Bulk Deuterium Acceleration in the Light Sail Regime

A. Alejo, S. Kar – Queen's University Belfast

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A-SAIL
ADVANCED STRATEGIES FOR ACCELERATING IONS WITH LASERS

2nd EAAC, Isola d'Elba, 2015

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Queen's University Belfast

A. Alejo
A. Green
H. Ahmed
S. Kar
M. Zepf
M. Borghesi

The Ohio State University

AG. Krygier
JT. Morrison
RR. Freeman

University of Oxford

M. Oliver
P. Norreys

Science & Technology Facilities Council Central Laser Facility

M. Notley
RJ. Clarke
APL. Robinson

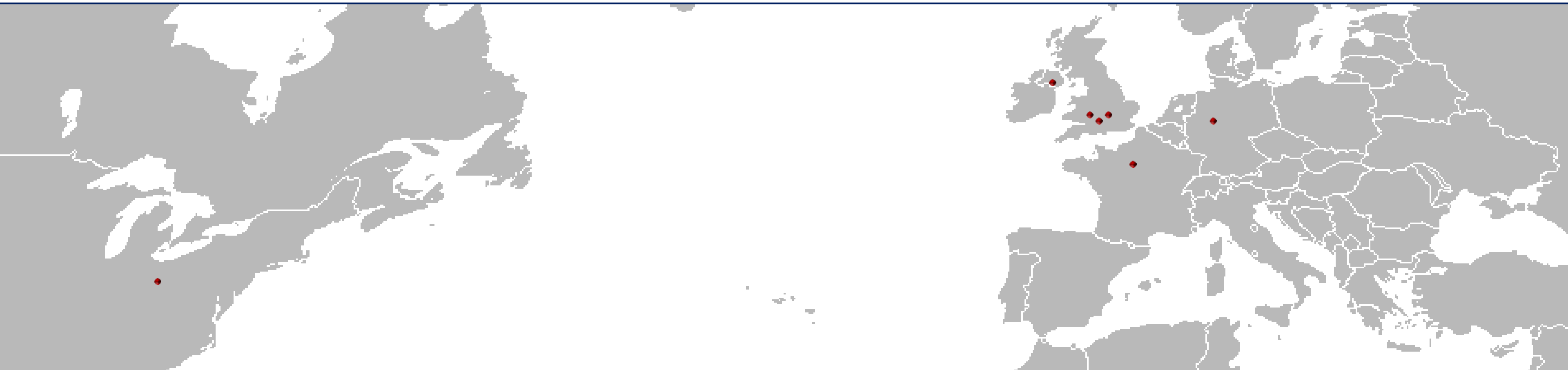
Imperial College London

H. Nakamura
Z. Najmudin

Technische Universität Darmstadt

A. Kleinschmidt
M. Roth

L. Vassura
J. Fuchs



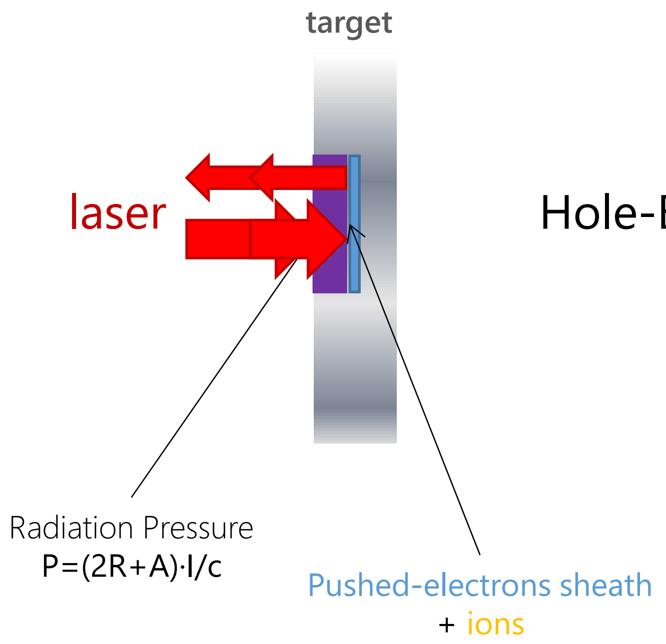
Outline

- Radiation Pressure Acceleration. Theory
- Experimental Setup
- Ion vs Neutron Spectroscopy
- Parameter Scaling
- The problem with transparency
- Simulations

Motivation

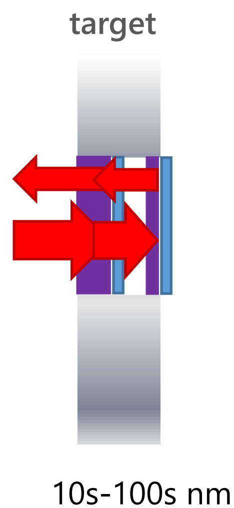
- A fast-neutron source has a wide range of applications, but limited access to facilities
- Laser-driven sources appear as a possible solution
  - Neutron sources based on TNSA have been the most studied, but suffer its limitations
  - Slow ion energy scaling and lack of bulk species
- Radiation Pressure Acceleration appears as an alternative given its advantages
  - Acceleration of bulk ions, fast scaling, more directional

RPA. Theory



Hole-Boring Ion acceleration

RPA. Theory

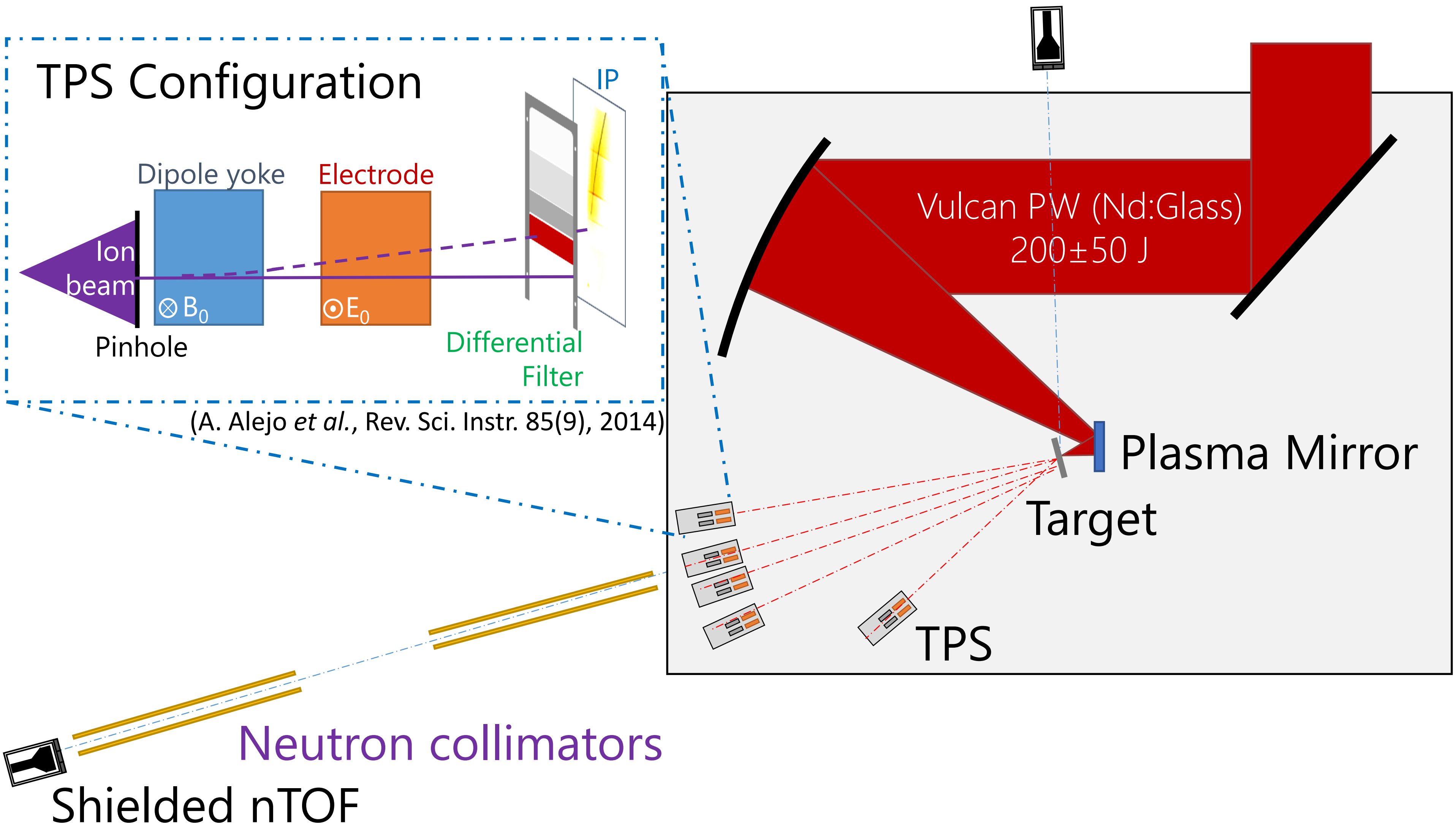


Light-Sail Ion acceleration

Characteristics of the source

- Quasi-monoenergetic spectrum
- Ion energy $E \propto \left(a_0^2 \tau_p / \chi\right)^{\alpha} \equiv (E_{laser} / \rho_{target} l_{target})$
- Bulk ions accelerated

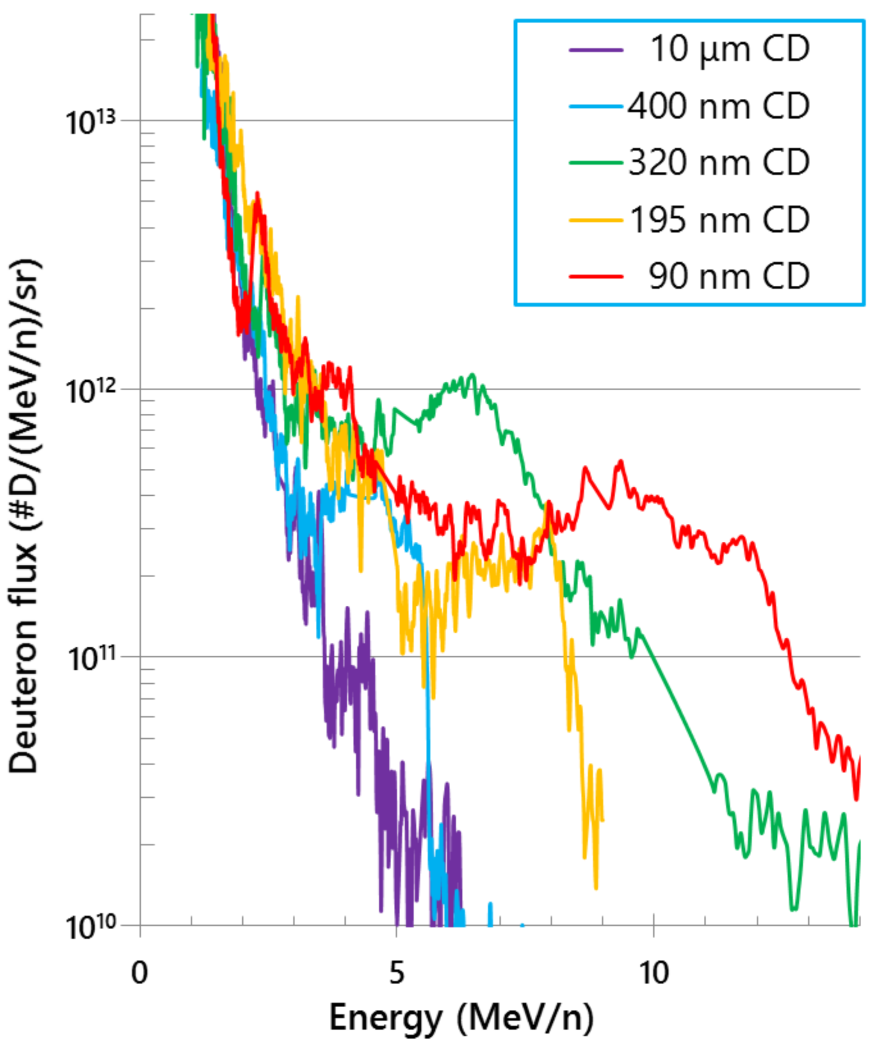
Experimental Setup



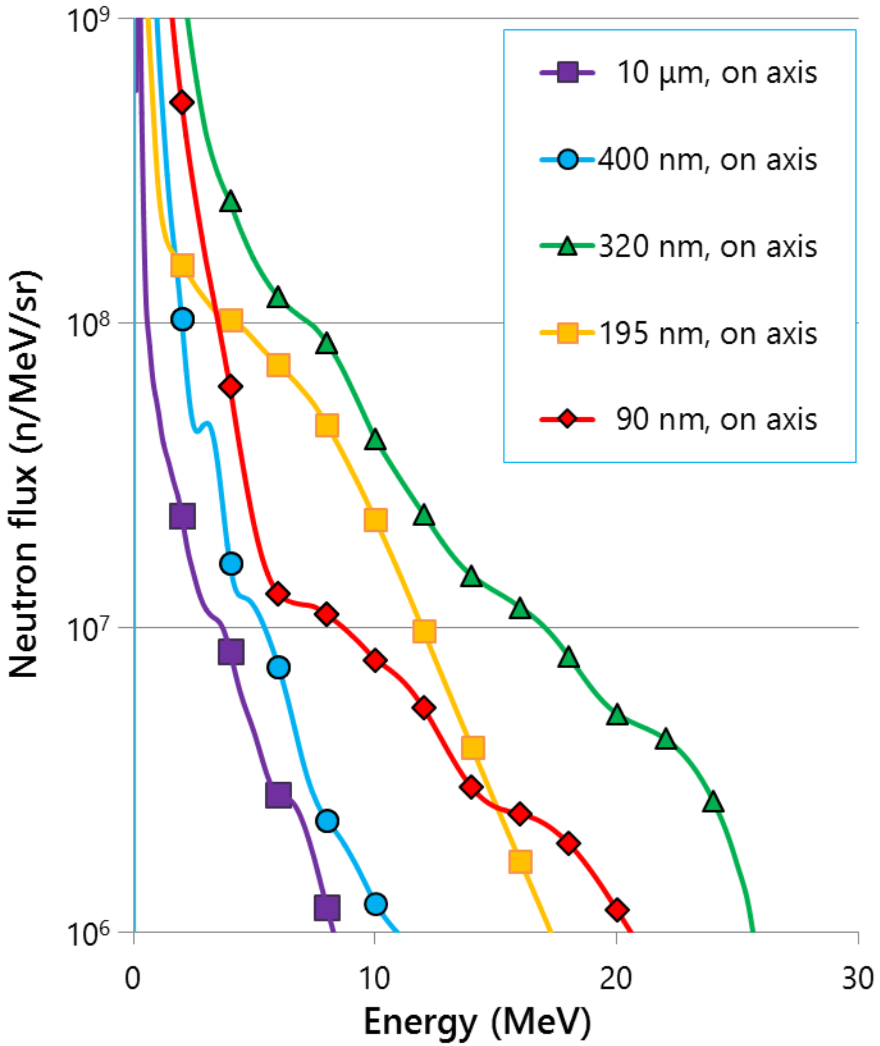
(SR. Mirfayzi *et al.*, Rev. Sci. Instr. 86(7), 2015)

Correlation of Spectra

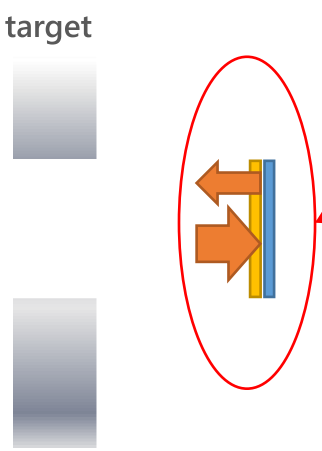
ions



neutrons



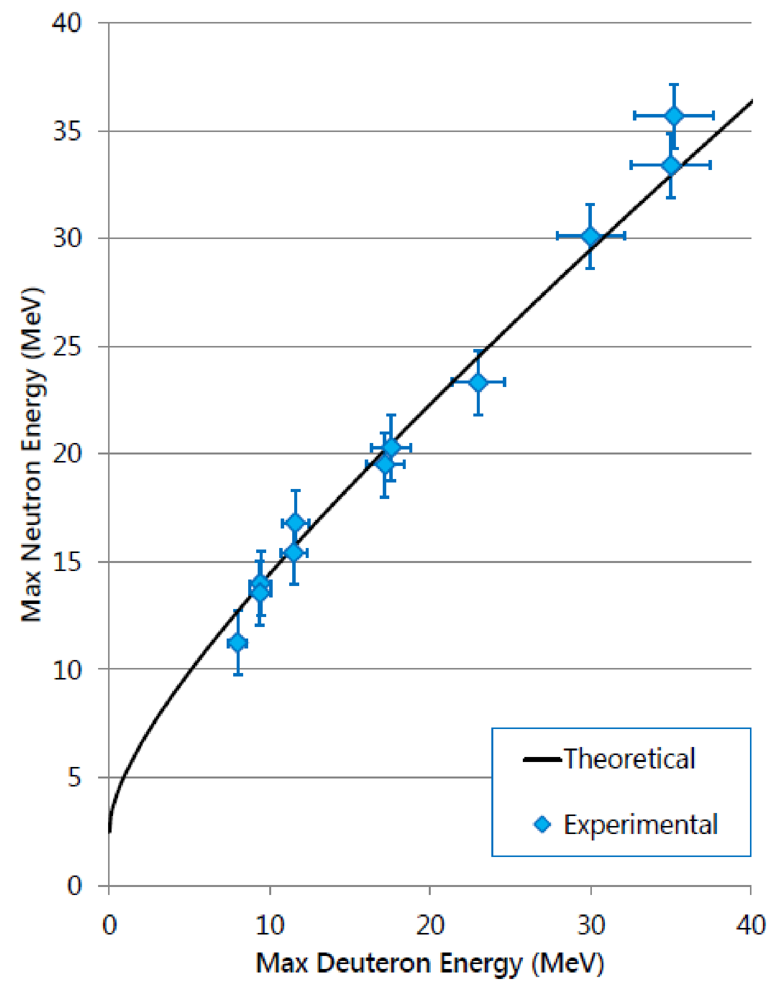
RPA Revisited



Highly-dense deuteron bunch travelling together long time

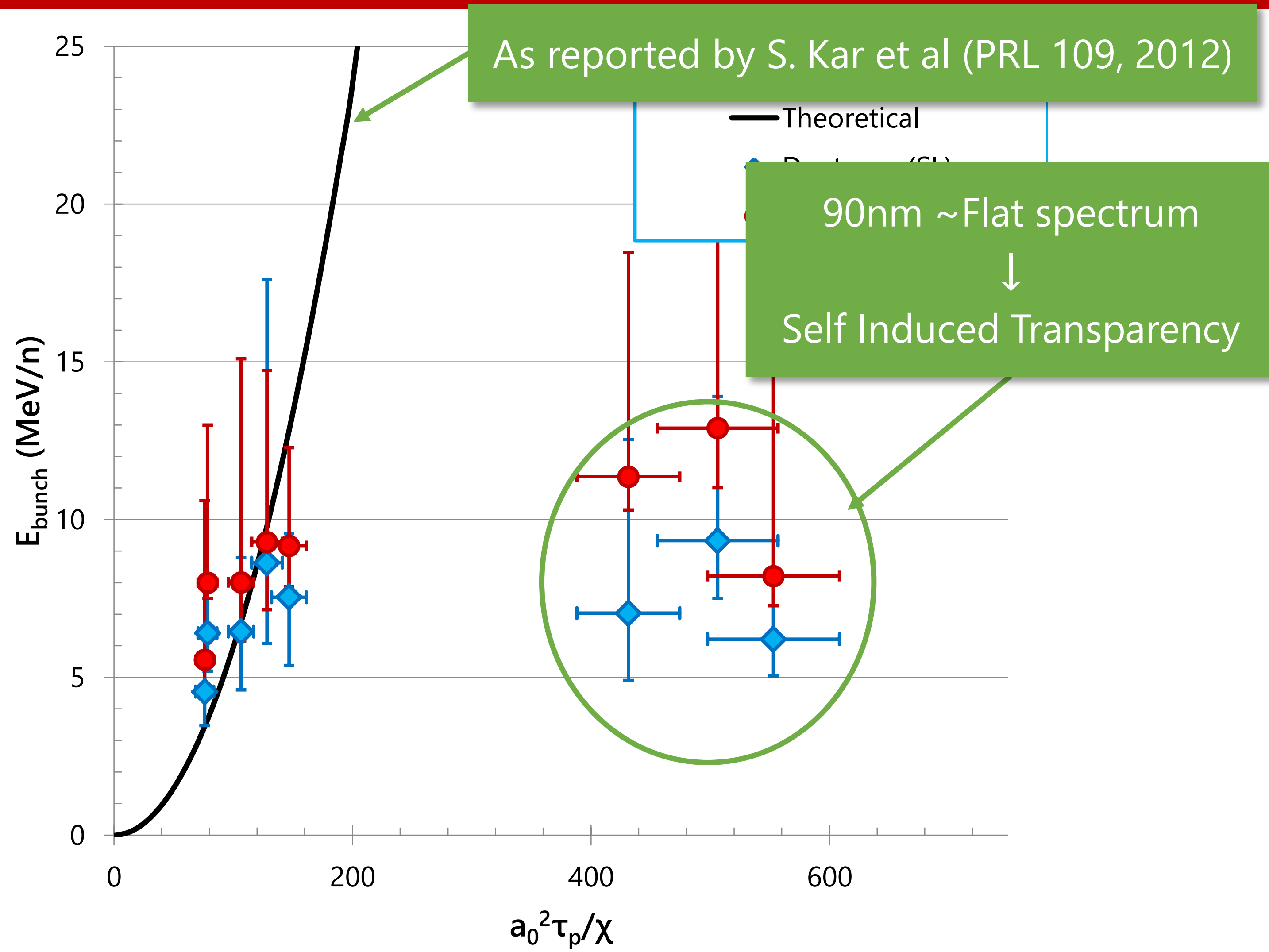
$$Y_n \simeq \frac{\tau_{burn}}{2} \int n_d^2 \cdot \langle \sigma v \rangle \, \mathrm{d}V$$

DD becomes main reaction



Still doesn't explain 90nm

Energy scaling



Transparency constraint

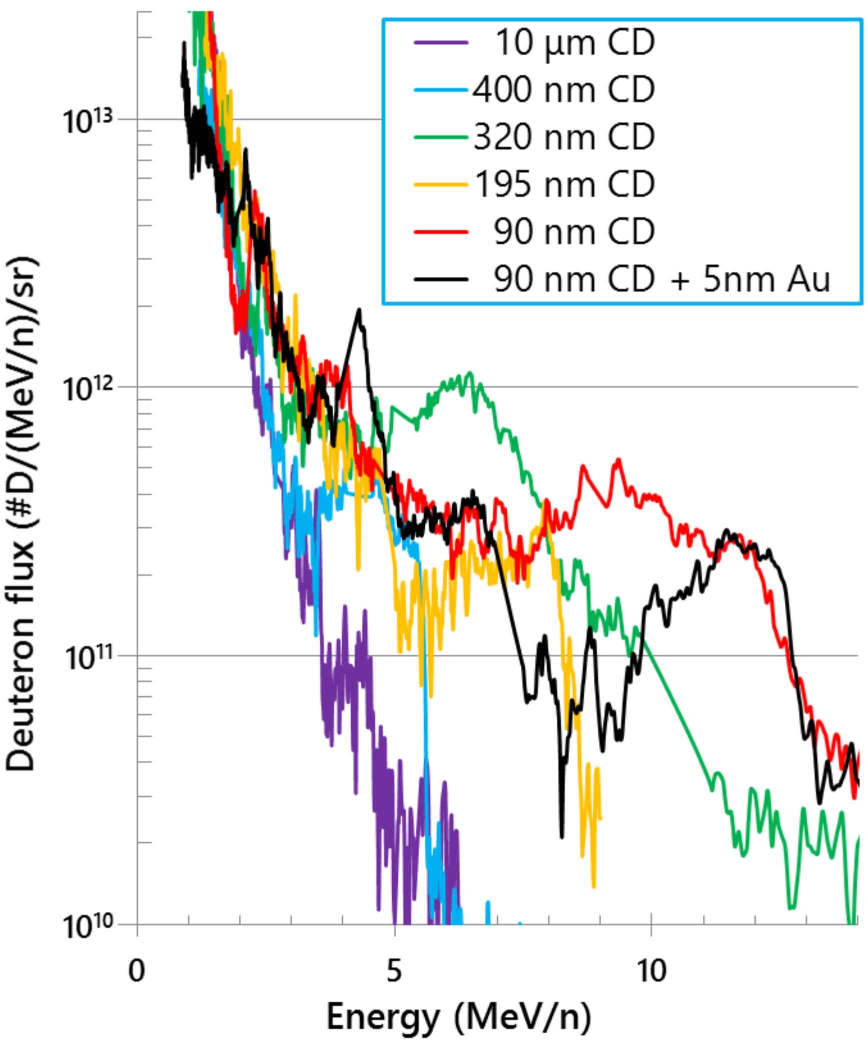
- Low-density targets are prone to early transparency
  - Deformation of the target
  - Relativistically induced transparency ($n_{c,rel}=\gamma\ n_{c,0}$)
  - Need of a sacrificial ion species

- Solution: New target to spot those problems
  - Compensate the relativistic correction increasing the number of electrons
  - Incorporate high-Z ions, which will sacrifice while the low-Z species stay bunched

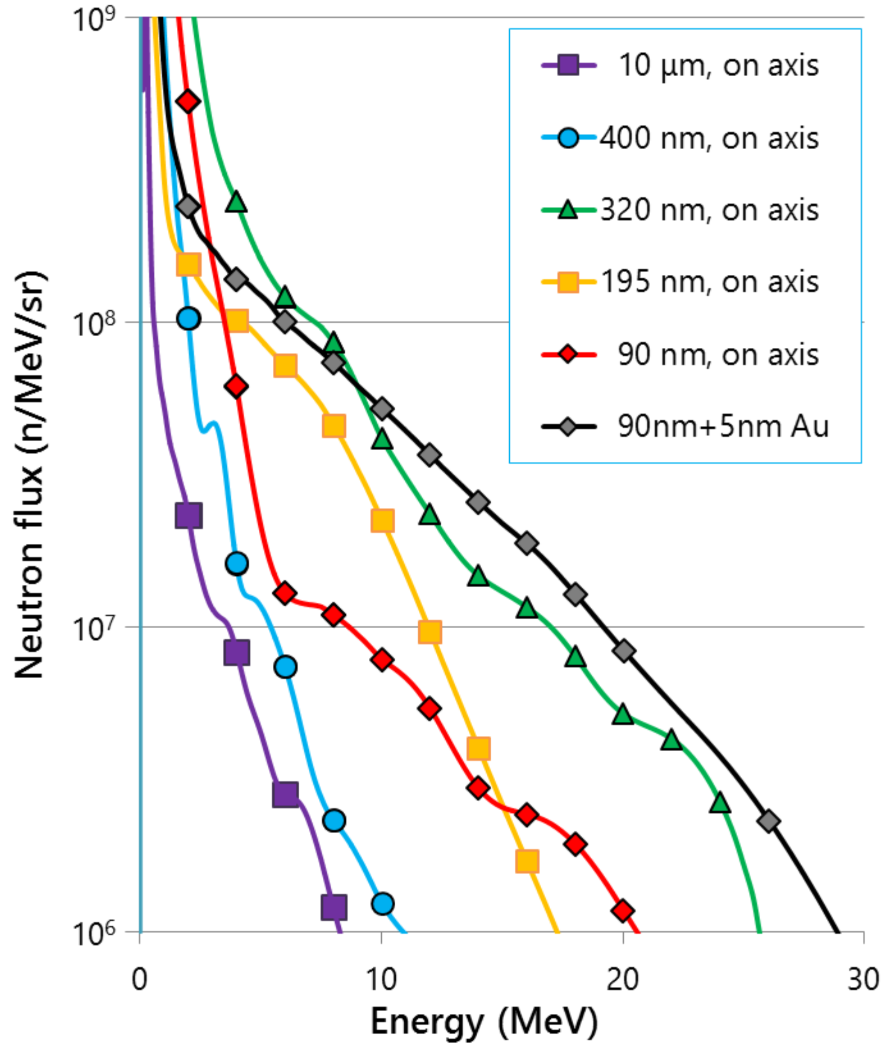
→ Thin targets with gold layer deposited at the rear

Correlation of Spectra

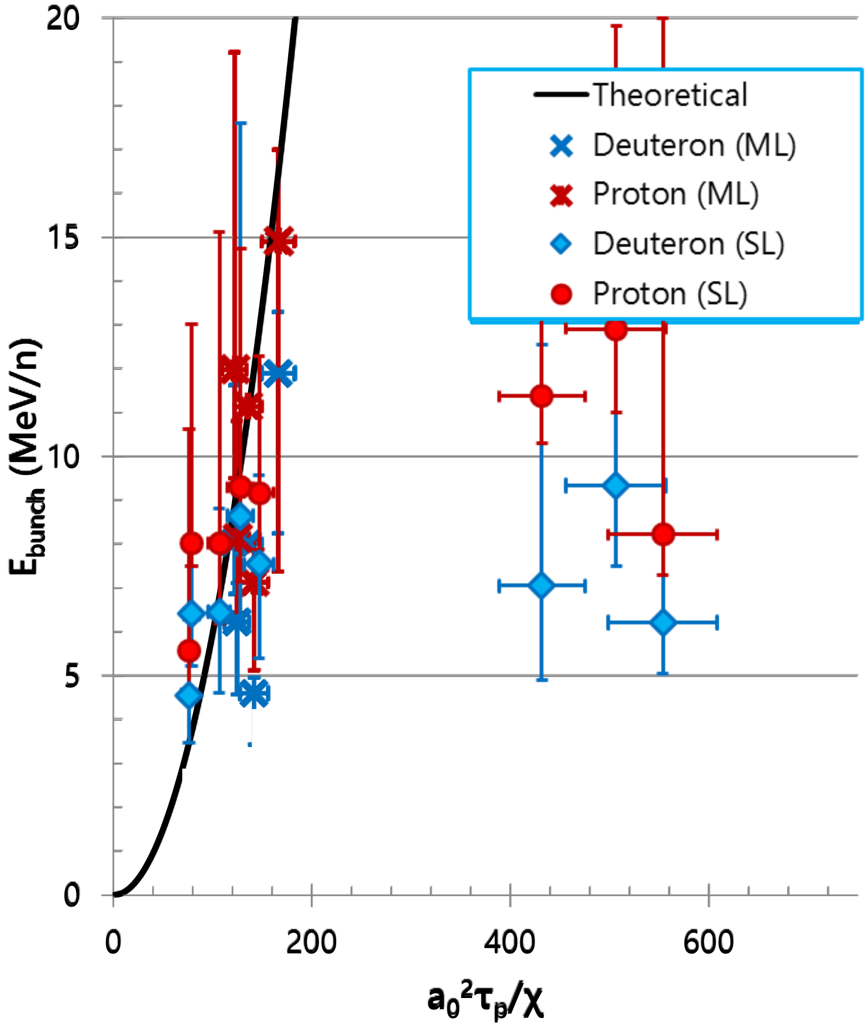
ions



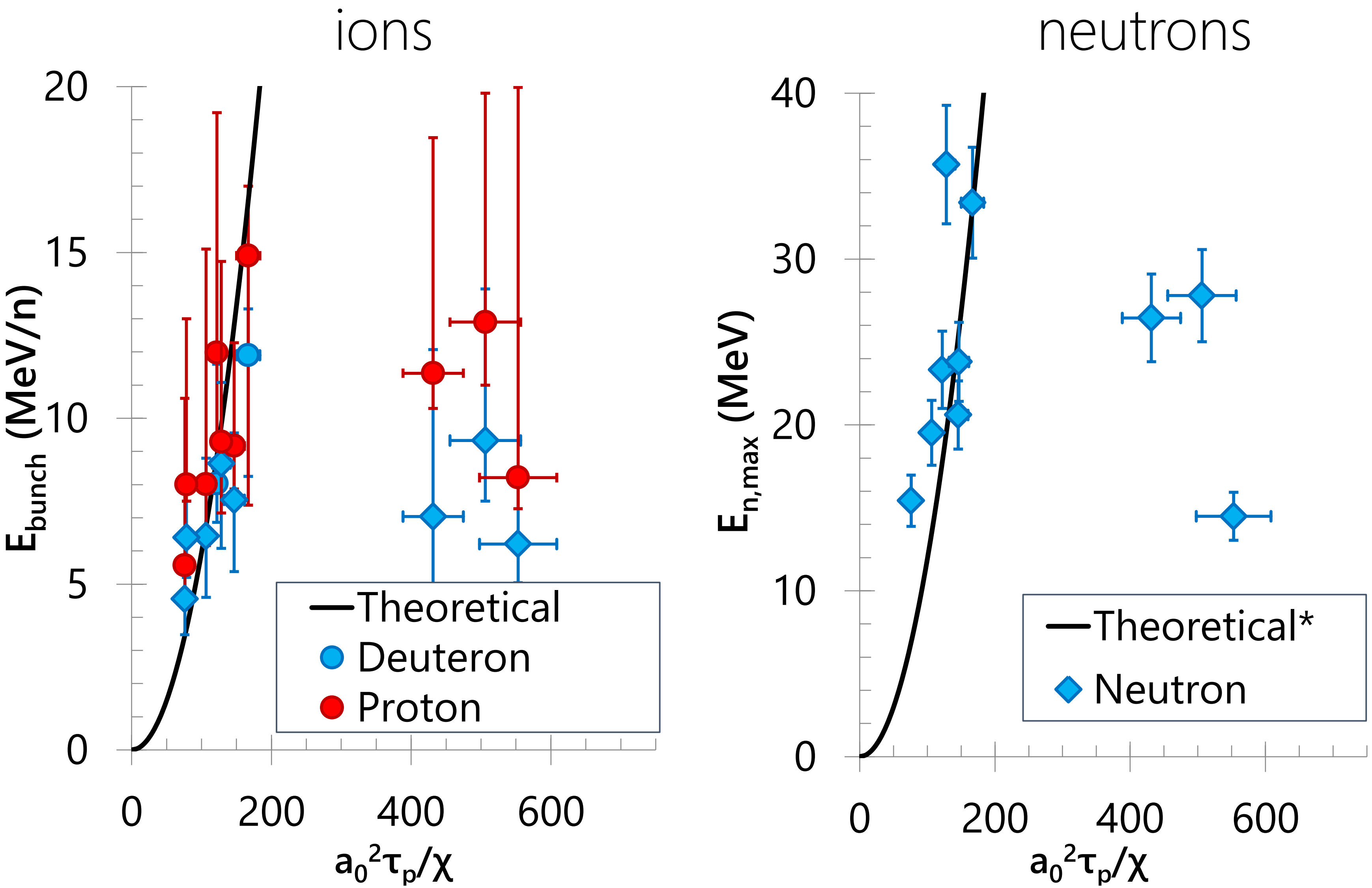
neutrons



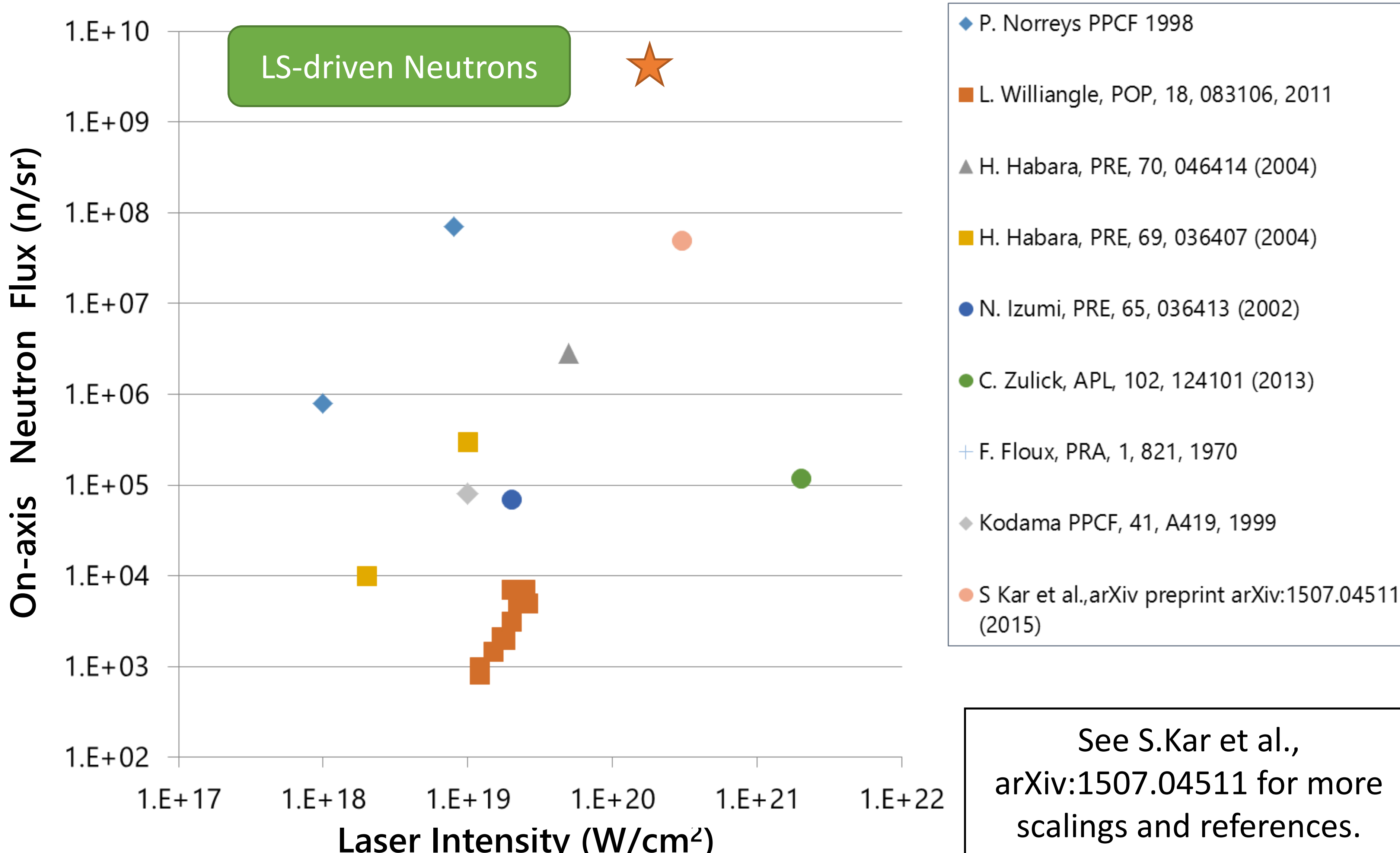
Energy scaling



Energy scaling



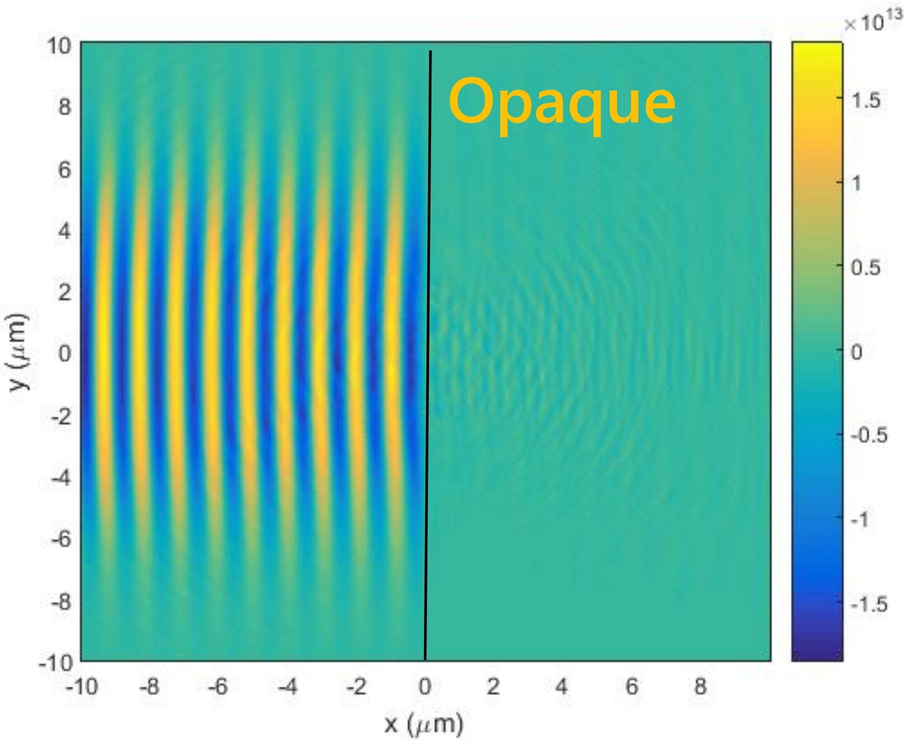
Flux scaling



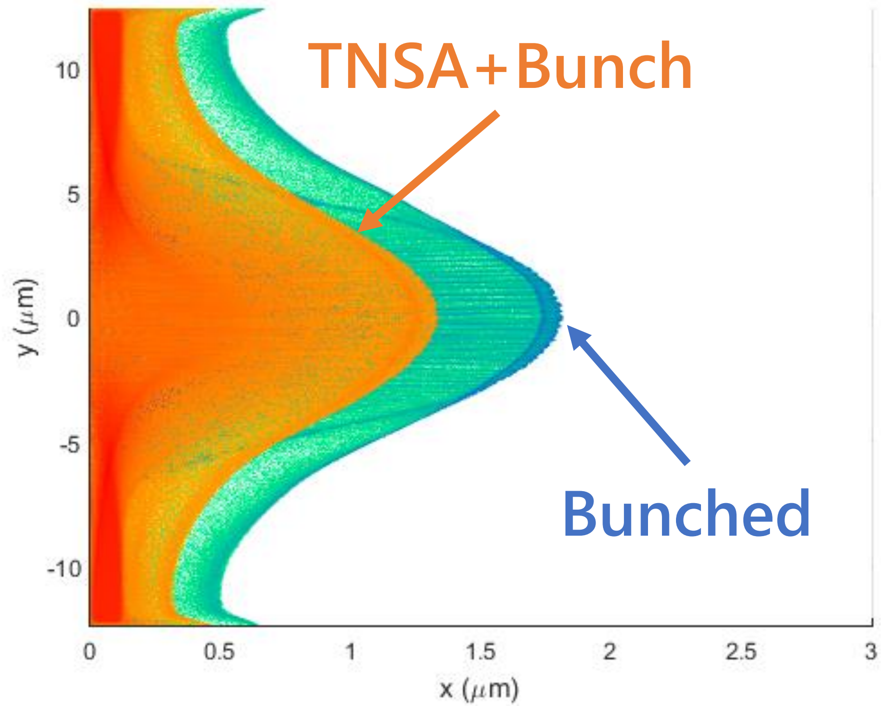
See S.Kar et al., arXiv:1507.04511 for more scalings and references.

Simulation - 320nm

Electric Field

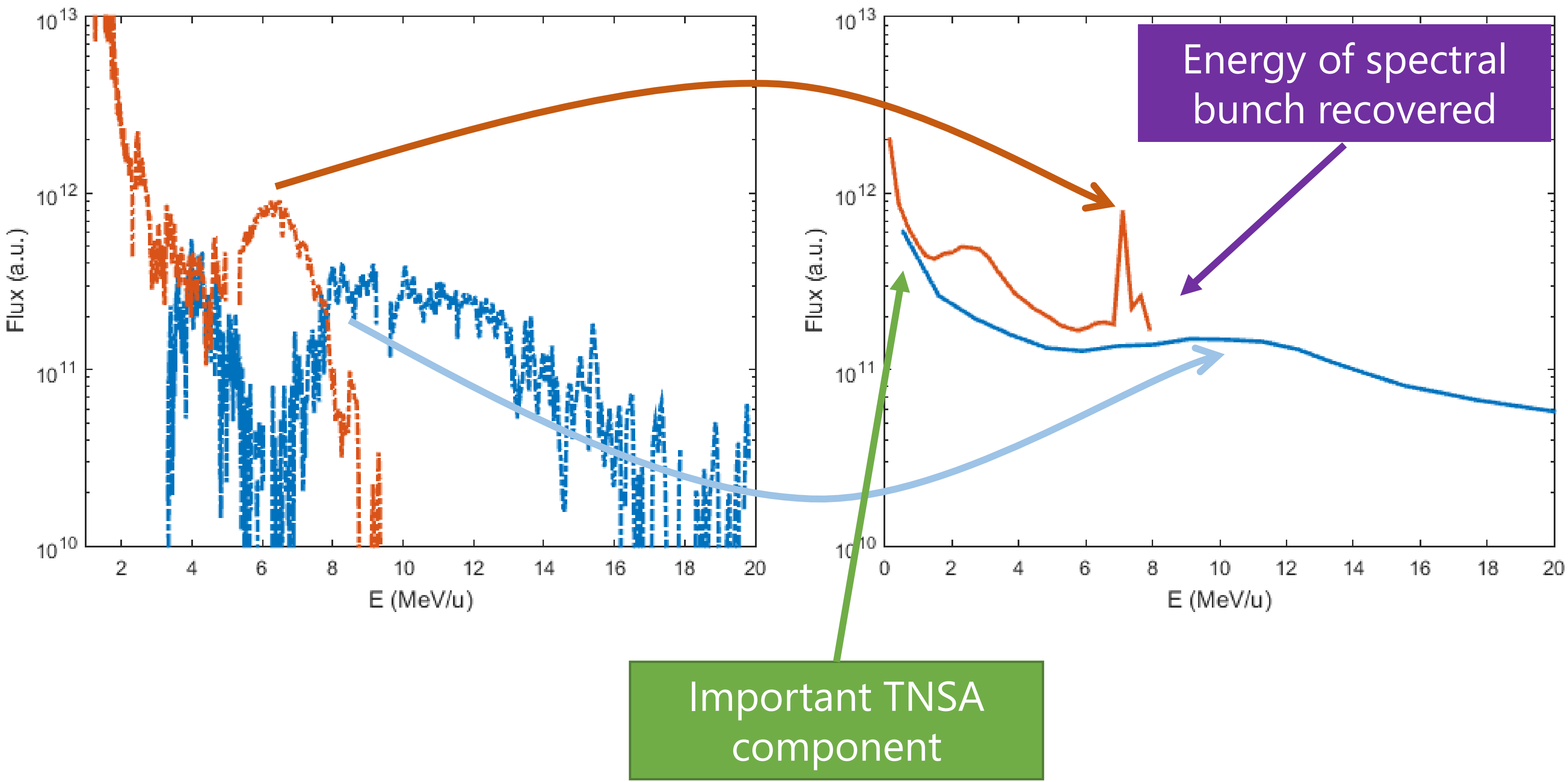


Density Profile



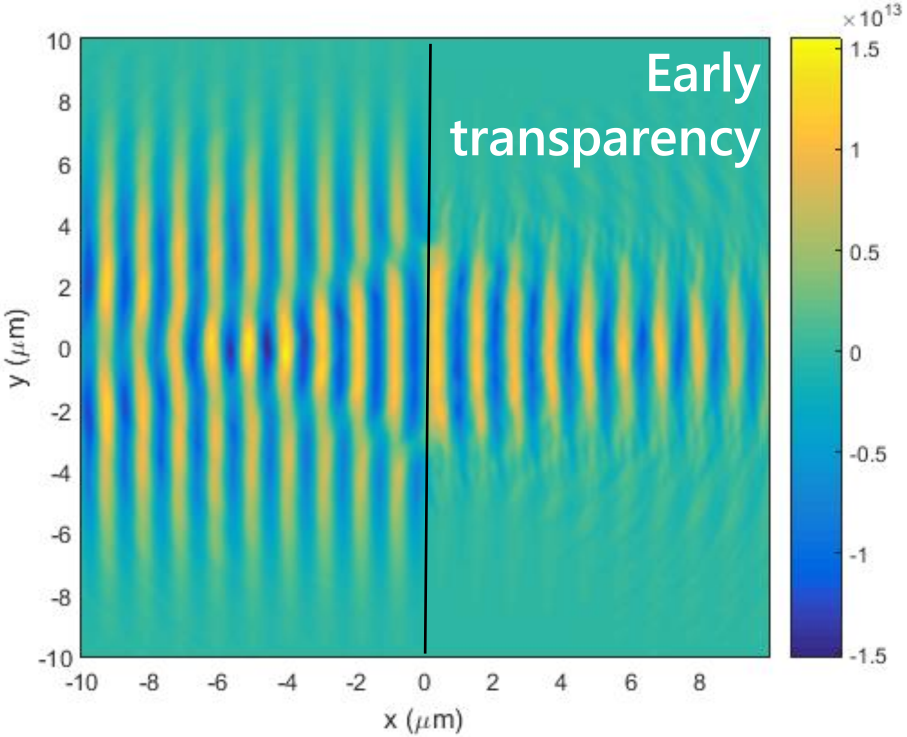
320nm. Ion spectra

Experimental **2D PIC Simulation**

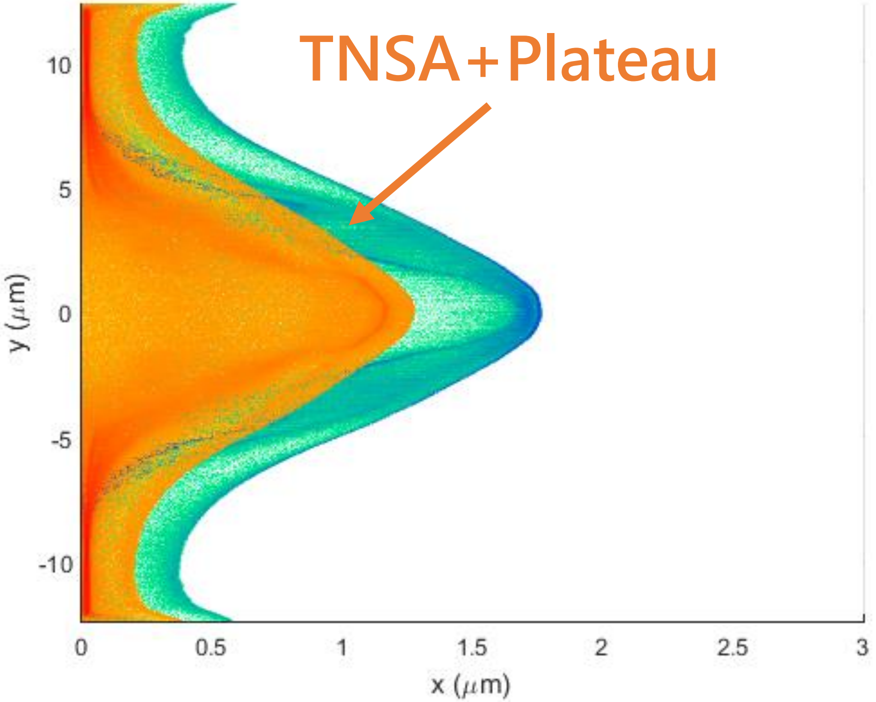


Simulation - 90nm

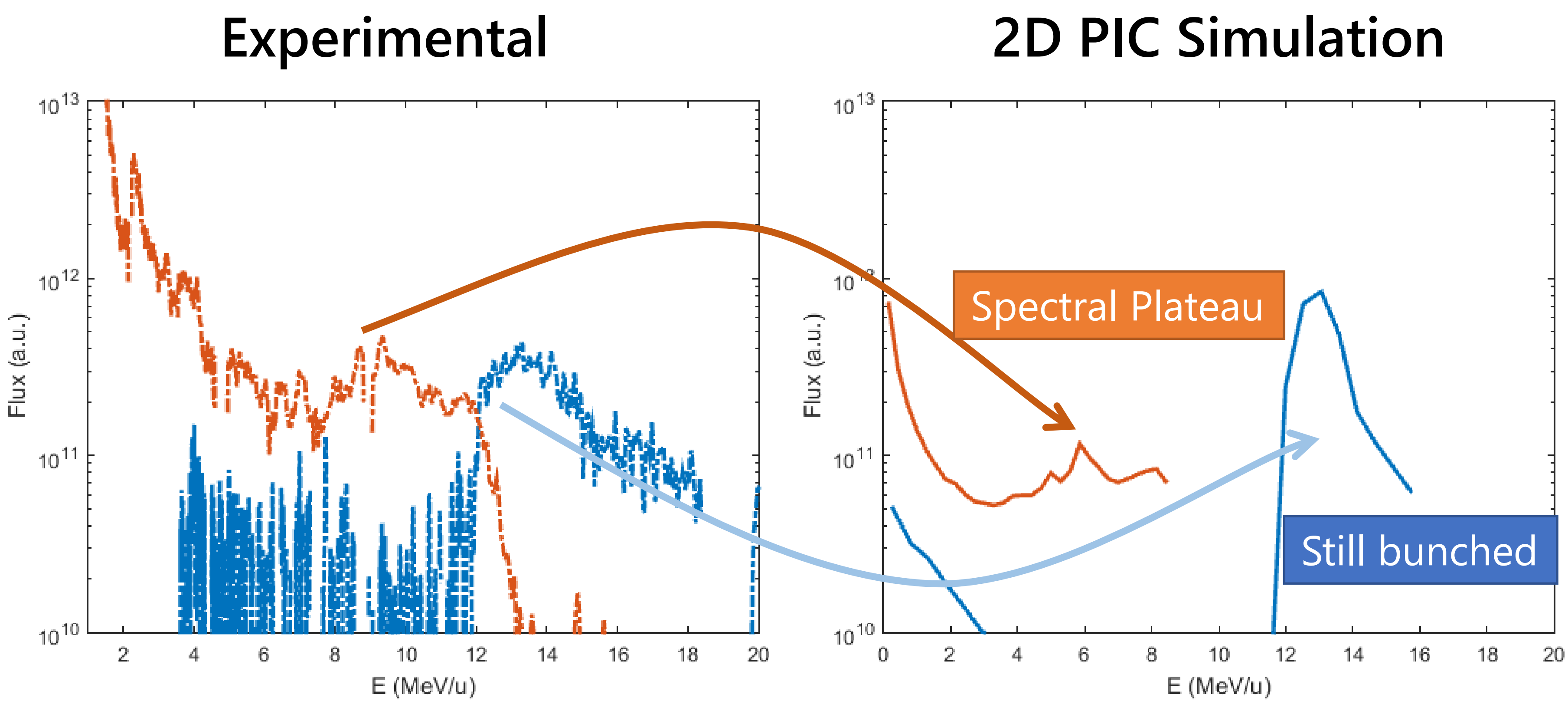
Electric Field



Density Profile

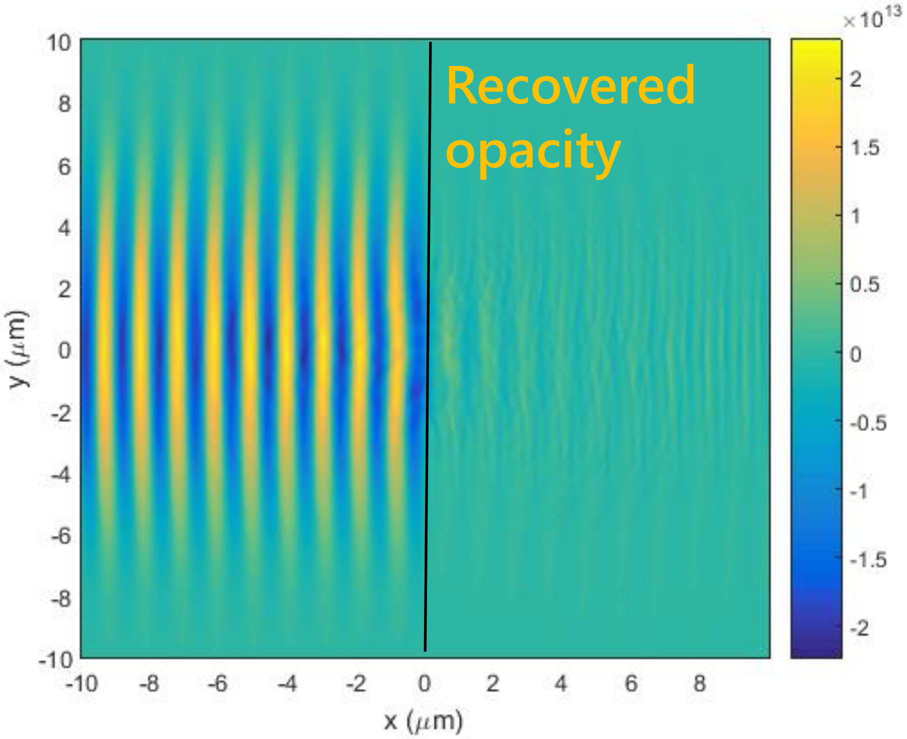


90nm. Ion spectra

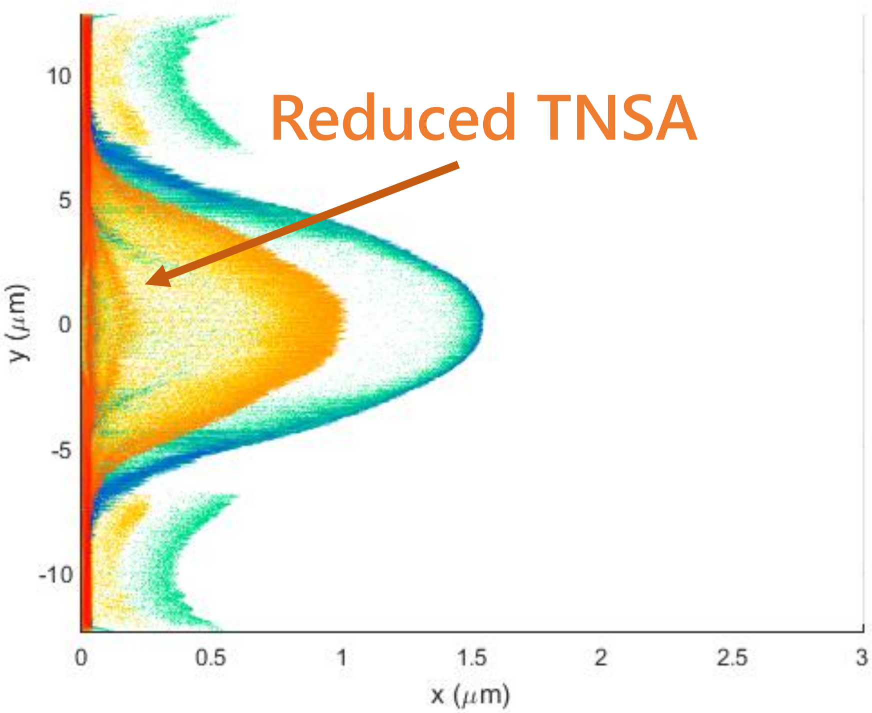


Simulation - 90nm+Gold

Electric Field

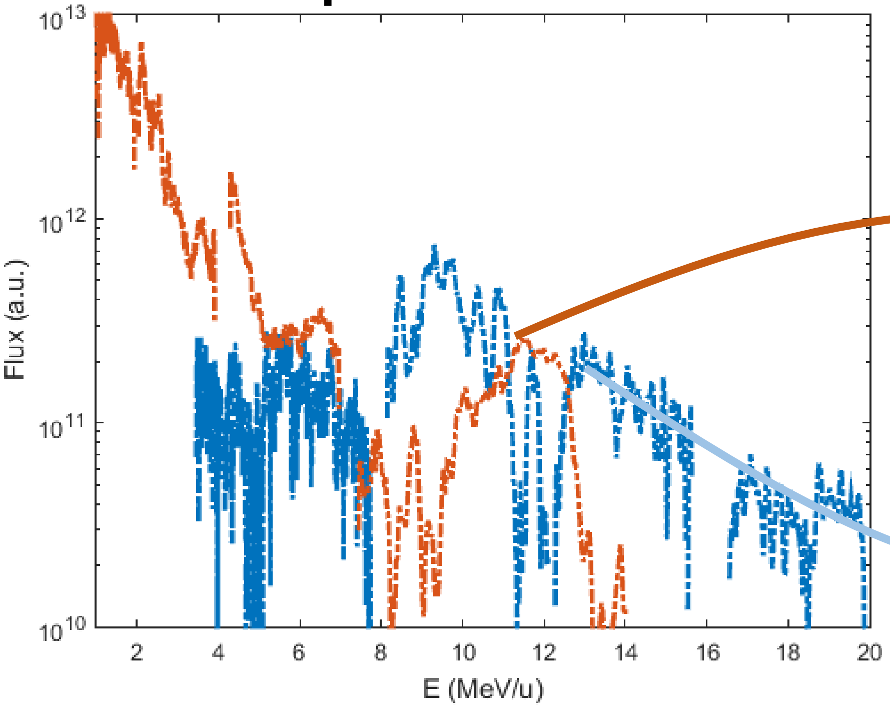


Density Profile

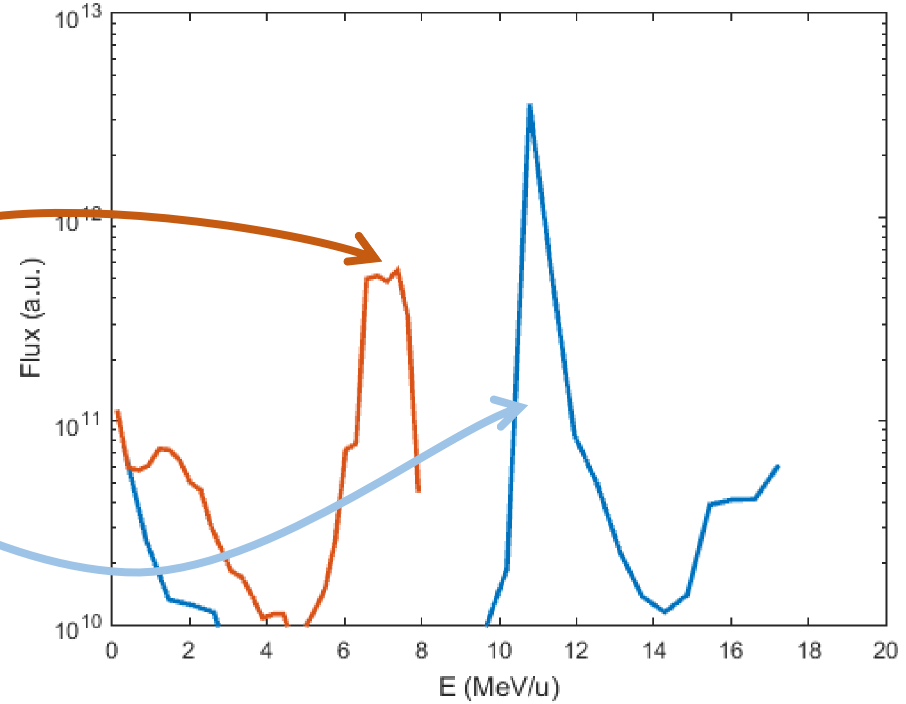


90nm+Au. Ion spectra

Experimental



2D PIC Simulation



Improved bunch shape
+ high energy

Conclusions

- RPA is an intrinsically good mechanism for neutron generation
  - Flux can be further increased including a catcher
- SIT limits the capabilities of RPA
  - Multi-layer targets can help extending LS range to low-density materials
- Neutron spectroscopy allows to retrieve hard-to-get information about interaction itself

Thank you for you attention