Coulomb Dissociation measurement of the $^{15}O(2p,\gamma)^{17}Ne$ cross section

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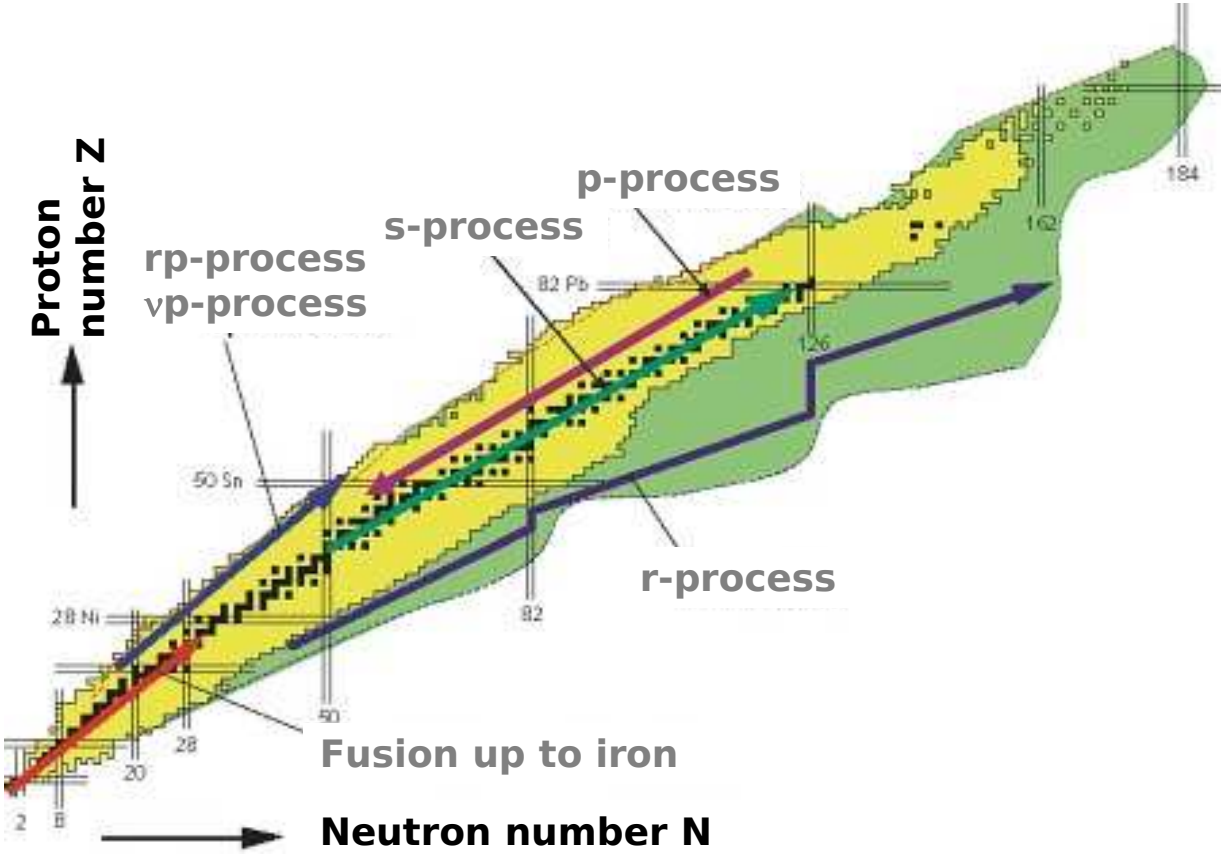
outline

- ***rp*** **process and motivation;**
- **coulomb dissociation as a source of information on radiative capture processes;**
- **experimental setup;**
- **results**
  - **backgraund subtraction;**
  - **coulomb dissociation cross section;**
  - **strength function;**
  - **(γ,*2p*) cross section;**
- **summary.**

rp process

- in cataclysmic binary systems (novae, X-ray bursts);
- sequence of proton captures and β^+ decays;
- the proton capture is inhibited and the long half-life
  => the waiting points.



motivation

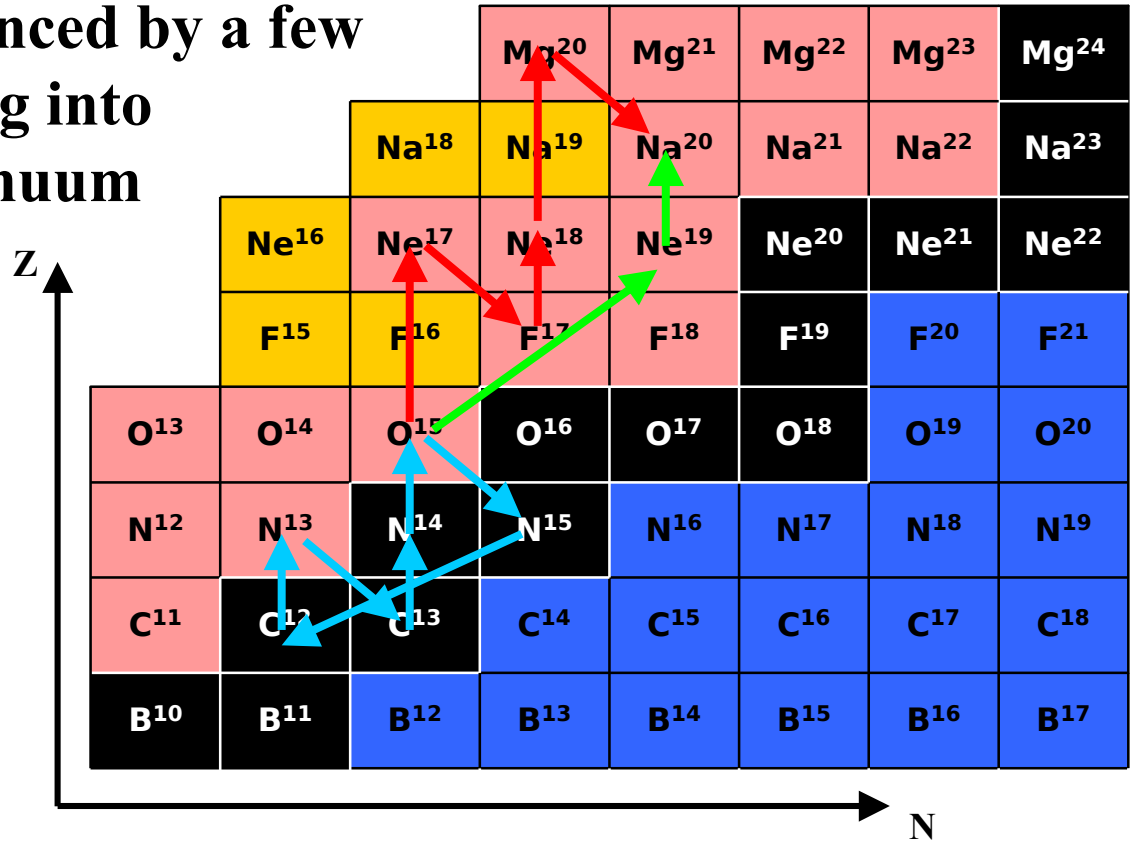
1. the nucleus ^{15}O => a waiting point for the break-out of the CNO cycle

CNO cycle: $^{12}C(p,\gamma)^{13}N(e,\nu)^{13}C(p,\gamma)^{14}N(p,\gamma)^{15}O(e,\nu)^{15}N(p,\alpha)^{12}C$

Heavier elements: $^{15}O(\alpha,\gamma)^{19}Ne(p,\gamma)^{20}Na$

Alternative reaction: $^{15}O(2p,\gamma)^{17}Ne(\beta)^{17}F(p,\gamma)^{18}Ne(2p,\gamma)^{20}Mg(\beta)^{20}Na$

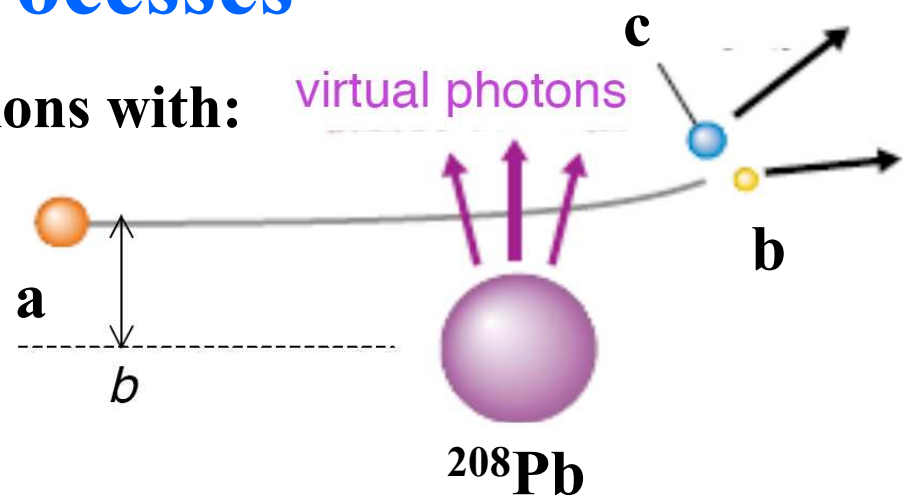
2. the reaction rate can be enhanced by a few orders of magnitude by taking into account the three-body continuum states;



coulomb dissociation as a source of information on radiative capture processes

Useful to measure radiative-capture reactions with:

- **small cross sections;**
- **unstable nuclei;**
- **three particles in entrance channel.**



b + c ⟶ a + γ => γ + a ⟶ b +c (time-reversed process)

the nuclear Coulomb field => a source of the photodisintegration processes

a + Z ⟶ b + c + Z

$$\frac{d\sigma_{\mathrm{CD}}}{dE_\gamma} = \frac{1}{E_\gamma} n\sigma_{(\gamma,b)}$$

← **virtual photon theory**

detailed balance theorem ⟶

$$\sigma_{(b,\gamma)} = \frac{2(2j_a+1)}{(2j_b+1)(2j_c+1)} \frac{k_\gamma^2}{k^2} \sigma_{(\gamma,b)}$$

coulomb dissociation as a source of information on radiative capture processes

Advantages:

- high virtual photon flux;
- large cross section at low E_{cm};
- charged particle detection;
- kinematically focused;
- experiments with radioactive ion beams possible.

Disadvantages:

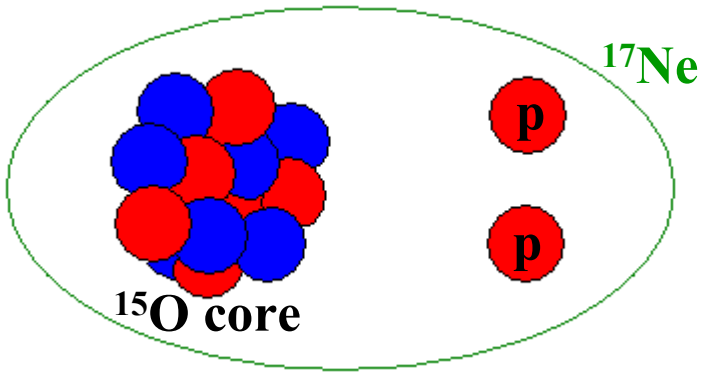
- indirect method;
- bad energy resolution;
- multipole admixtures must be clarified;
- nuclear contributions.

^{17}Ne ground state

The uncertain part => the configuration of the two protons outside the ^{15}O core, which occupy either *s*-wave ([s^2]) or *d*-wave ([d^2]) orbitals

$$\Psi_{g.s.} \sim \alpha[s^2] + \beta[d^2]$$

[s^2] – dominant

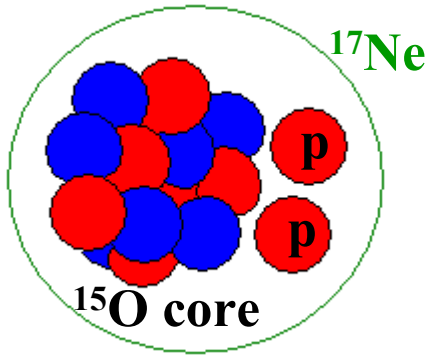


large σ_{CD}

↓

large $\sigma_{(2p,\gamma)}$

[d^2] – dominant



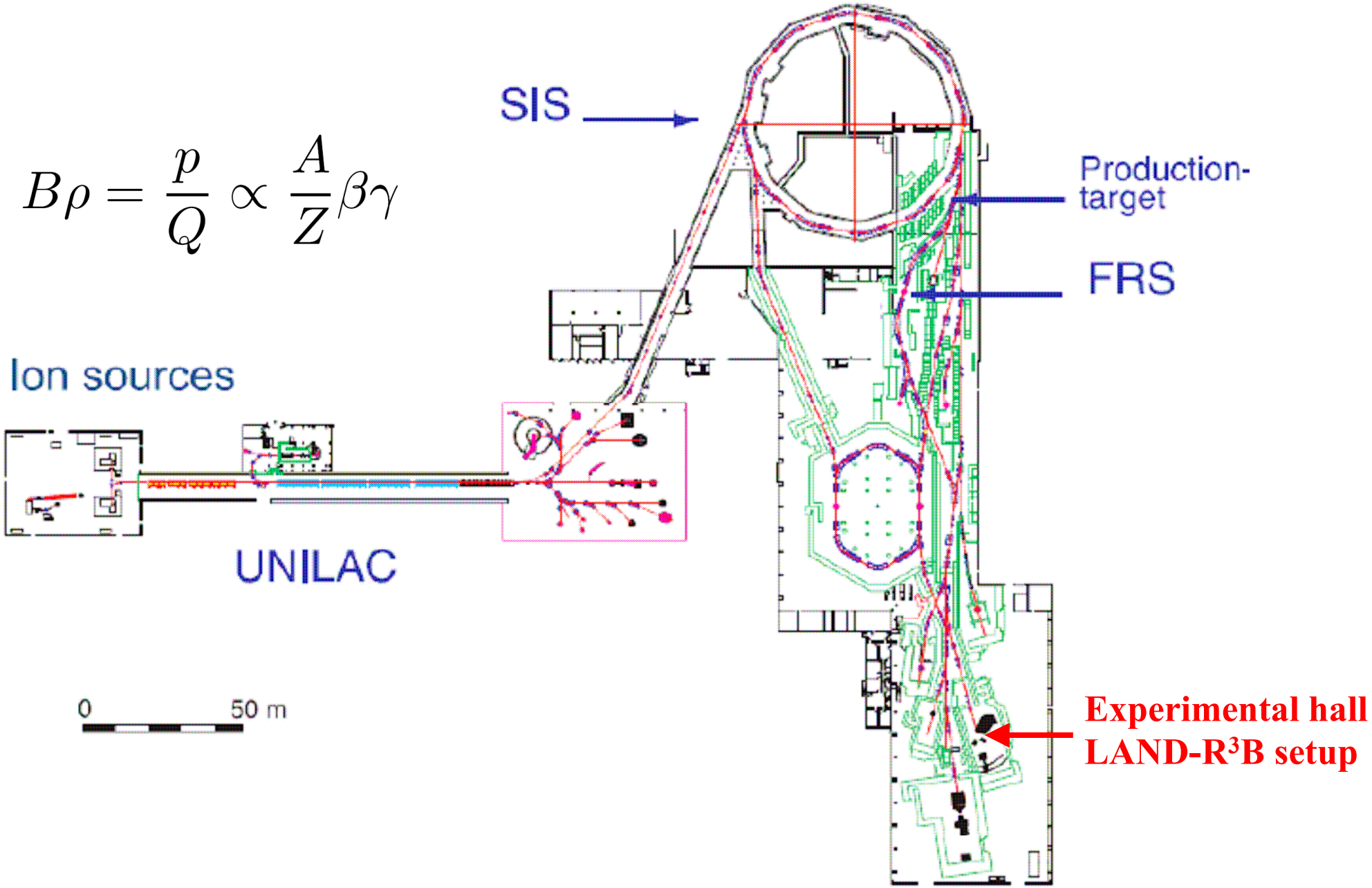
small σ_{CD}

↓

small $\sigma_{(2p,\gamma)}$

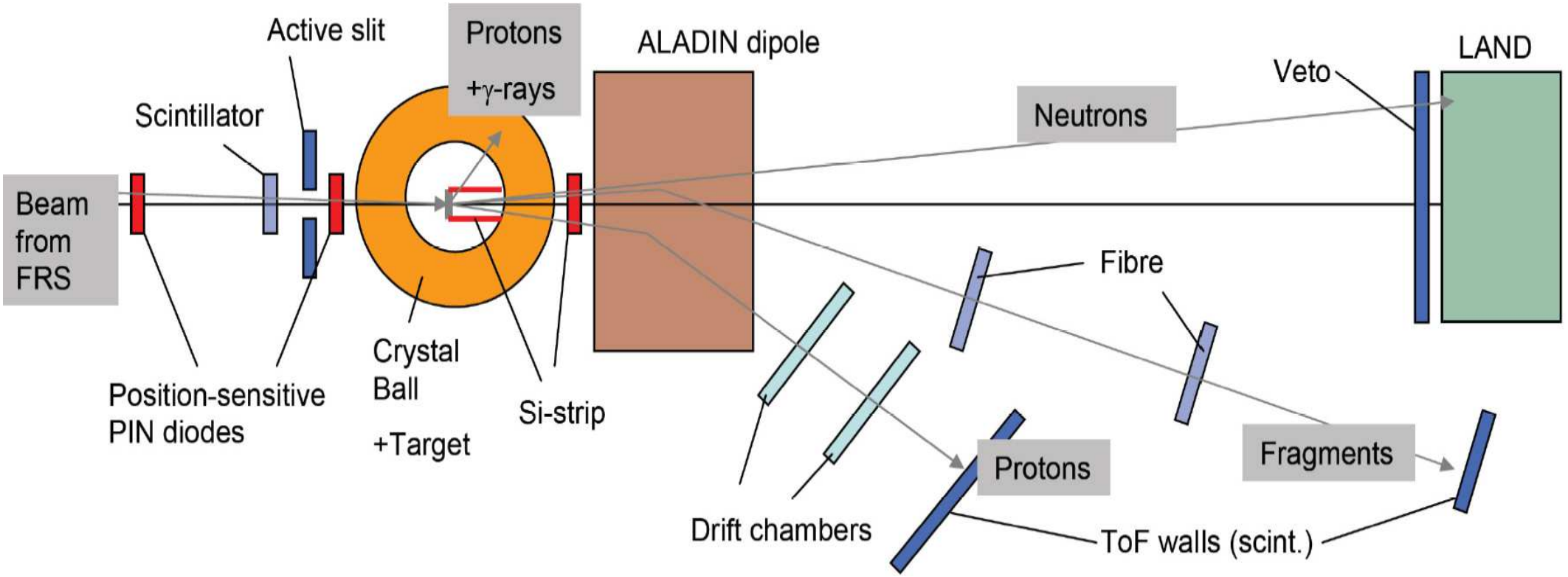
production of exotic beam setup

$$B\rho = \frac{p}{Q} \propto \frac{A}{Z}\beta\gamma$$



LAND-R^{3}B experimental setup

The energy of incoming beam = 500 MeV/u



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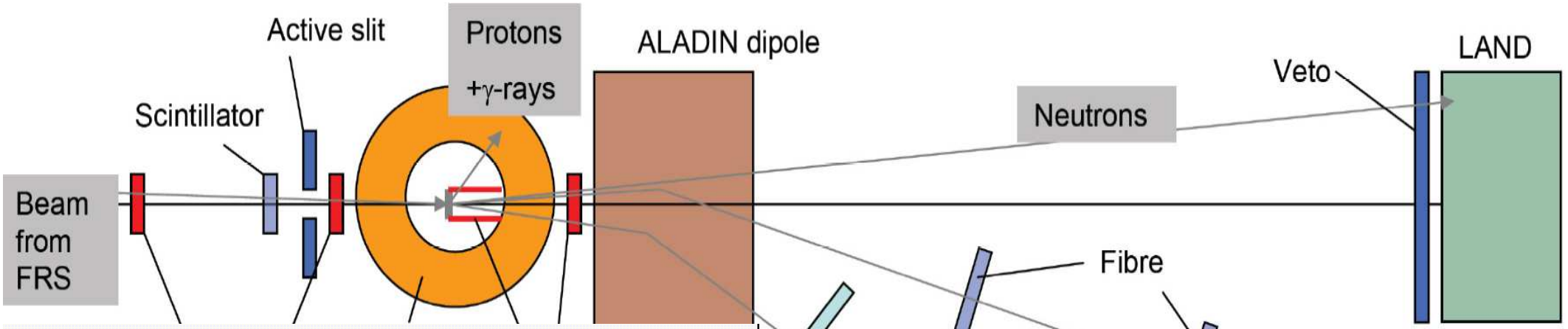

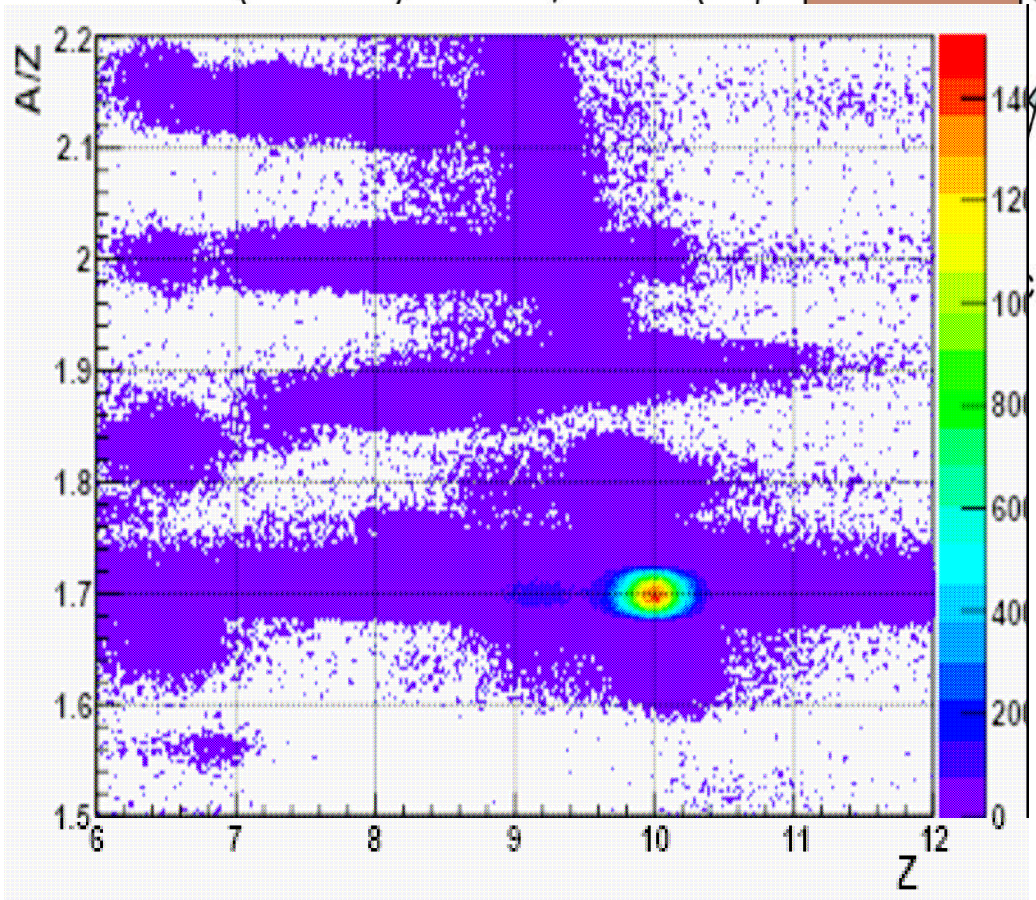

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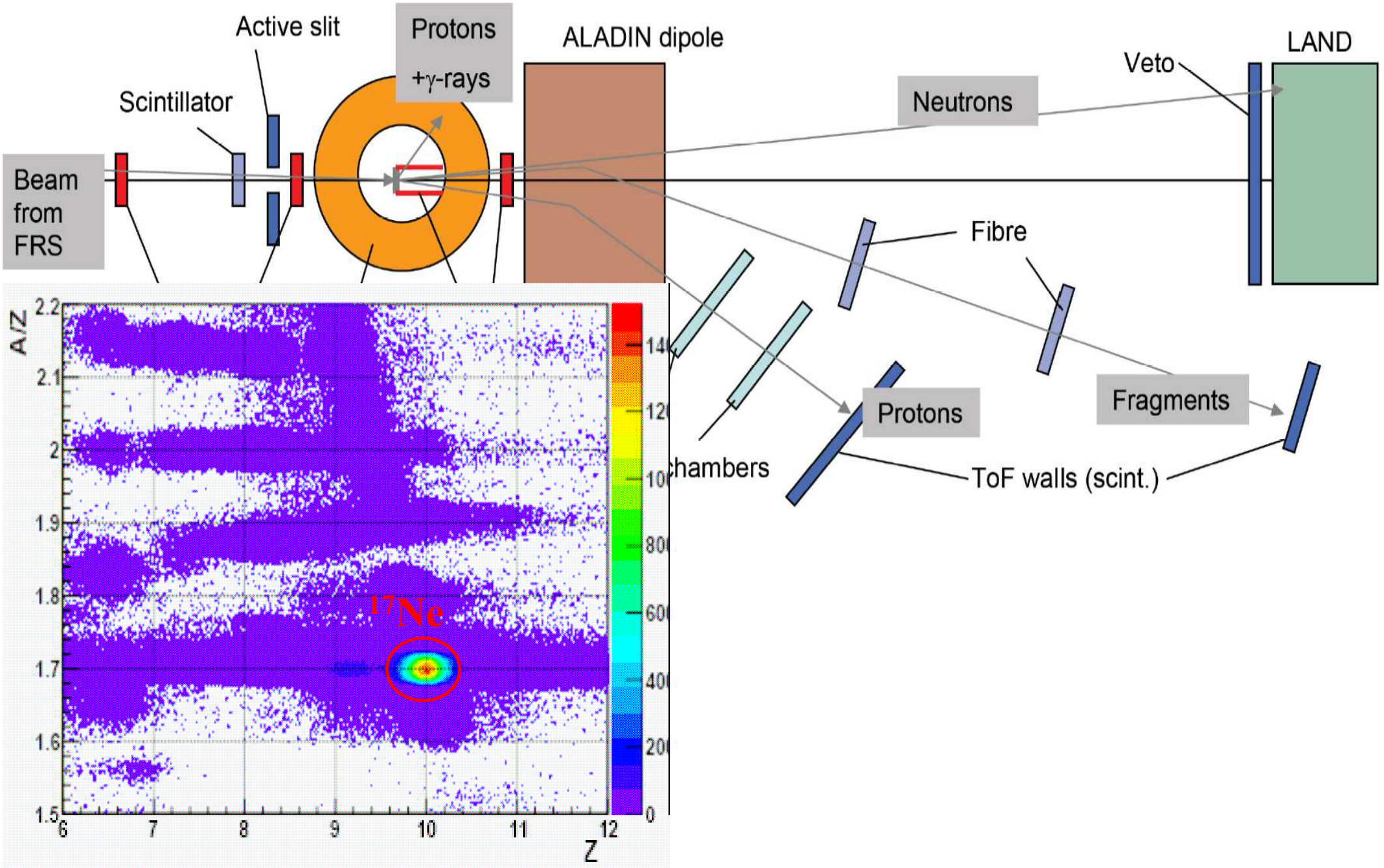

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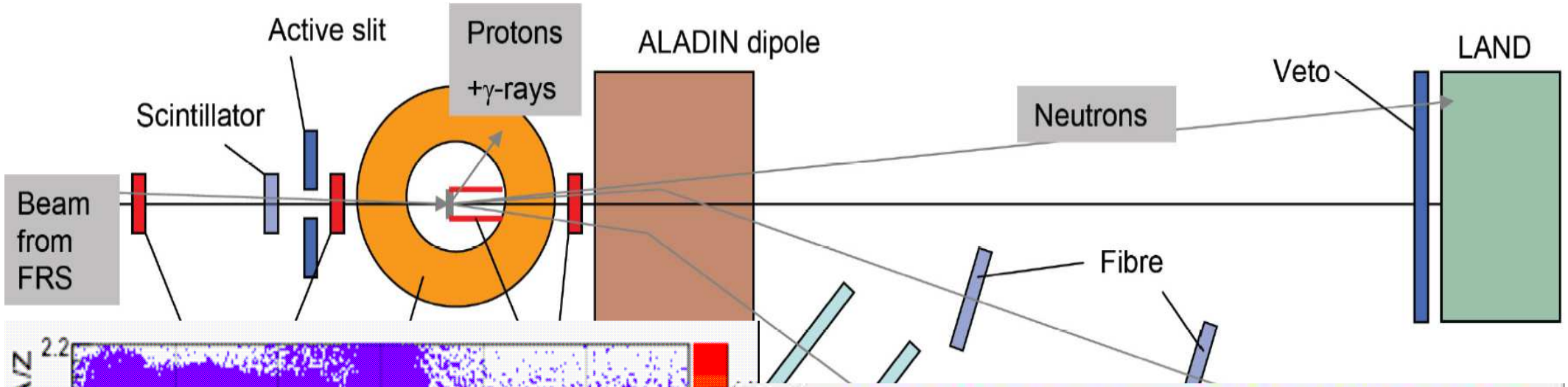

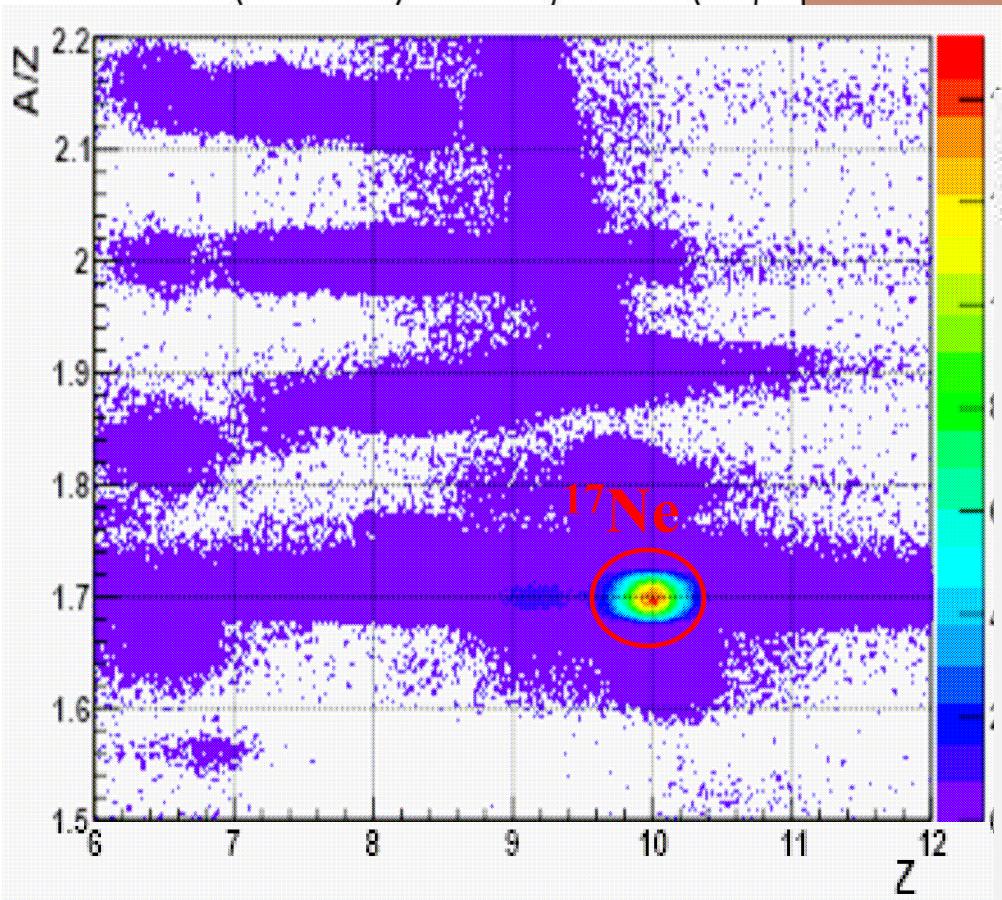

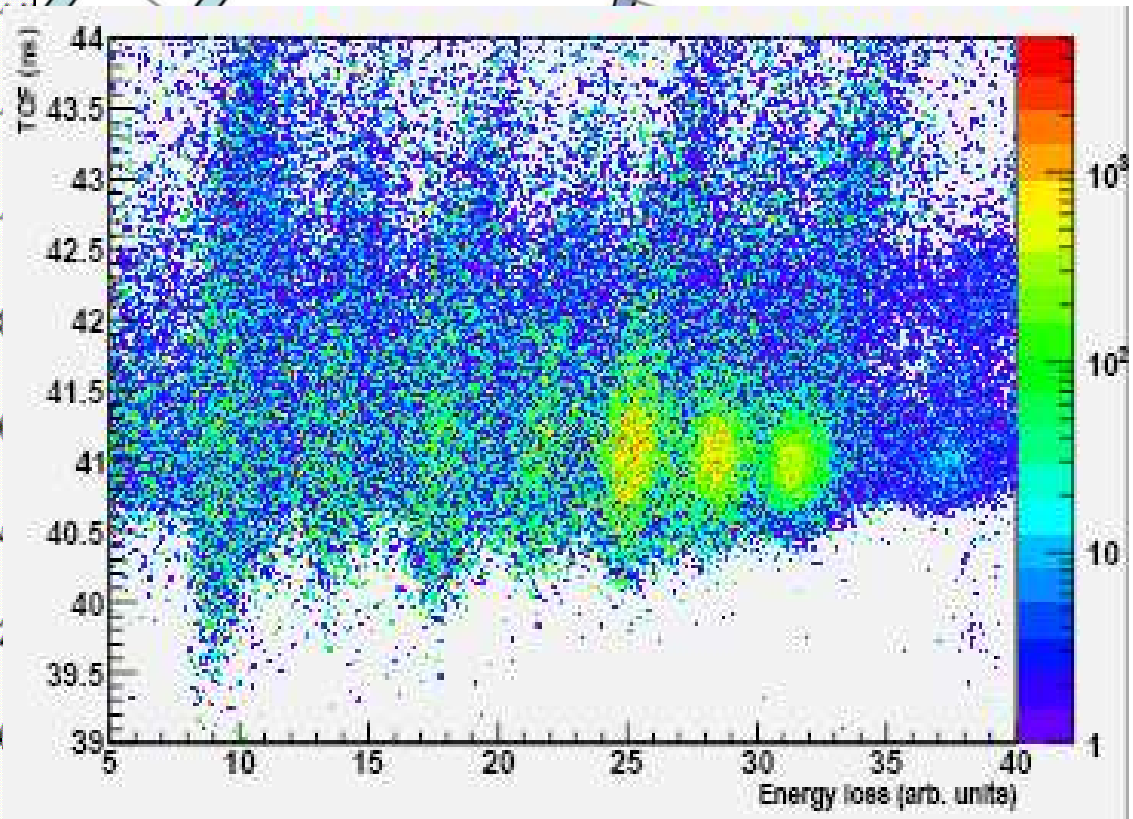

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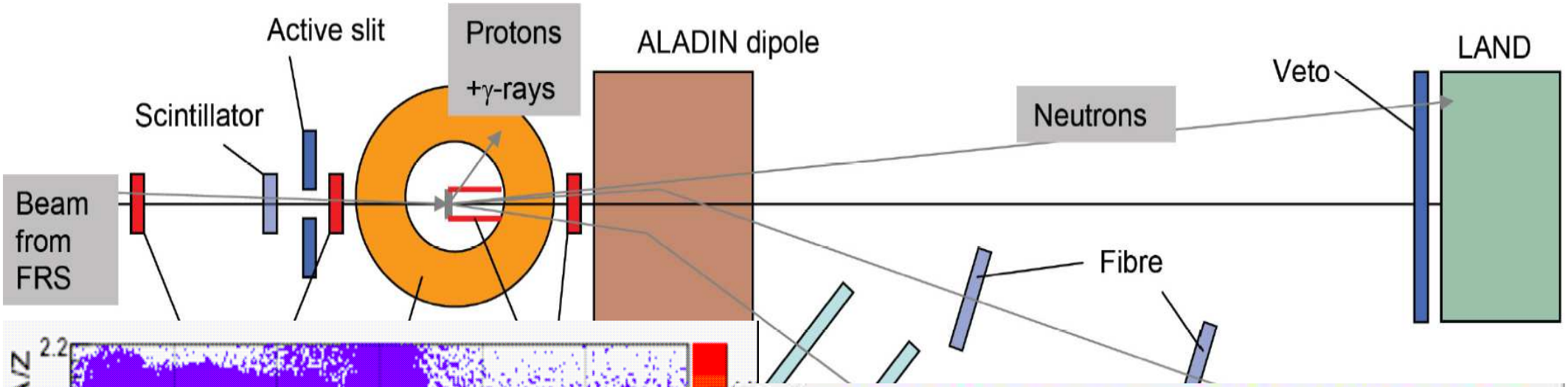
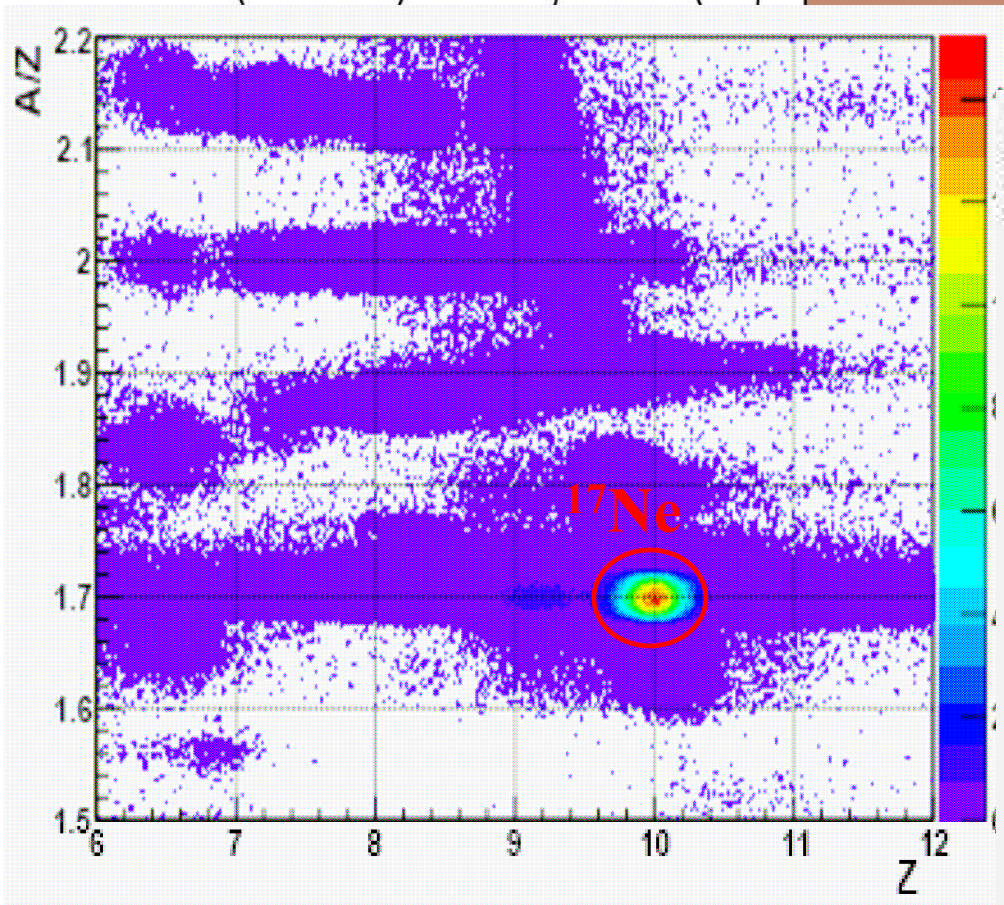
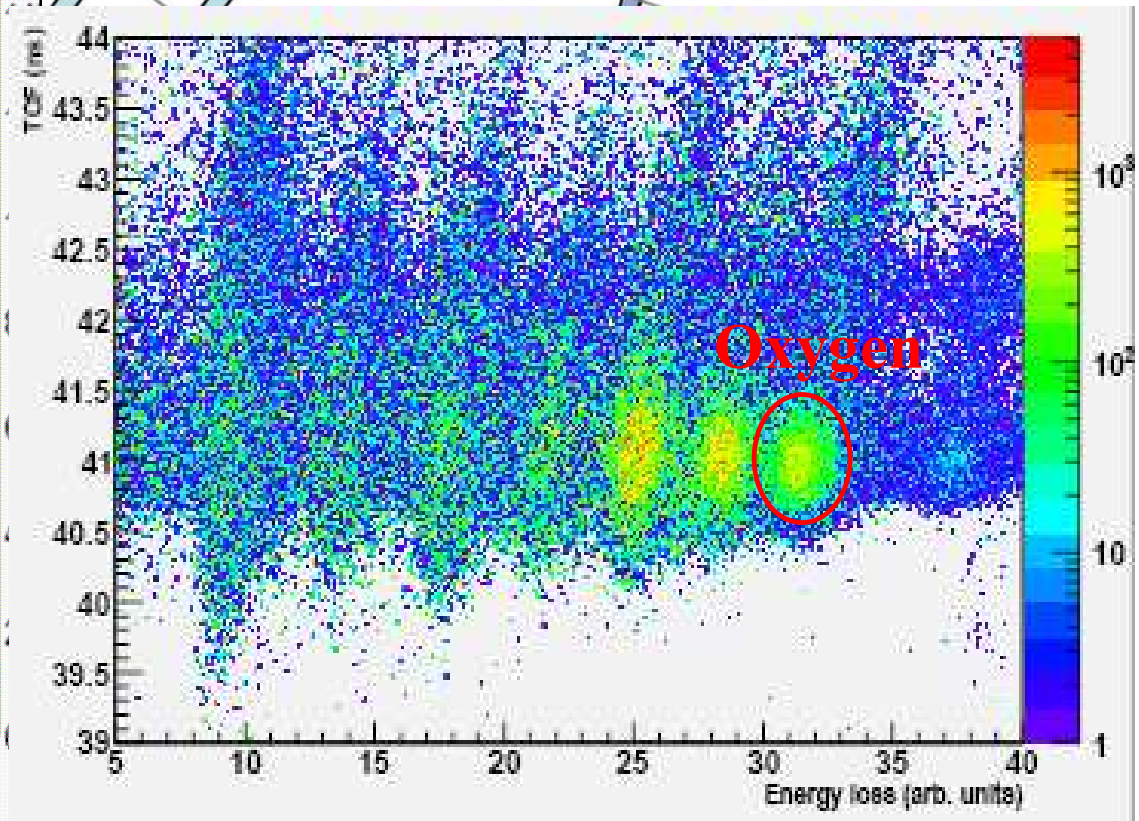
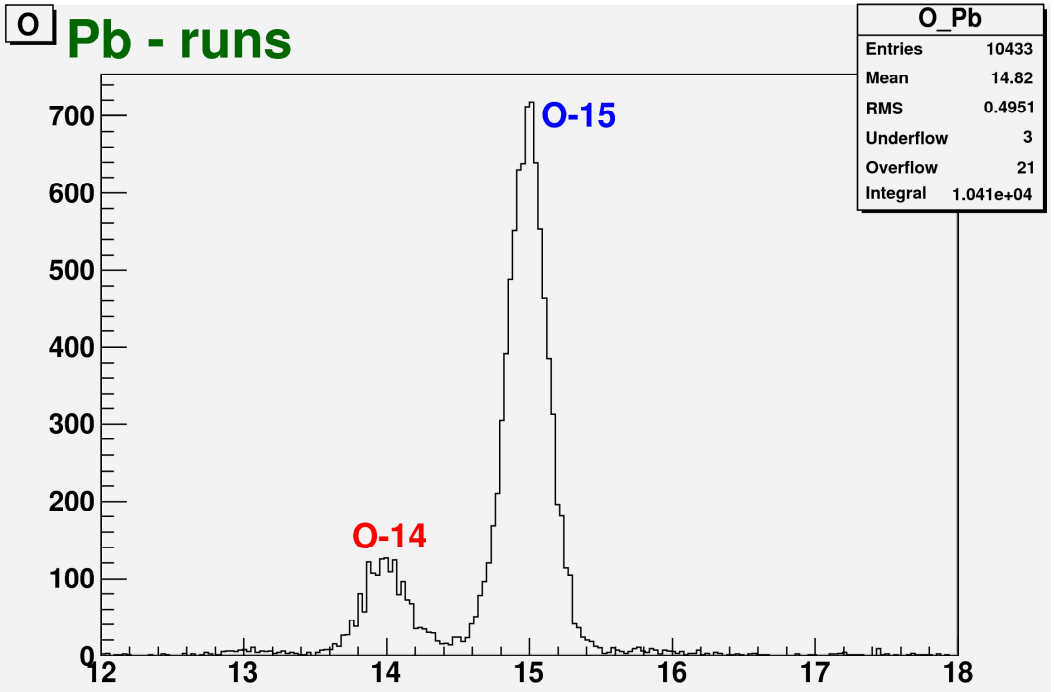
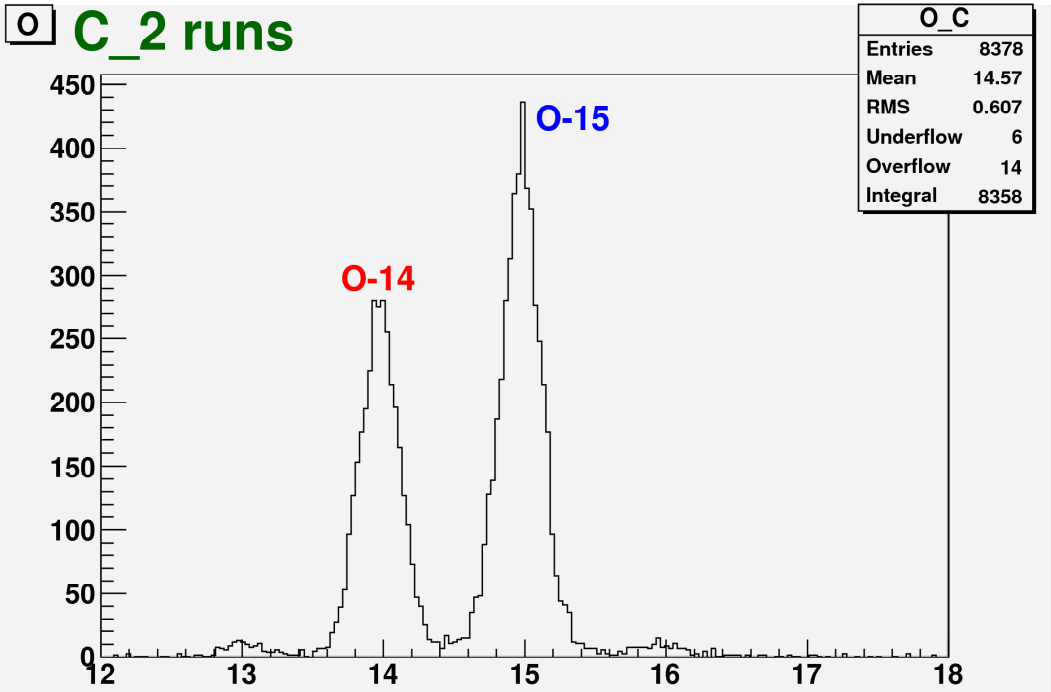


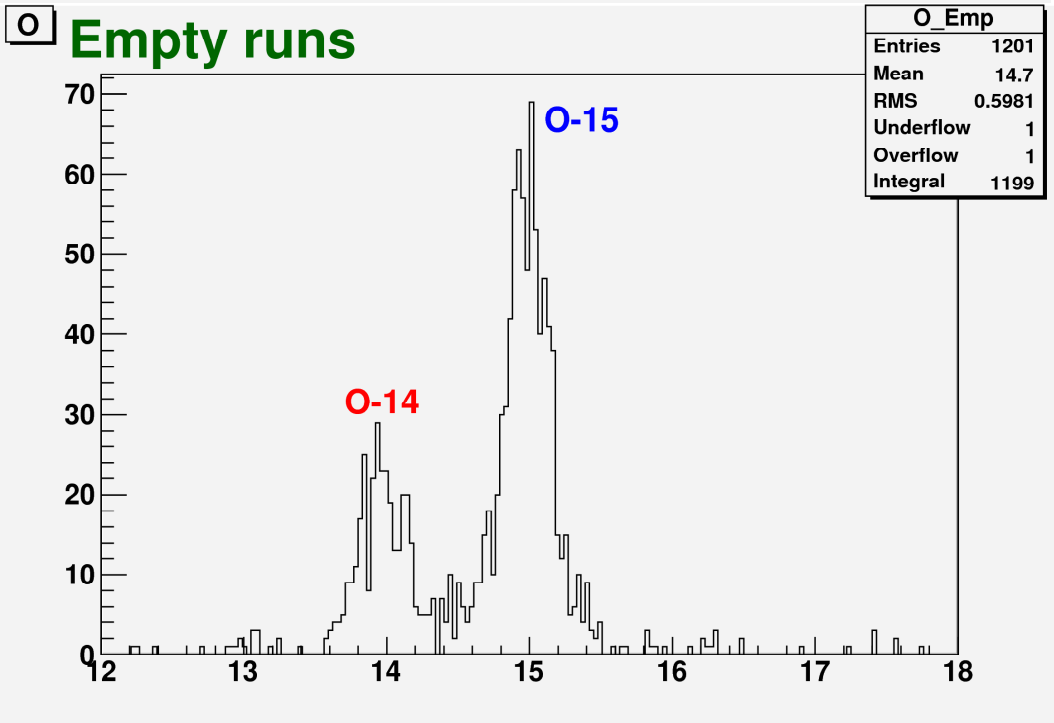


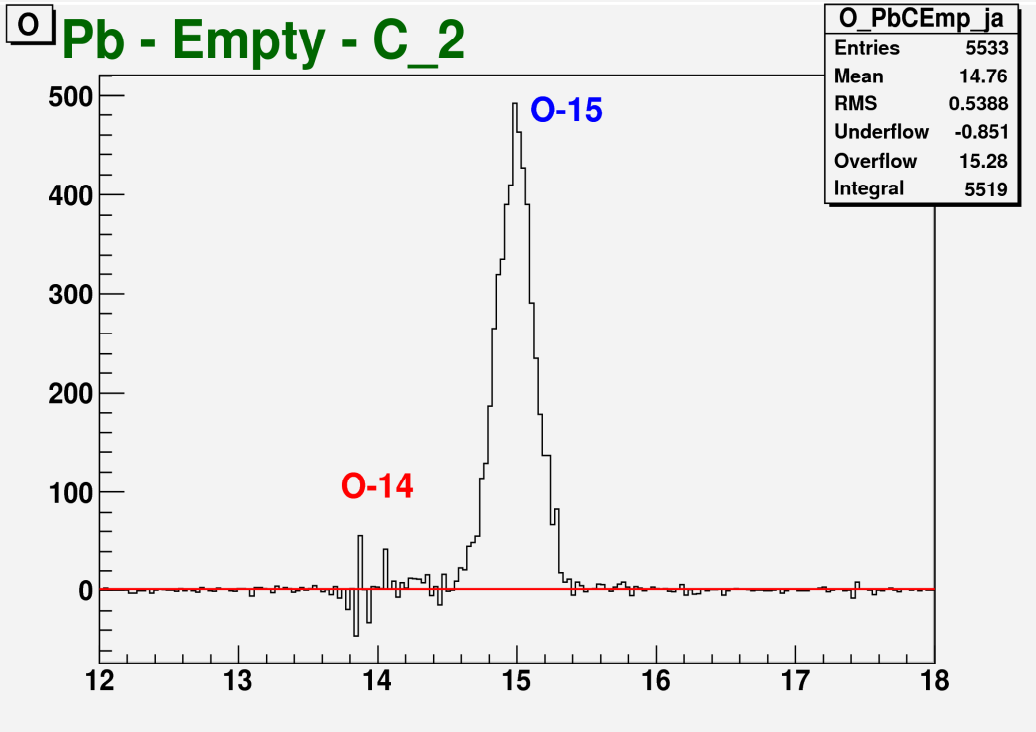


background subtraction



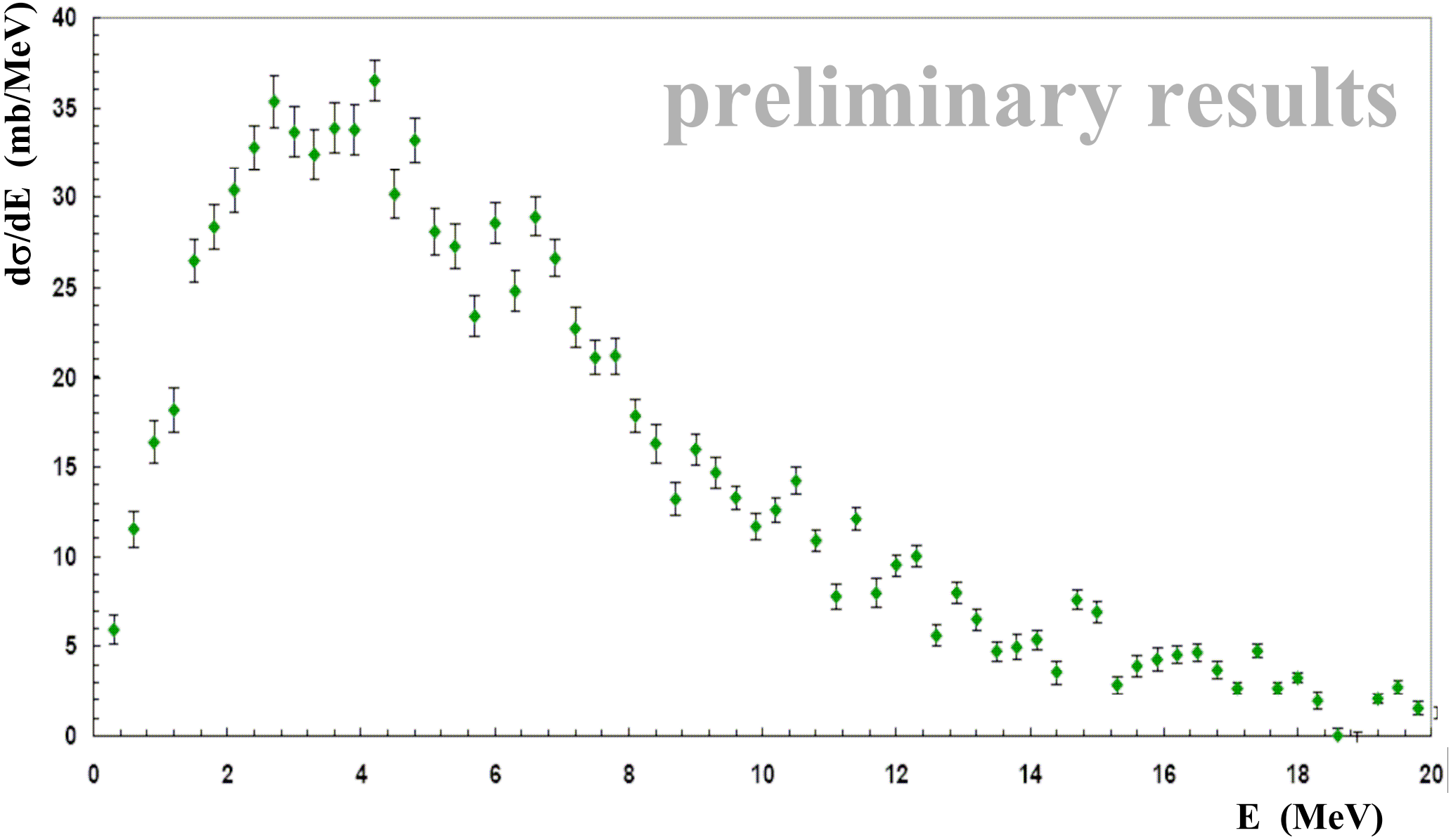






coulomb dissociation cross section

$$\sigma_{\mathrm{CD}} = p_{\mathrm{Pb}}\left(\frac{M_m(Pb)}{d_{\mathrm{Pb}}N_{Av}}\right) - p_{\mathrm{C}}\left(\alpha_{\mathrm{Pb}}\frac{M_m(C)}{d_{\mathrm{C}}N_{Av}}\right) - p_{emp}\left(\frac{M_m(Pb)}{d_{\mathrm{Pb}}N_{Av}} - \alpha_{\mathrm{Pb}}\frac{M_m(C)}{d_{\mathrm{C}}N_{Av}}\right)$$



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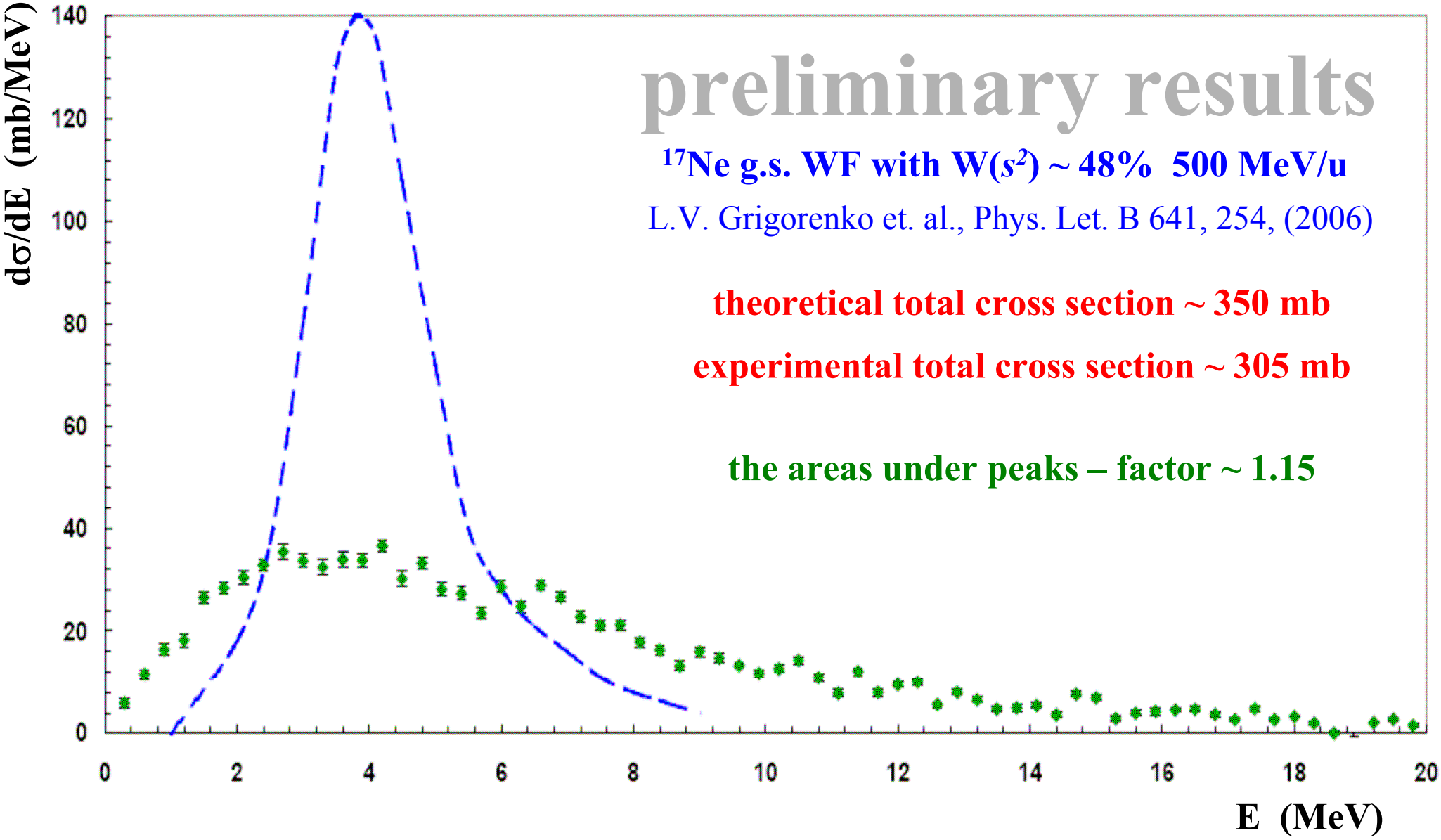


preliminary results

^{17}Ne g.s. WF with W(s^2) ~ 48% 500 MeV/u

L.V. Grigorenko et. al., Phys. Let. B 641, 254, (2006)

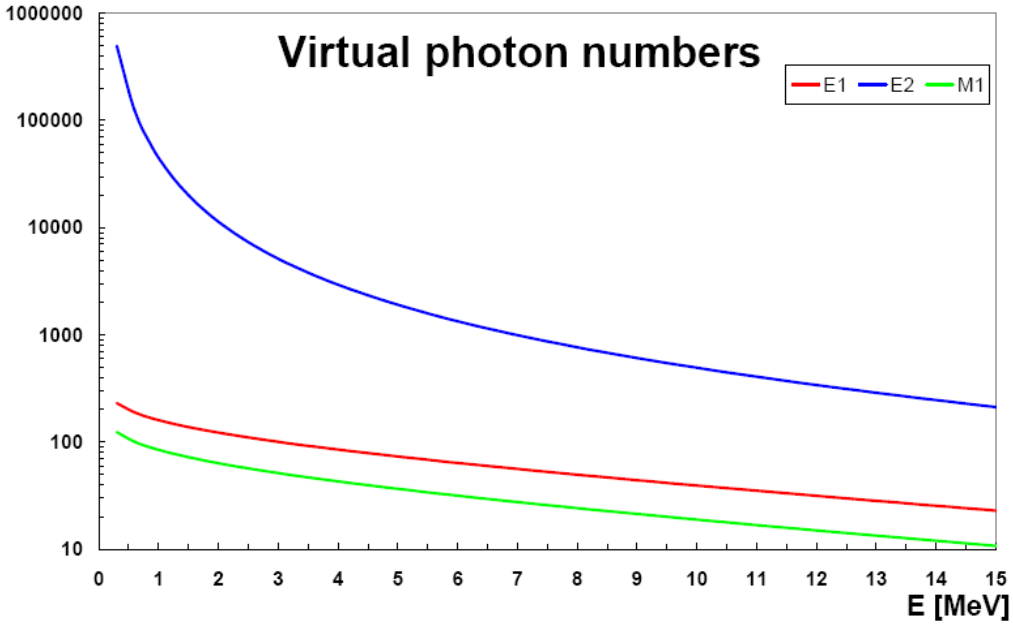
theoretical total cross section ~ 350 mb

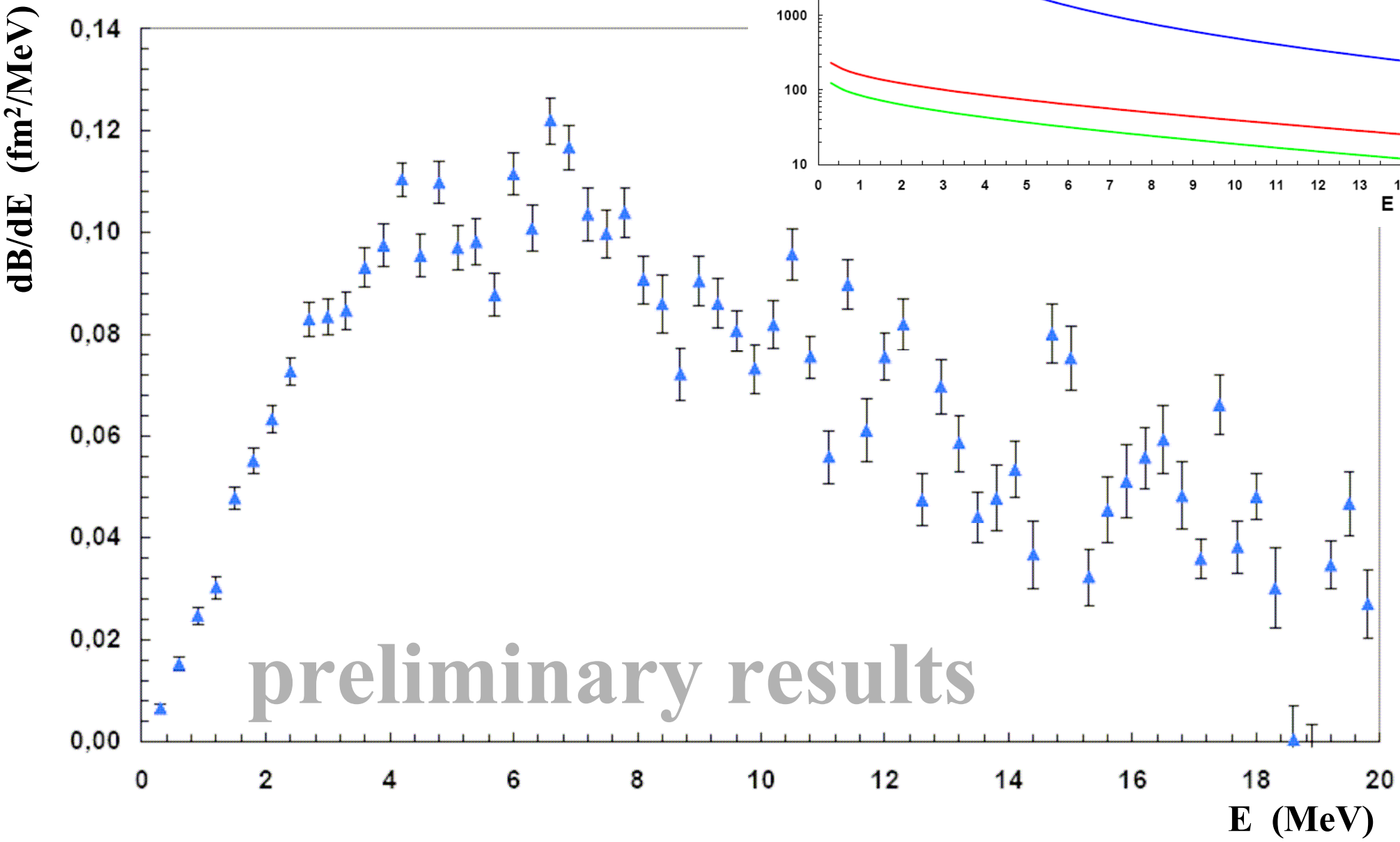
experimental total cross section ~ 305 mb

the areas under peaks – factor ~ 1.15

E1 strength function

$$\frac{d\sigma_{\mathrm{CD}}}{dE} = \frac{16\pi^3}{9\hbar c} N(E_\gamma) \frac{dB}{dE}$$





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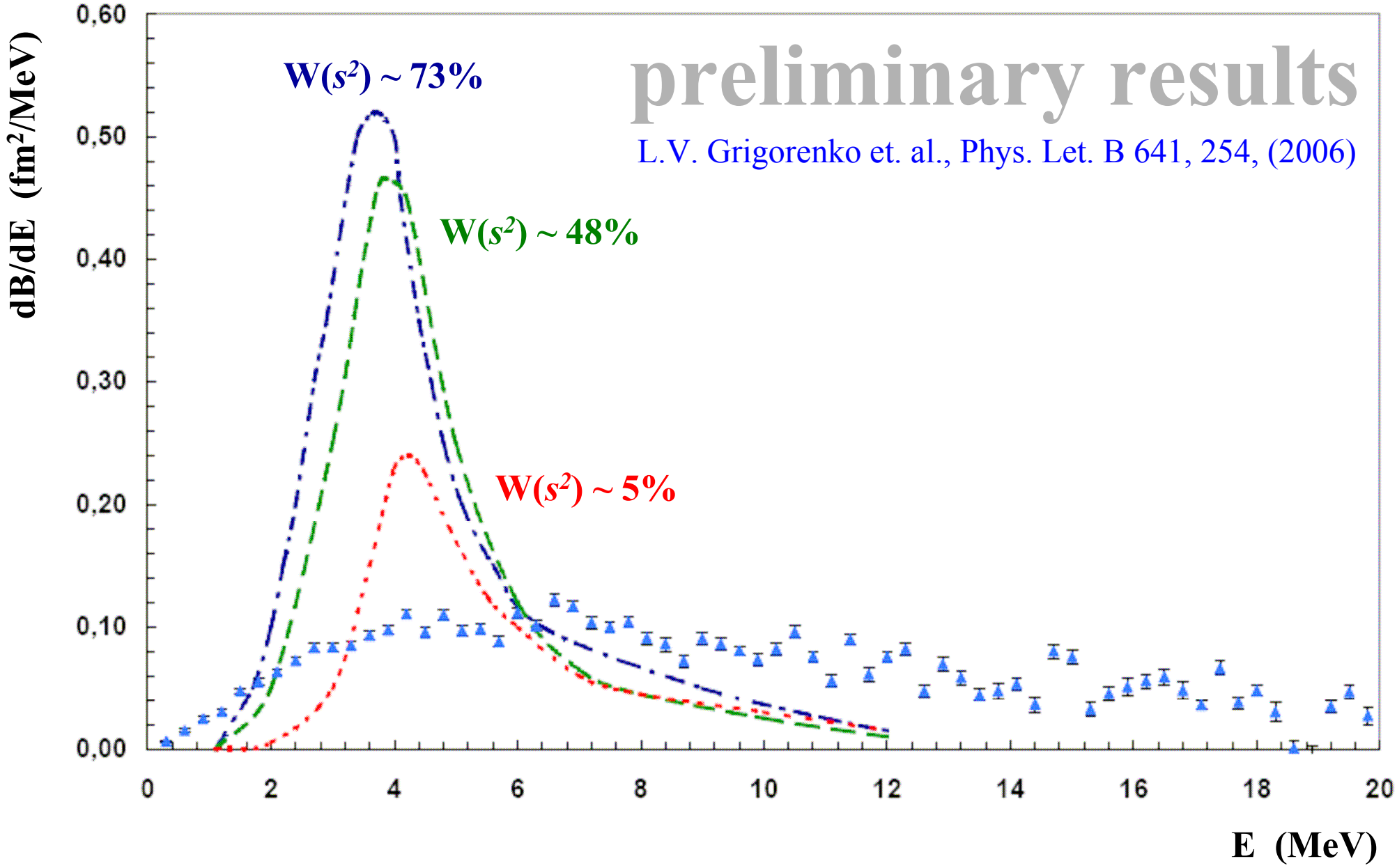
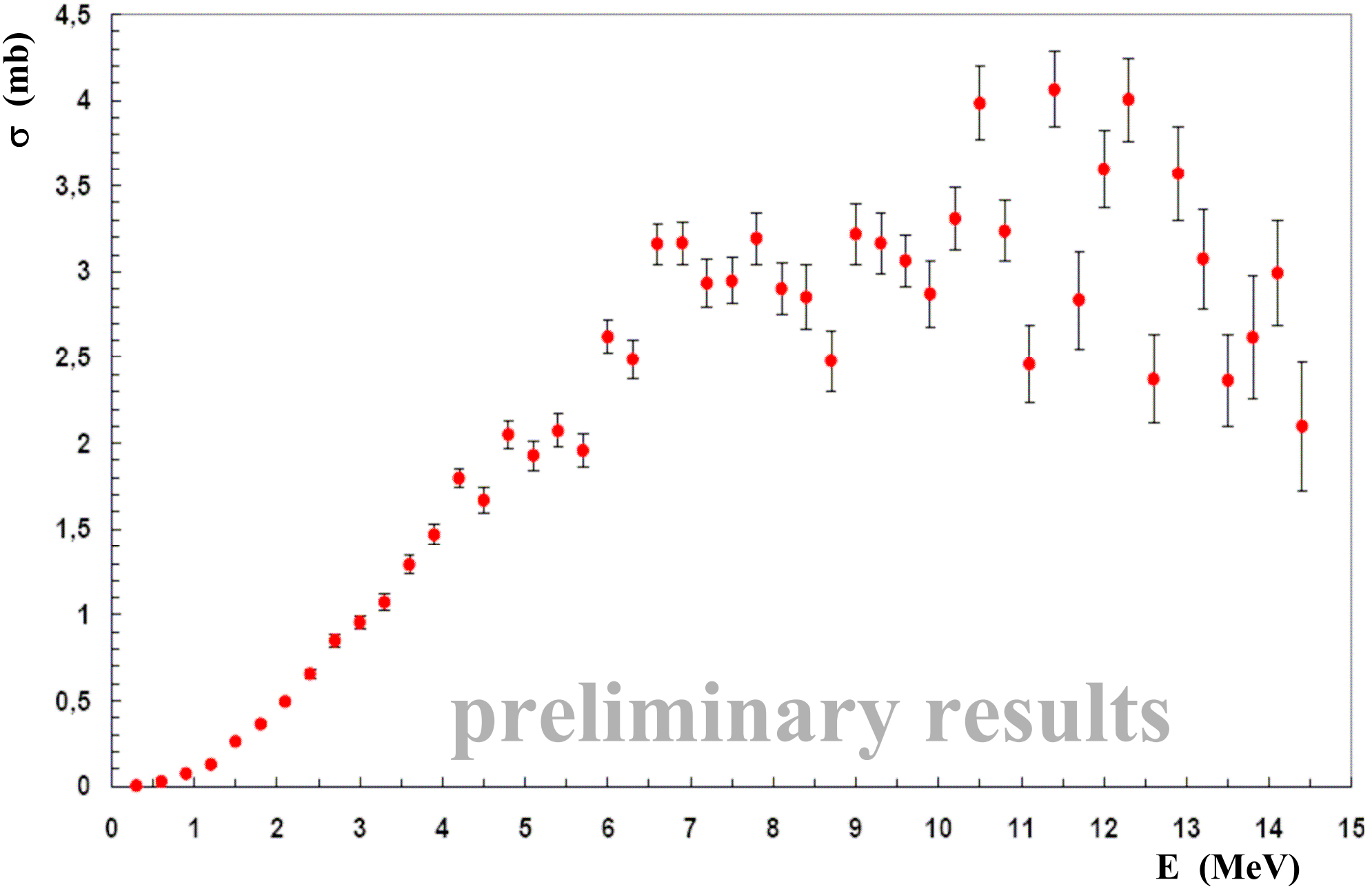


(γ,2p) cross section



summary

- **the Coulomb dissociation method => only one way to the three particles in entrance channel measurements;**

- **the preliminary Coulomb dissociation cross section is consistent with the theoretical prediction;**

- **^{17}Ne is the halo nucleus ?**

- **the calculation of ^{15}O($2p,\gamma$)^{17}Ne cross section => in progress.**

Collaboration:

T. Aumann[1], M. Heil[1], R. Plag[1], F. Wamers[1]
for LAND-R^{3}B collaboration

1. Kernreaktionen und Nuklear Astrophysik, GSI Darmstadt, Germany

Thank you!