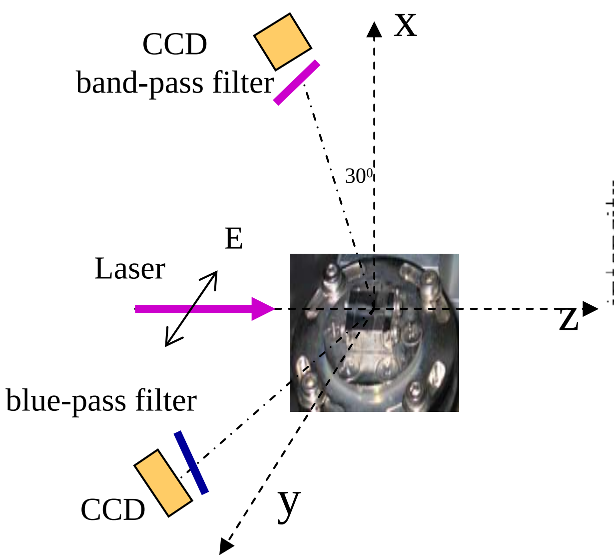
Electron spectrum from 10mm-long gas column

Laser Power
202 TW

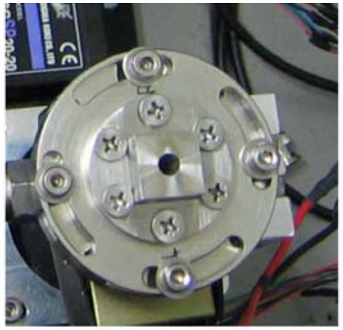
Gas Pressure
2.5 Mpa

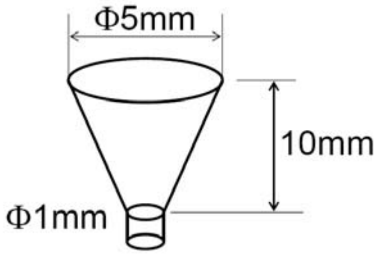




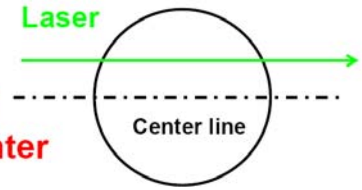


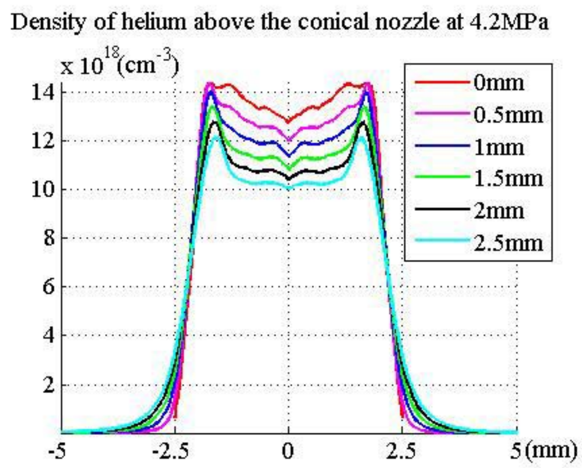
Conical nozzle used in the experiment

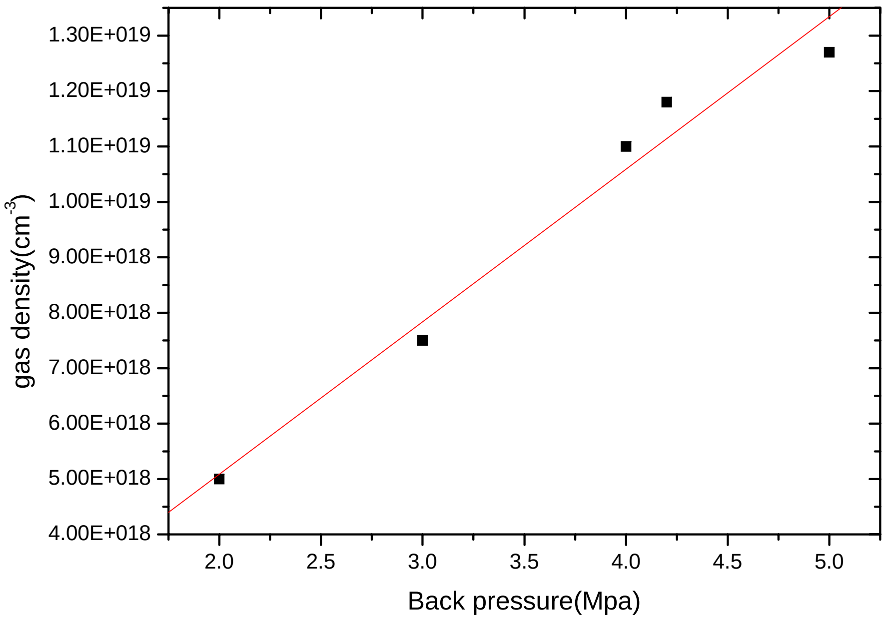


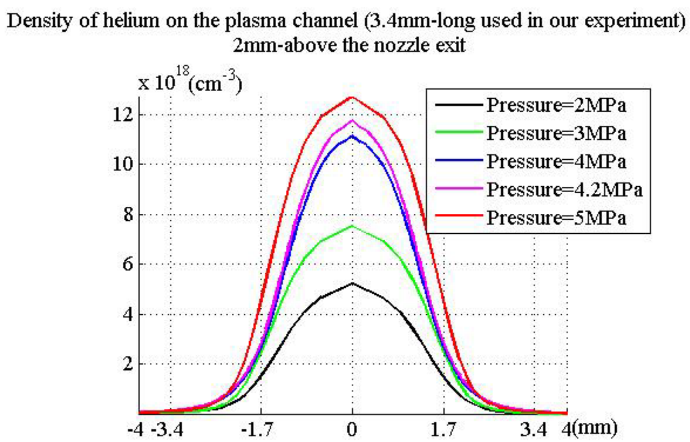


Adjusting plasma length
by setting gas nozzle off-center



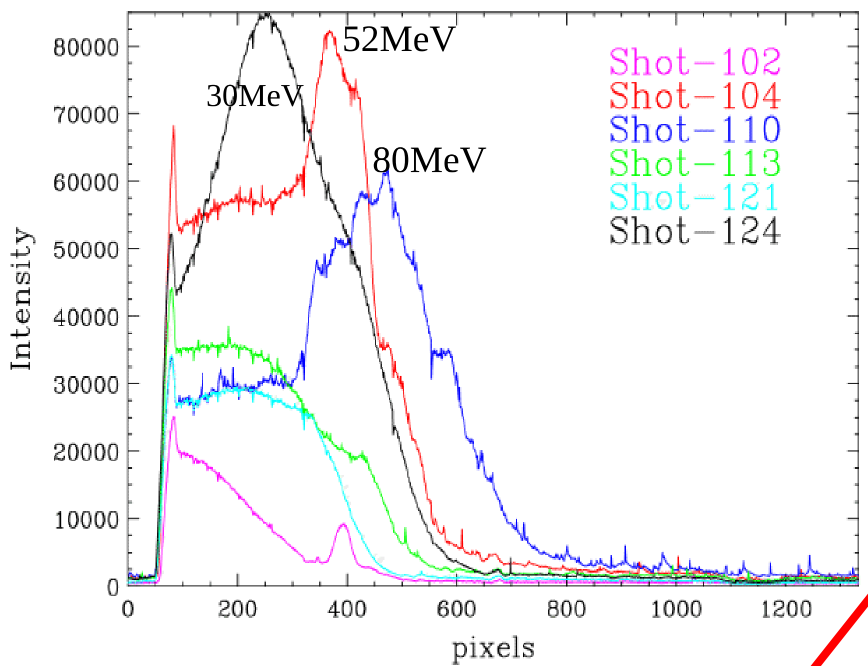


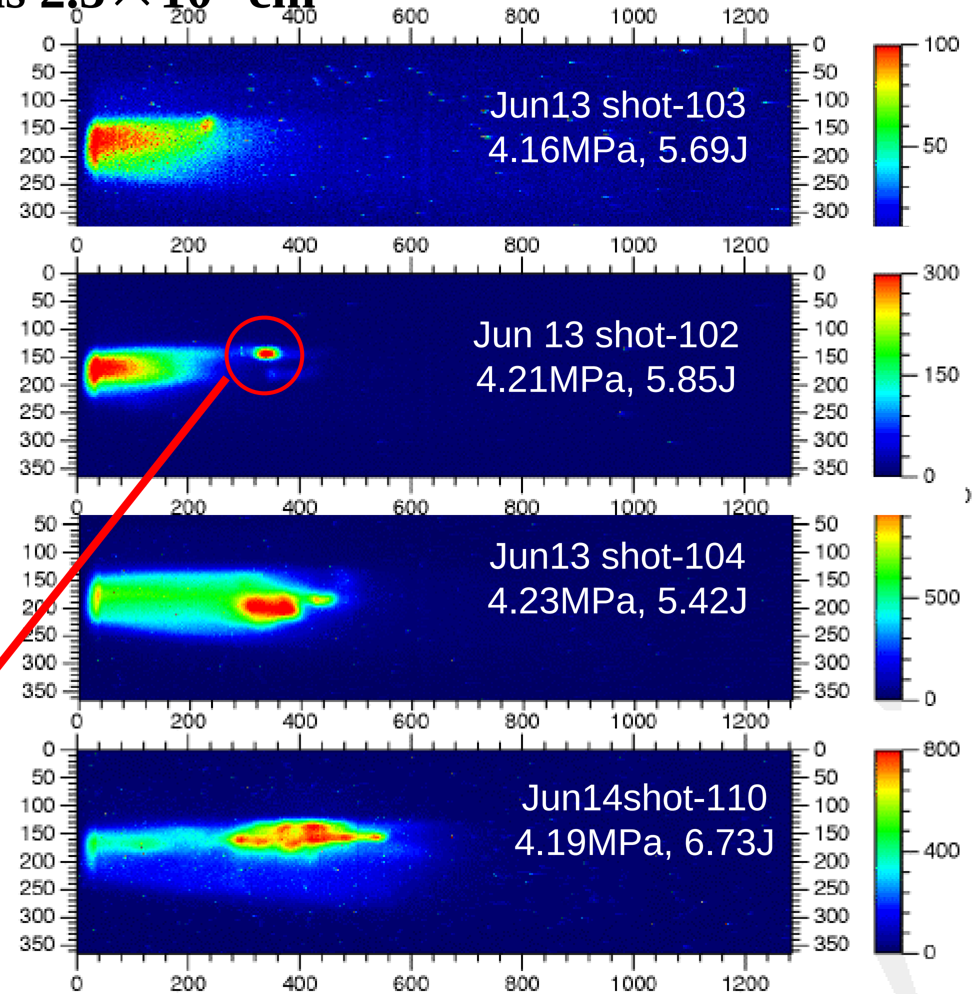




Electron spectrum from 4.2mm-long gas column

- **30MeV~80MeV monoenergy electron beams were generated by 200TW/30fs laser 5-mm long He2 gas jet and laser contrast ratio is better than 10^5. plasma density is $2.5\times10^{19}cm^{-3}$**





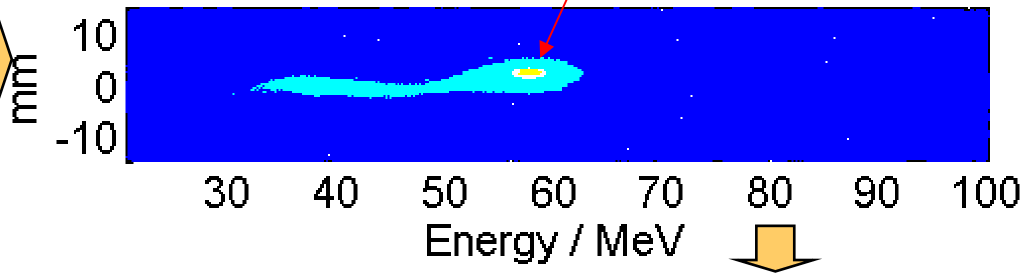
$$\varepsilon = \frac{x_0}{L}\sqrt{x_1^2 - x_0^2} \longrightarrow \varepsilon_n = 9.2\pi\ mm \cdot mrad$$

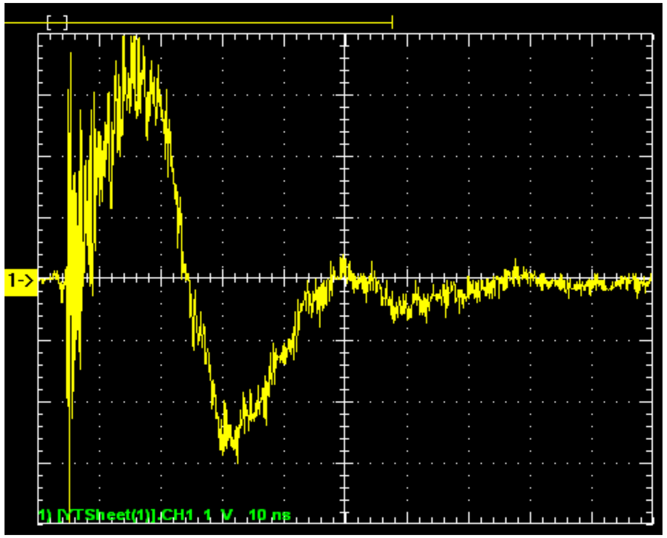
Electron spectrum from 2.7mm-long gas column

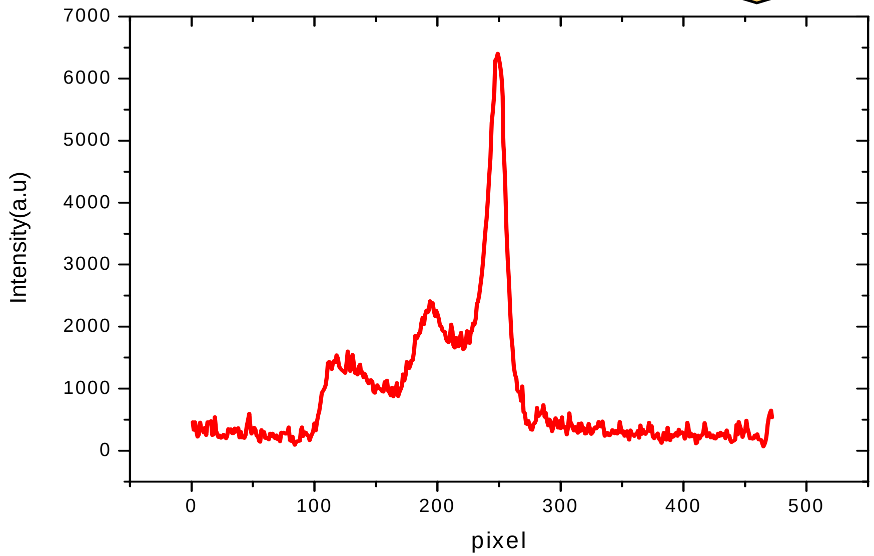
No. 0923072
Energy:2.1 J（70TW）
Backing Pressure: 2.5MP
Plasma density: $2.3\times10^{19}cm^{-3}$

Contrast ratio 10^7

58MeV
0.15πmm.mrd







ICT signal . Integrating the the first peak , 15nC was reached.

Electron yields under different conditions

Shot No.	Laser energy(J)	Backing pressure(MPa)	Contrast ratio	Charges(nC)
0923070	1.311	2.3	10^7	6.878
0923071	2.3115	2.3	10^4	11.304
0923072	2.07	2.5	10^7	15.456
0923073	2.277	2.8	10^7	16.626
0923074	2.3805	2.9	10^4	11.732
0923075	3.8985	2.5	10^4	9.764
0923076	1.9665	2.5	10^7	4.936
0923077	2.4495	2.5	10^7	9.364
0923078	2.898	2.5	10^7	12.958
0923079	3.2085	2.5	10^7	20.13

Summery

- Electron acceleration experiments were conducted using 200TW/30fs laser interaction with different length gas jet.

- Monoenergy electrons From 50MeV to 130MeV were observed at plasma density larger than $2.5\times10^{19}/cm^3$

- The total beam charge number reached to 15nC, which is suitable for γ-ray generation.

Thanks for your attention!