Stable 10 MeV class quasi-mono energetic electron bunch generation by laser wakefield and self-channeling

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Joint Research between ILE and KPSI

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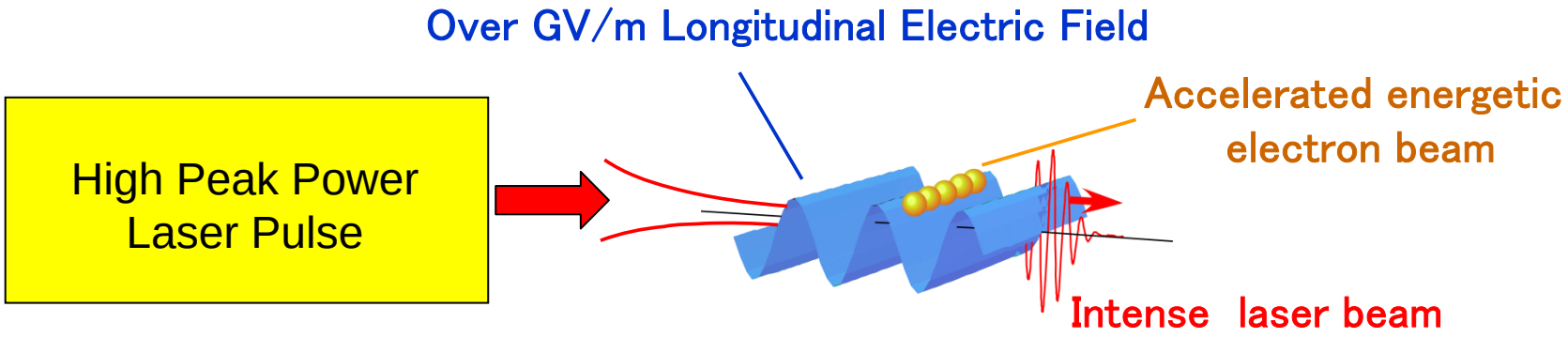
Y. Mizuta, K. A. Tanaka, H. Nishimura

Background



Electron plasma wave is excited by intense laser pulse, and it can generate extreme large acceleration field (TV/m).

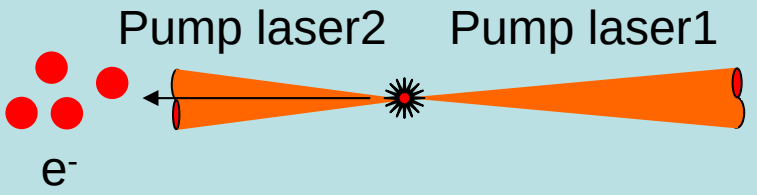
- **Compact accelerator → Cancer therapy**
- **Femtosecond bunch length → Pulse radiolysis**
- **Good Emittance → e-beam gun**
- **Wide range tunability → Cancer therapy・Material development**

→ Stable E-beam Generation is required!

How to get a stable acceleration

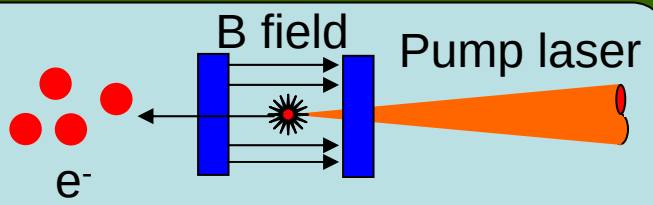
- Colliding-injection

  J. Faure et al., Nature **444**, 737 (2006)
  H. Kotaki et al., IEEE TPS **36**, 1760 (2008)



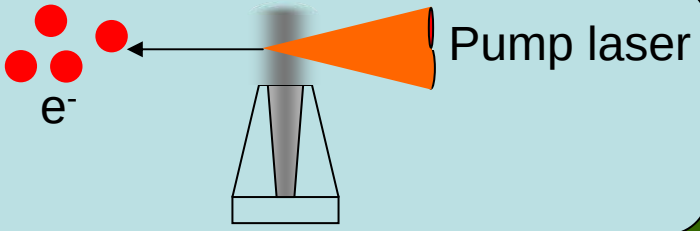
- Magnetized plasma

  T. Hosokai et al., PRL **97**, 075004 (2006)



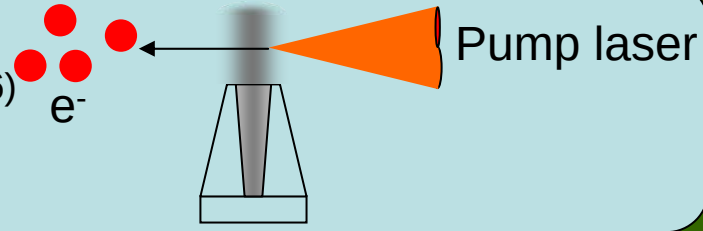
- Density ramp

  C.C.D. Geddes et al., PRL **100**, 215004(2008)



- Prepulse control

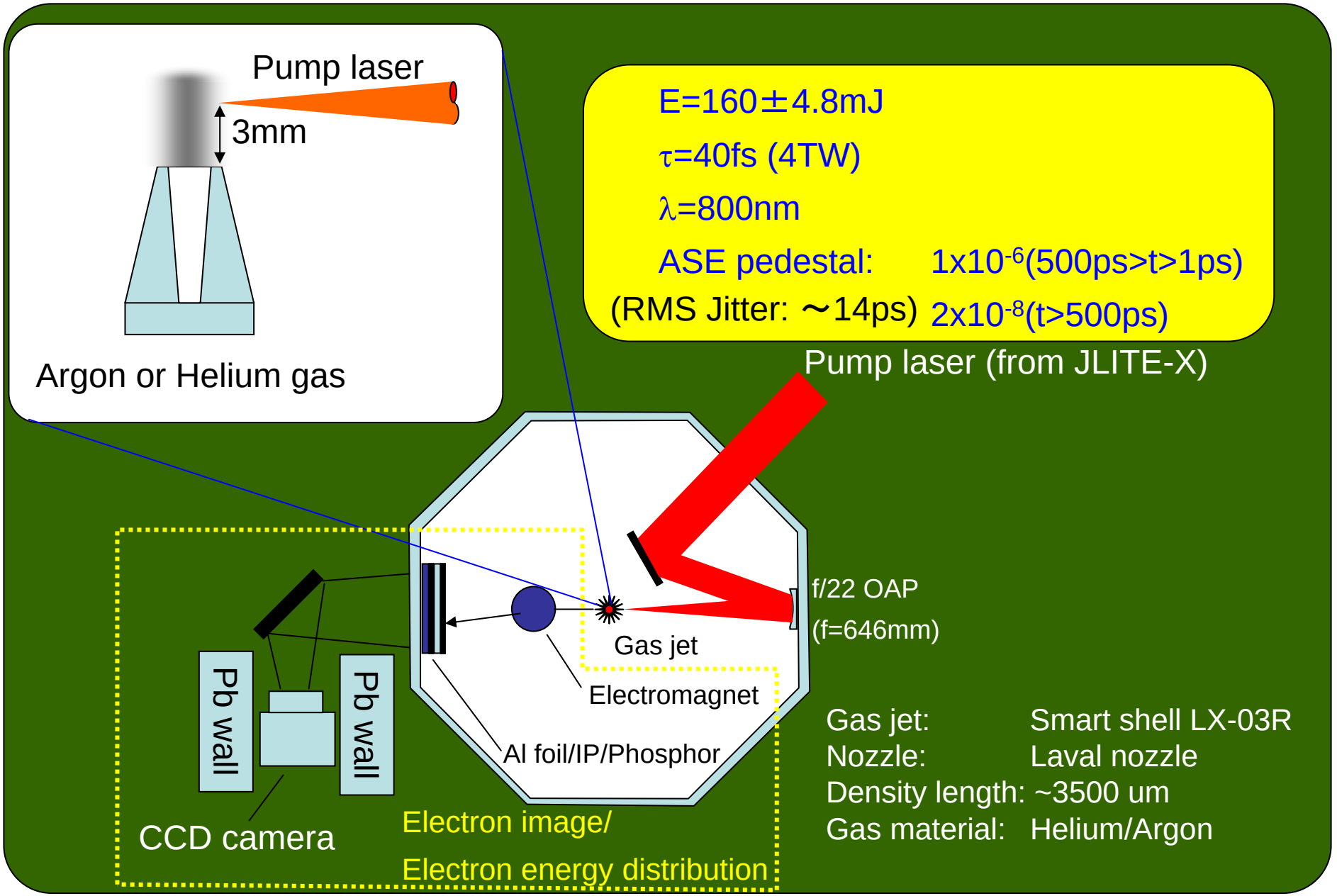
  S.P.D. Mangles et al., Plas. Phys. Cont. Fus. 48, B83 (2006)



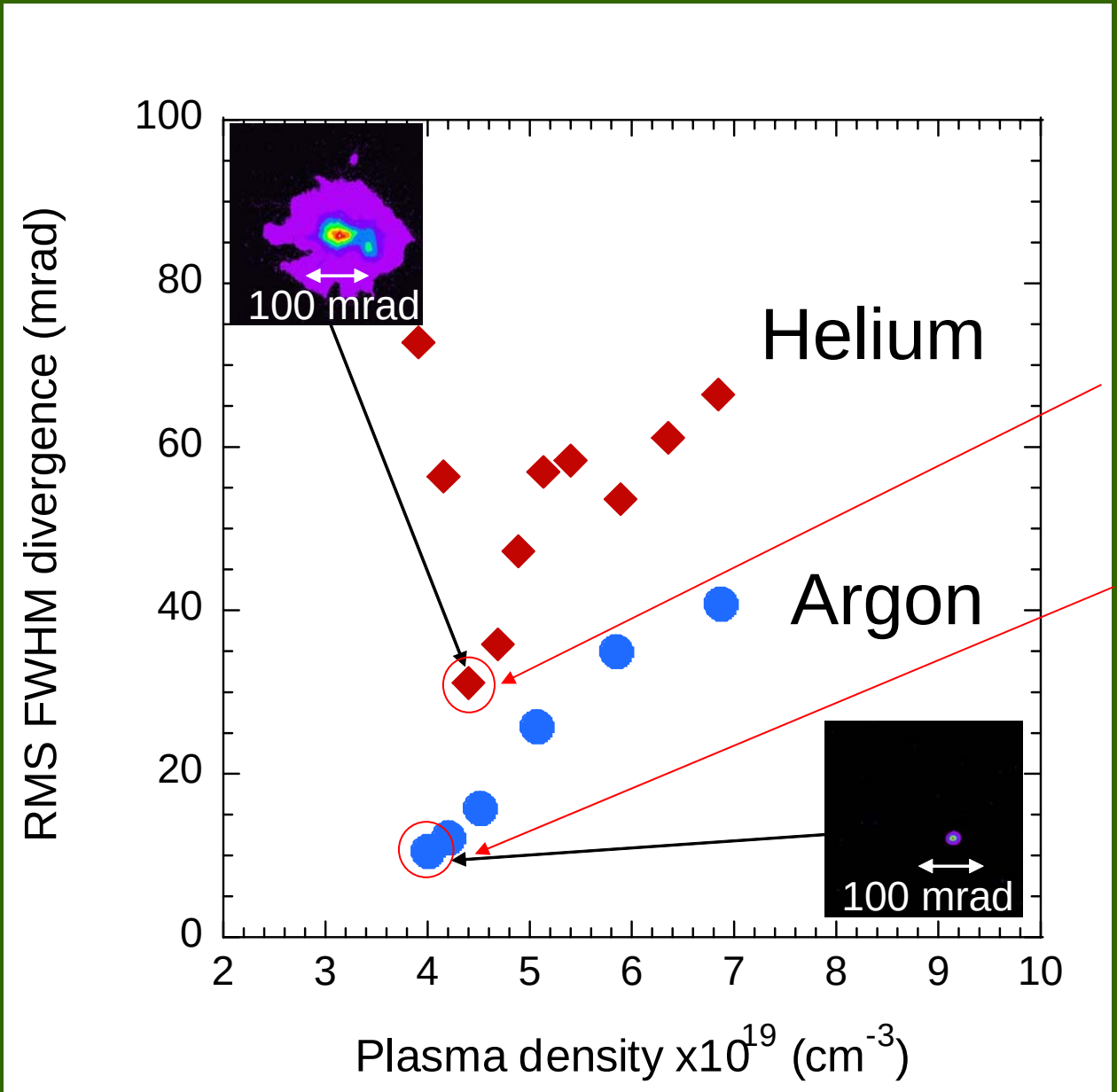
Control a wakefield by laser and target conditions

Gas material dependence (In this work)

Experimental setup



Result(1) e-beam divergence

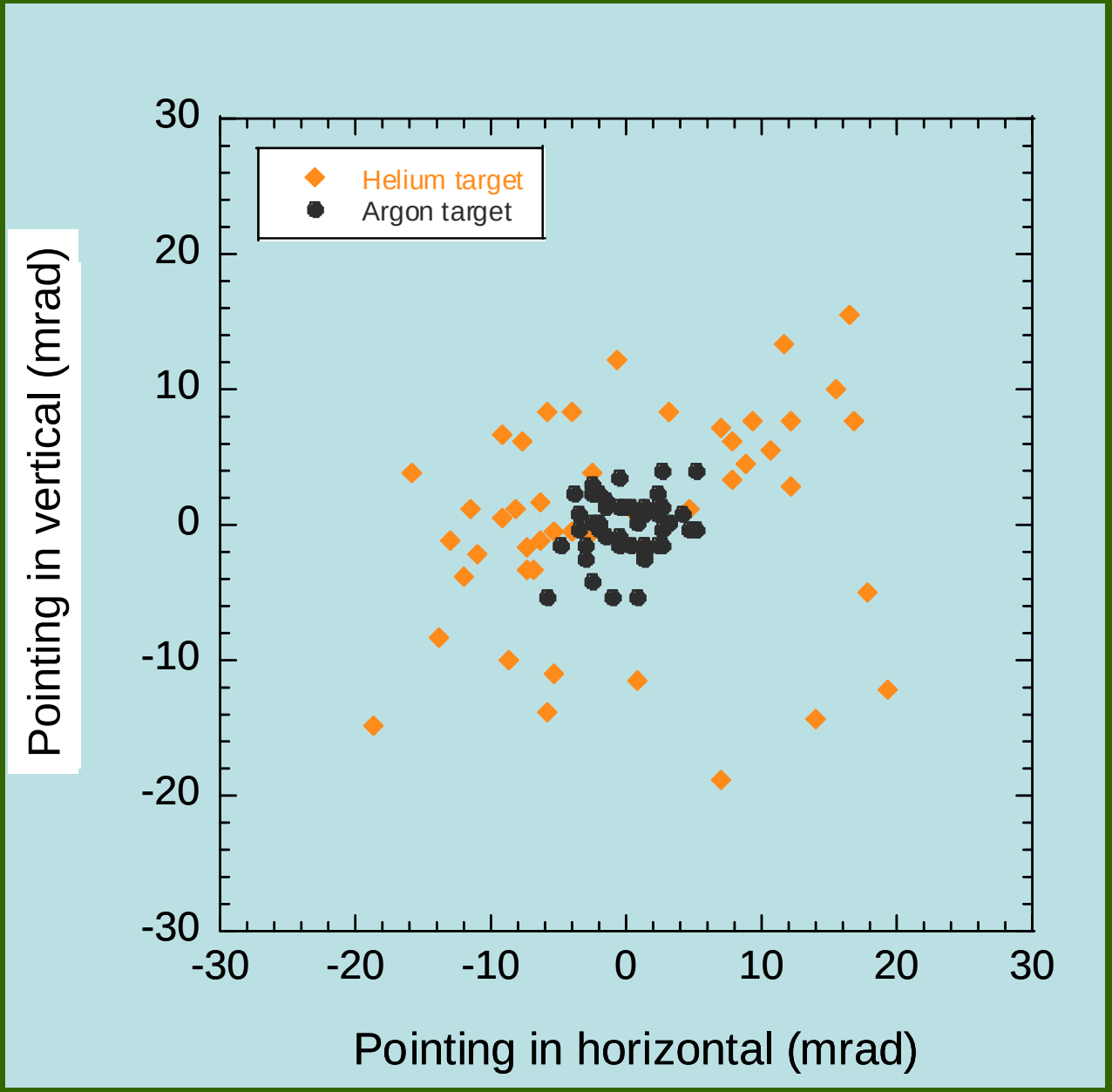


Beam divergence:

θ_{min}=31.1mrad@He

θ_{min}=10.6mrad@Ar

Result(2) e-beam pointing stability



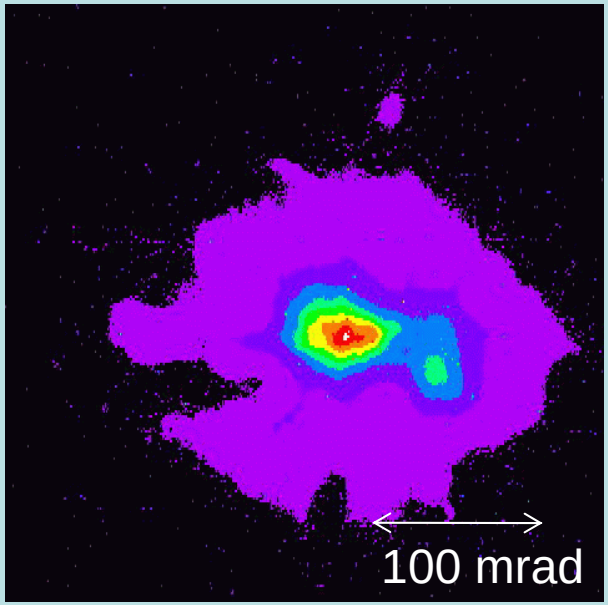
Pointing stability:

θ_{min}=2.4mrad@Ar

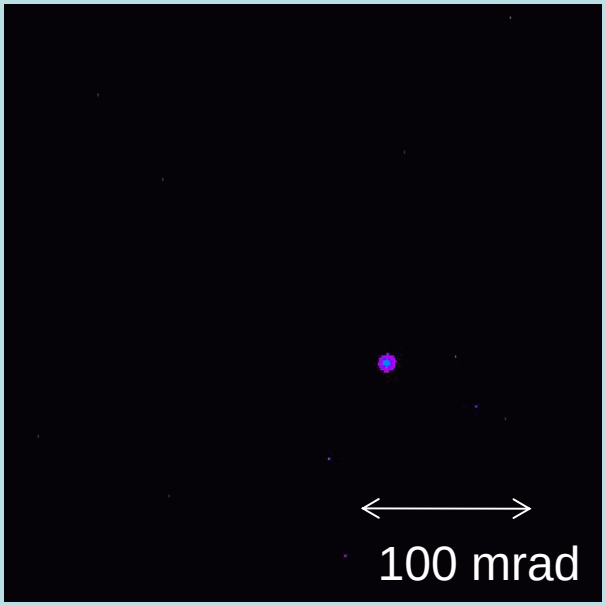
θ_{min}=9.8mrad@He

Result(3) e-beam divergence and pointing stability

Spatial profile of the e-bunch (>1MeV)



Helium target

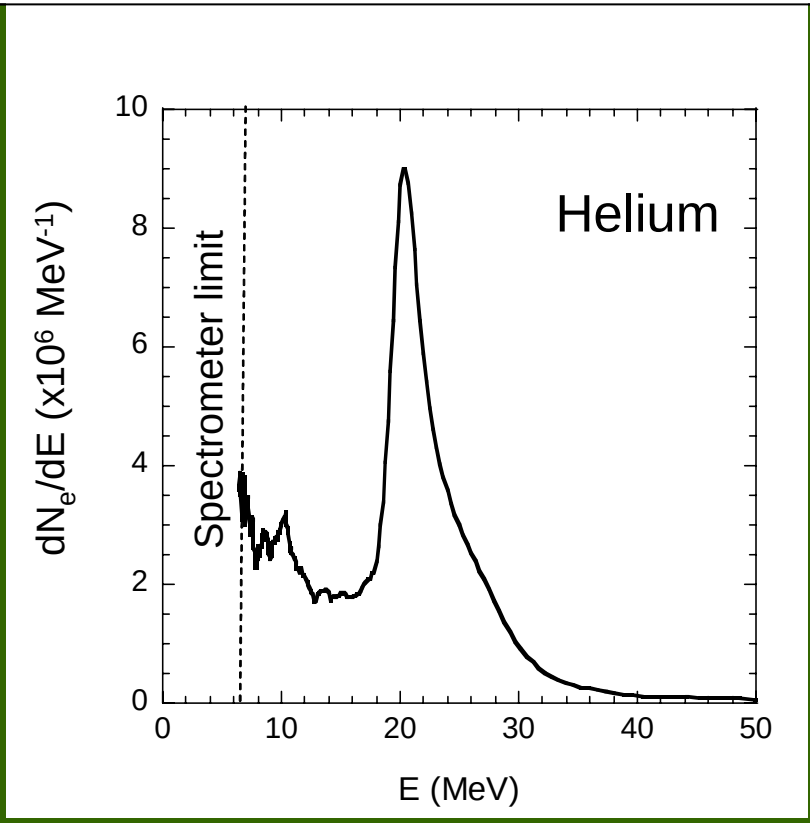


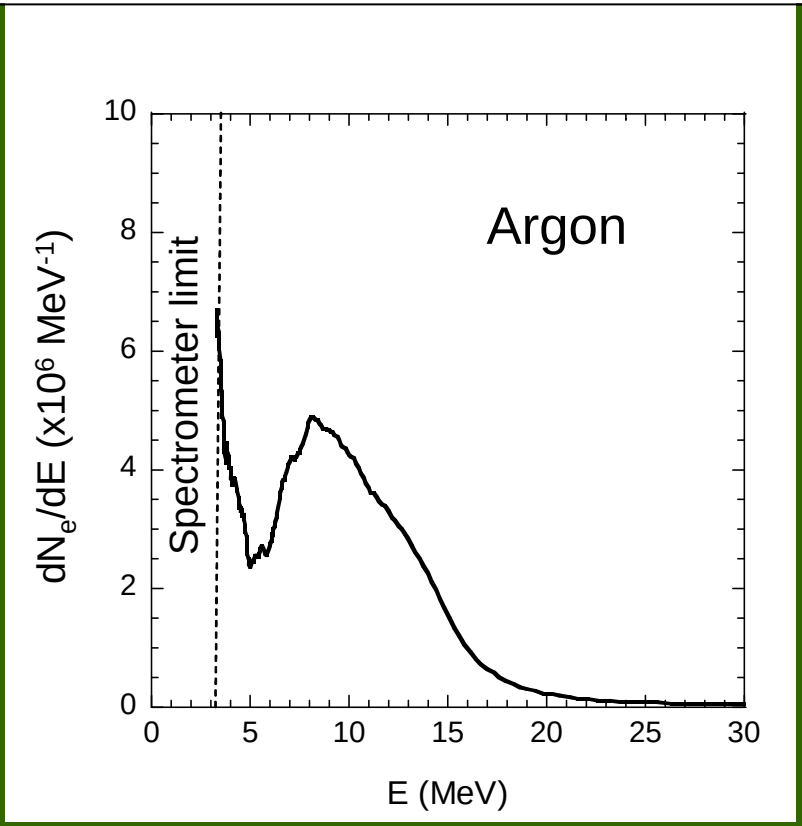
Argon target

Plasma density:

$n_e \sim 4 \times 10^{19}$ cm^{-3} (in He and Ar)

Result(4) e-beam energy distribution



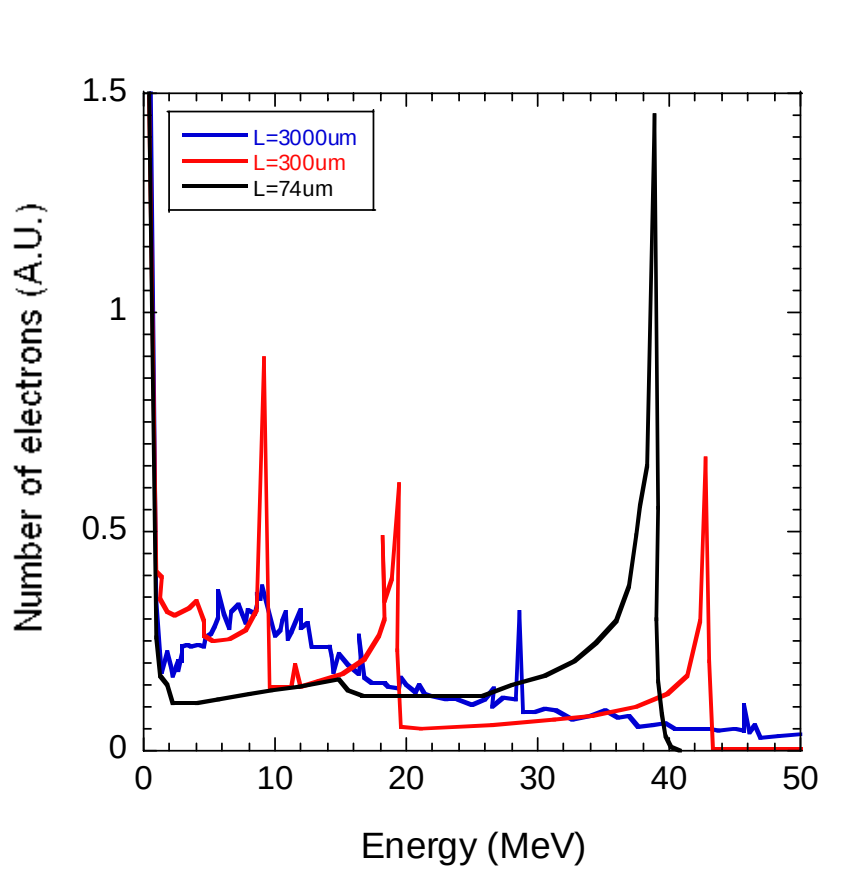


	Helium Target	Argon Target
Peak Energy (MeV)	24.8±3.6	8.5±0.8
Provability of Generation of Q-Mono E-Beam (%)	38	84

Discussion(1): Energy dist./Beam div. · Pointing

1. Energy Distribution

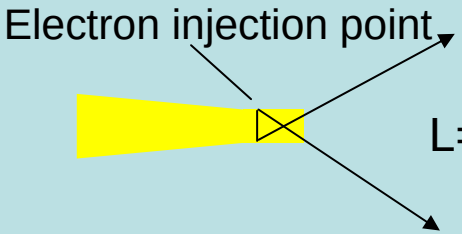
(Acceleration distance dependence)



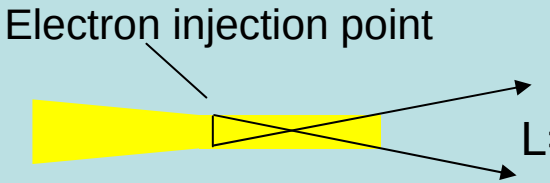
Nakanii et al., APL 93 081501 (2008).

Broad spectrum could be formed by the multi-dephasing with propagating over the dephasing length

2. Divergence / Pointing stability



→Divergence/Pointing: Worth



→Divergence/Pointing: Good

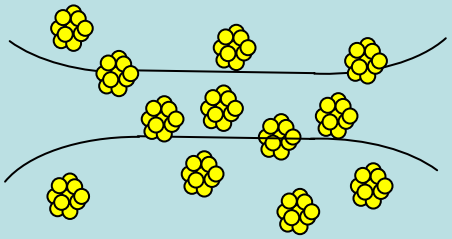
$$\Delta\theta \propto \tan^{-1}\frac{d_{wf}}{l_{wf}}$$

d_{wf} : Wakefield spot size

l_{wf} : Wakefield length

Discussion(2):laser propagation

Cluster



Refractive index of the cluster crowd

$$n_{cluster} = \sqrt{1 + 4\pi n_{cluster}\,\mathrm{Re}\left|\frac{\varepsilon_{cl} - 1}{\varepsilon_{cl} + 2} a^3\right|}$$

n_{cl}: *Cluster number density*

a: *Cluster size*

Dielectric constant of the cluster

$$\varepsilon_{cl} = 1 - \frac{\omega_p^{\,2}}{\omega_L^{\,2}\left(1 + i\frac{\upsilon_{ei}}{\omega_L}\right)}$$

ω_p: *Plasma frequency*

ω_L: *Laser frequency*

ν_{ei}: *electron-ion collision frequency*

Cluster media induces a positive lens effect by the strong polarization.

→ Positive lens effect

↓ Assisting a long propagation

I. Alexeev et al., PRL 90 103402 (2003).

$$n_{tot} = \sqrt{1 - \frac{\omega_{p,gas}^2}{\omega_L^2} + 4\pi n_{cluster}\,\mathrm{Re}\left|\frac{\varepsilon_{cluster} - 1}{\varepsilon_{cluster} + 2} a^3\right|}$$

T. Caillaud et al., PoP 13 033105 (2006).

Contribution by Gas

Contribution by Cluster (In He, no contribution)

Summary

- With Ar target, well collimated and pointing stabilized e-beam have been obtained rather than He target, while quasi-mono energetic distribution is also observed.

- These results suggest that a comparatively longer acceleration distance could be realized in Ar.

- With Ar, cluster jet can be formed. Index of cluster mixed media might affect a long propagation of focused laser pulse.

謝　謝　！！