

SUMTRAIC 2025

X-ray diagnostics and runaway electron measurement at GOLEM

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Helpers: Jaroslav Cerovsky

❖ Fusion Challenge

- Runaway electrons (REs) can reach 10's of MeV.
- Serious threat for plasma-facing components in large tokamaks like ITER.

❖ Why X-ray?

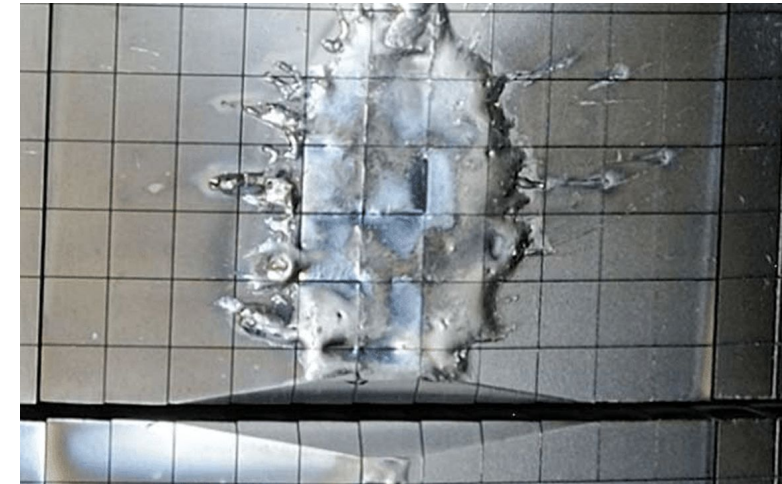
- REs emits bremsstrahlung X-ray when colliding with plasma /vessel/limiter.
- X-ray provide a non-intrusive diagnostic for RE detection.

❖ Why GOLEM?

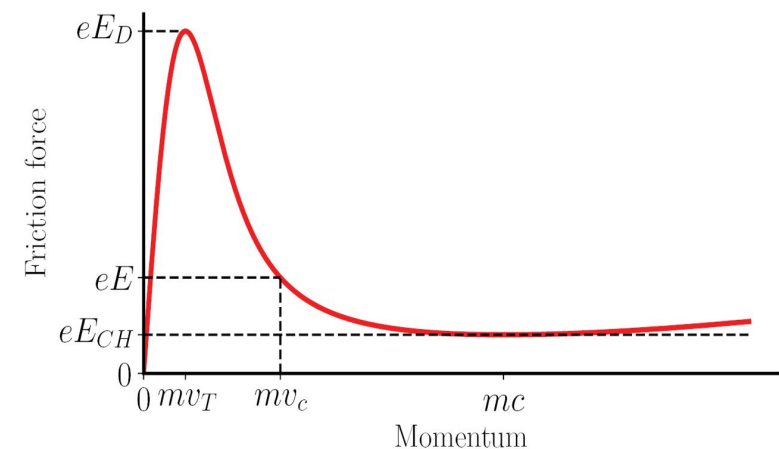
- Good for diagnostics development and testing.
- Accessible for hands-on experiment and training.

❖ Goal

- Analyse X-ray diagnostics to study RE dynamics



Courtesy: "EUROfusion"

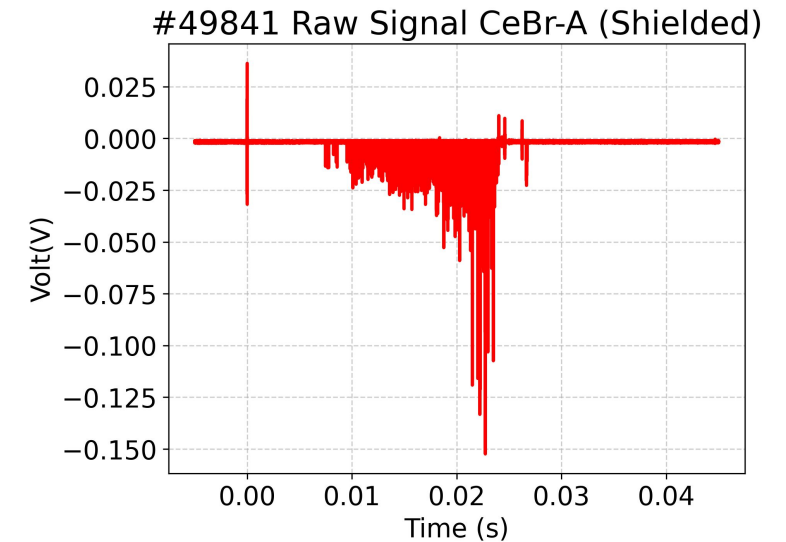
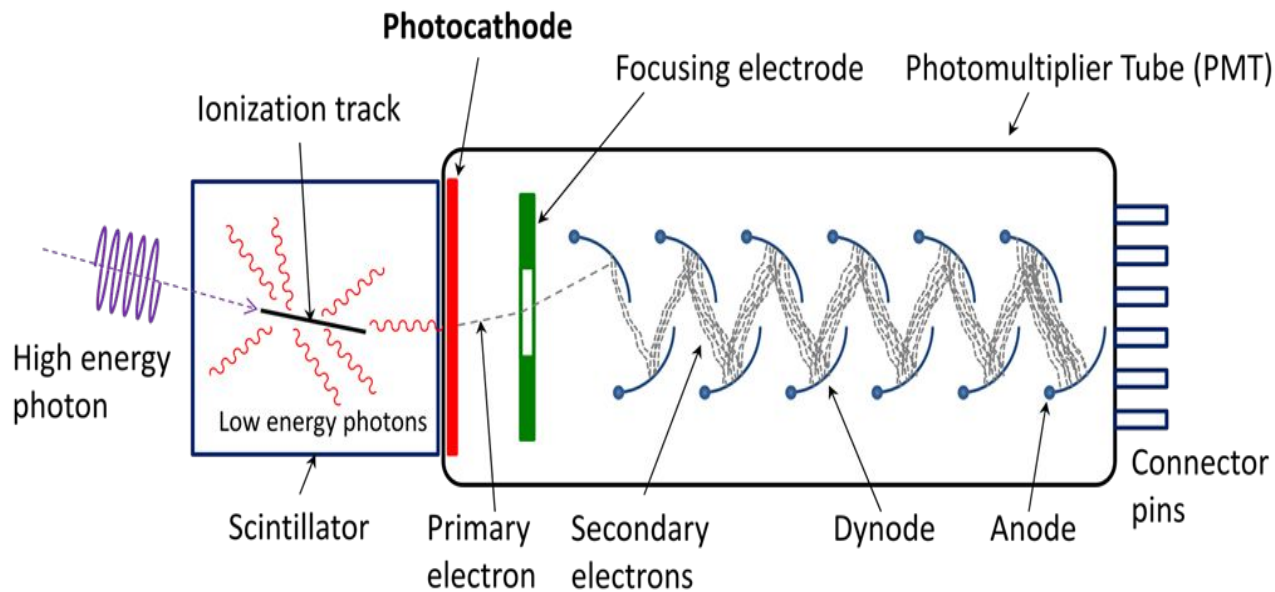


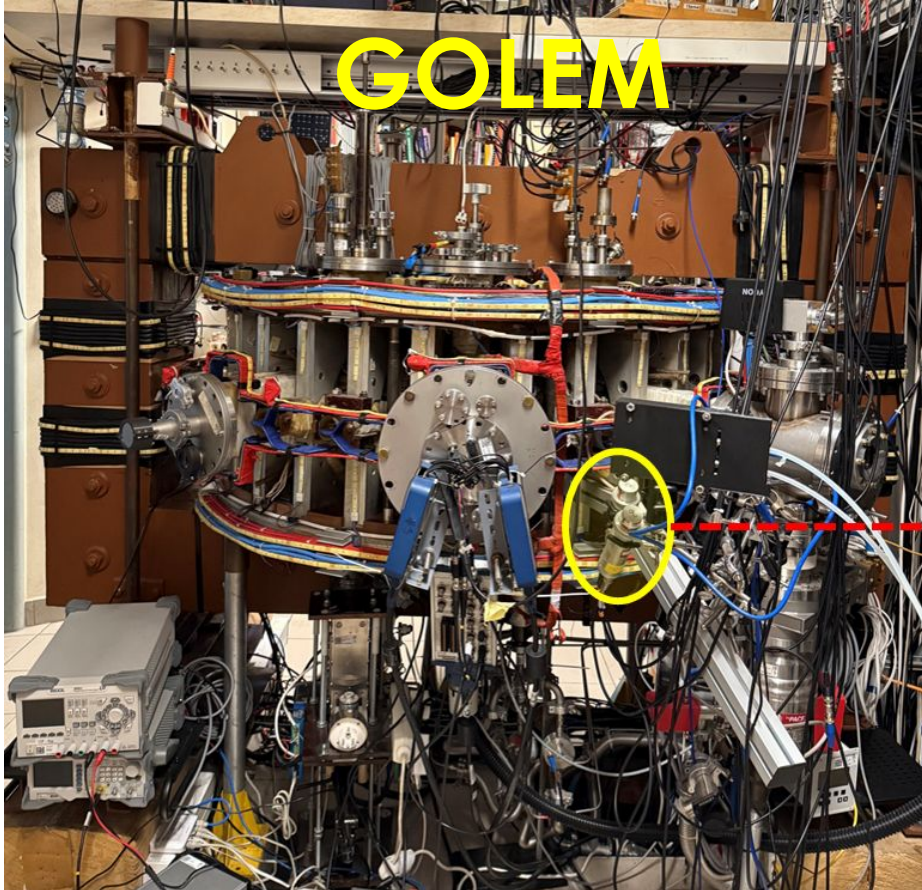
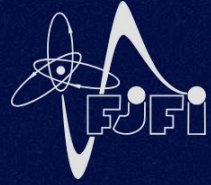
doi.org/10.1088/1741-4326/ab1822

- ❖ A radiation detector that converts ionizing radiation into light, which is then detected and measured.
- ❖ Used for detecting alpha, beta, gamma rays, and neutrons

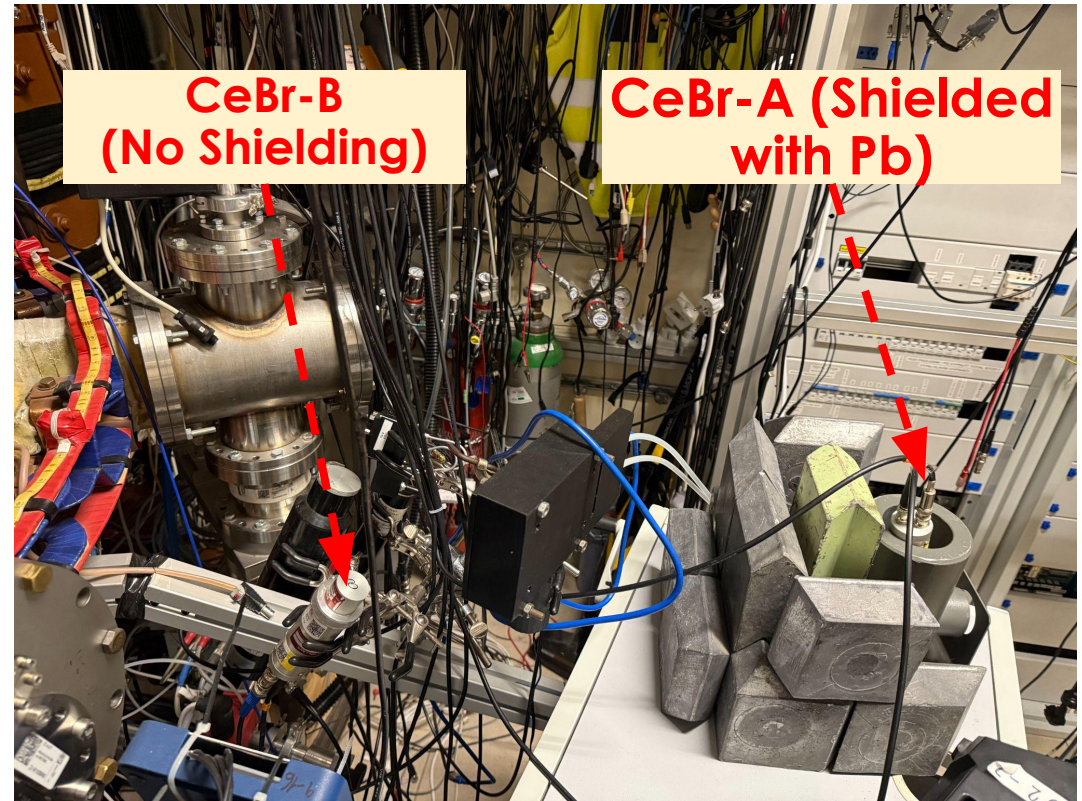
★ Importance

- Provides high sensitivity and energy measurement for radiation detection.
- Used in medical imaging, nuclear physics, and radiation safety.



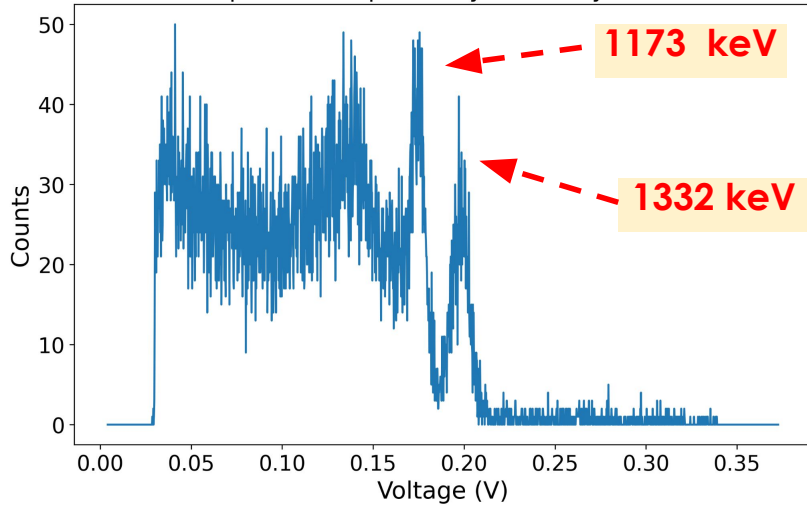


CeBr3

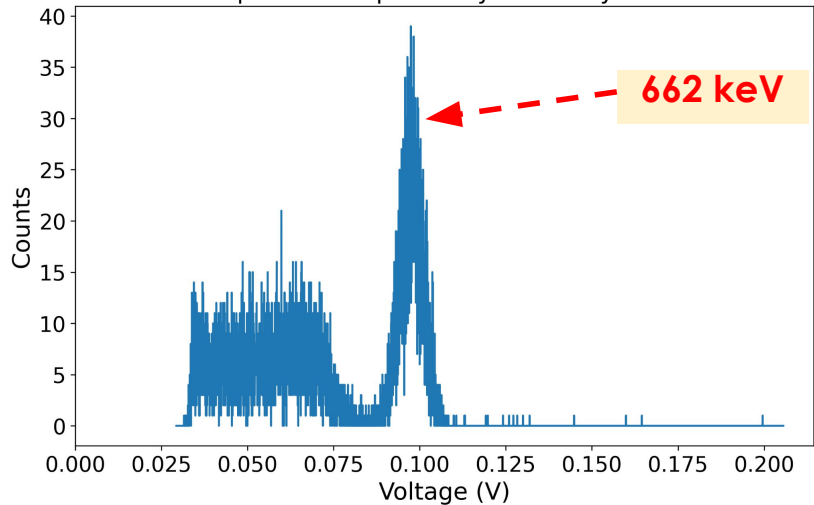




Co-60 Spectrum Captured by CeBr₃ Crystal at 600V



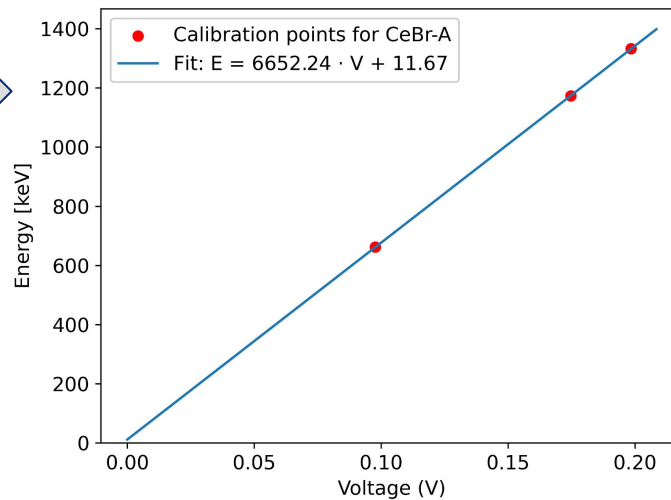
Cs-137 Spectrum Captured by CeBr₃ Crystal at 600V



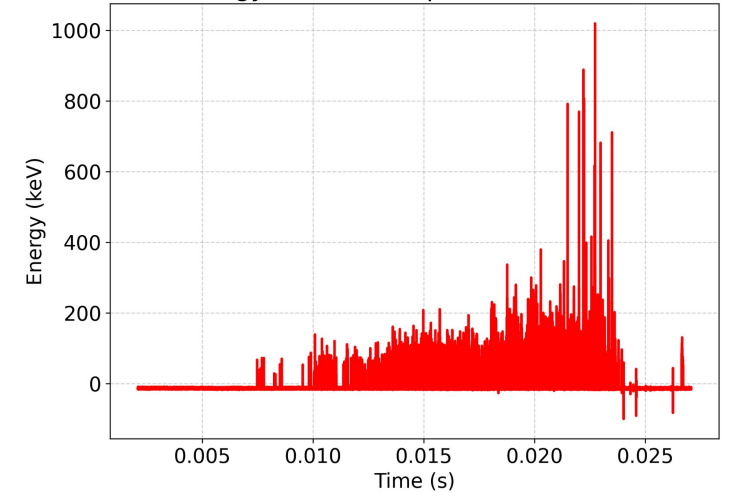
spectrum captured by Standard Sources

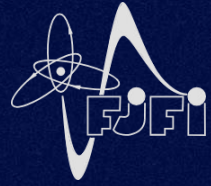
Produce linear fit to have calibration points

Calibrate the raw spectrum after the experiment



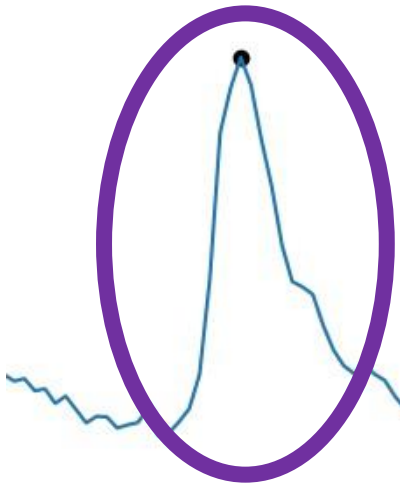
#49841 Energy Calibrated Spectrum CeBr-A (Shielded)



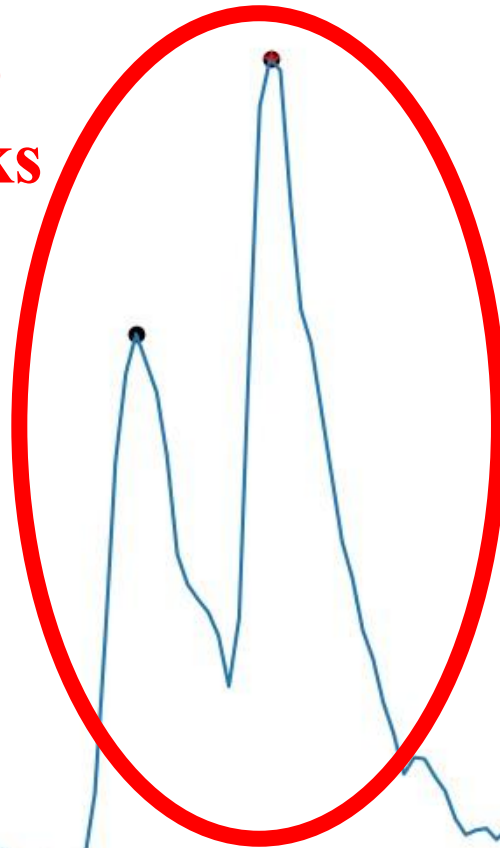




Clean Peak



Pile-up of Peaks



Pile up filter
time = 50 nsec

Find all peaks



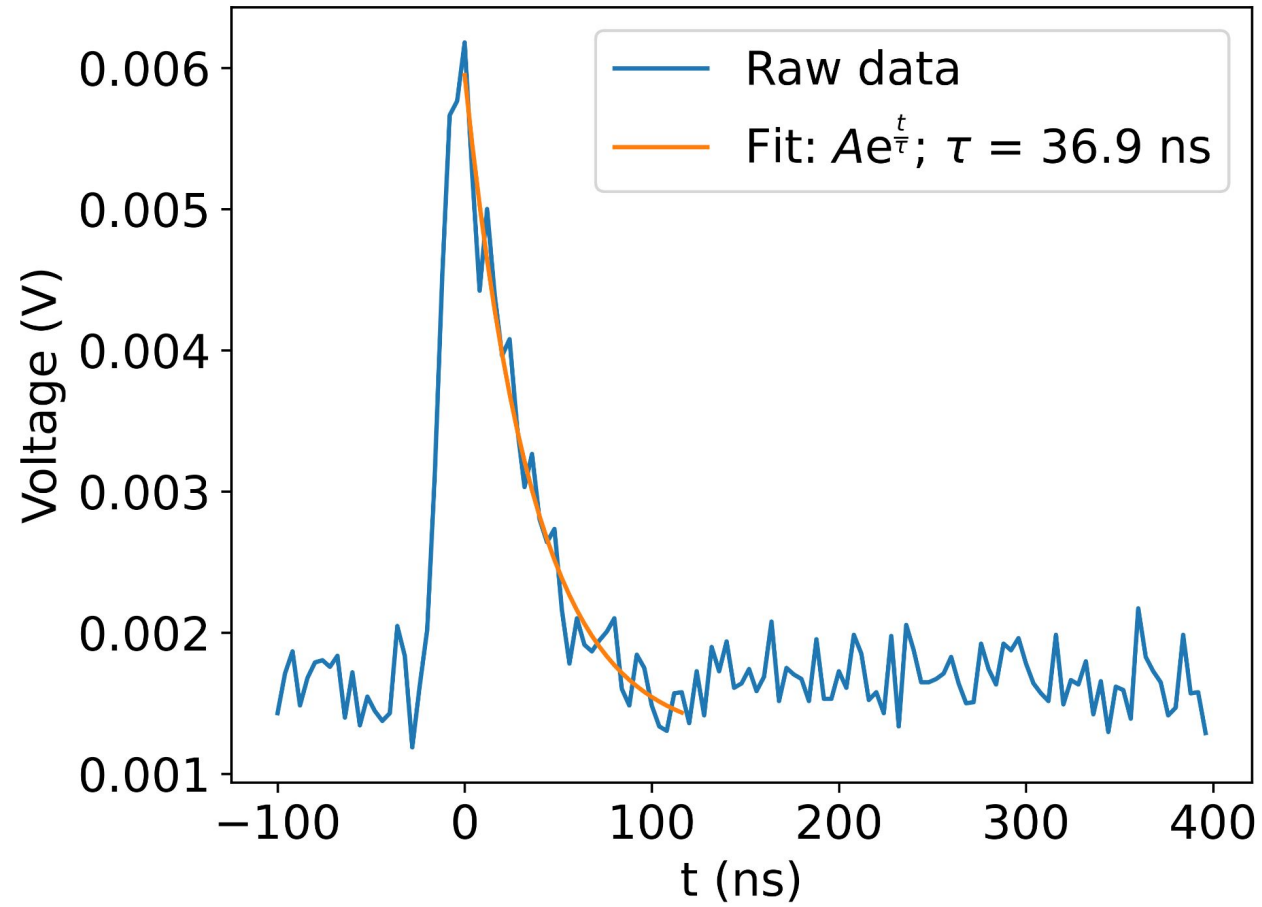
Find 20% of each
peak height



If this height has
decay time < 50ns

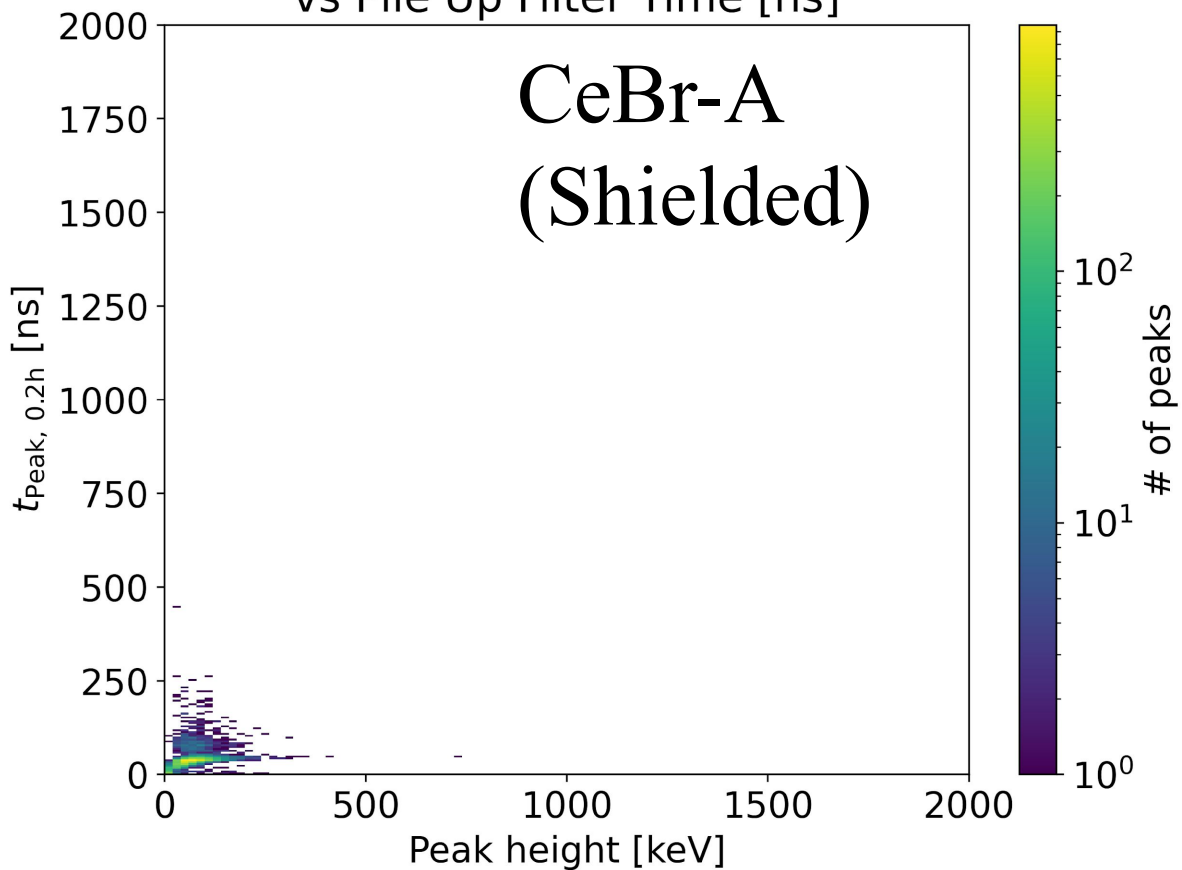


Clean Peak

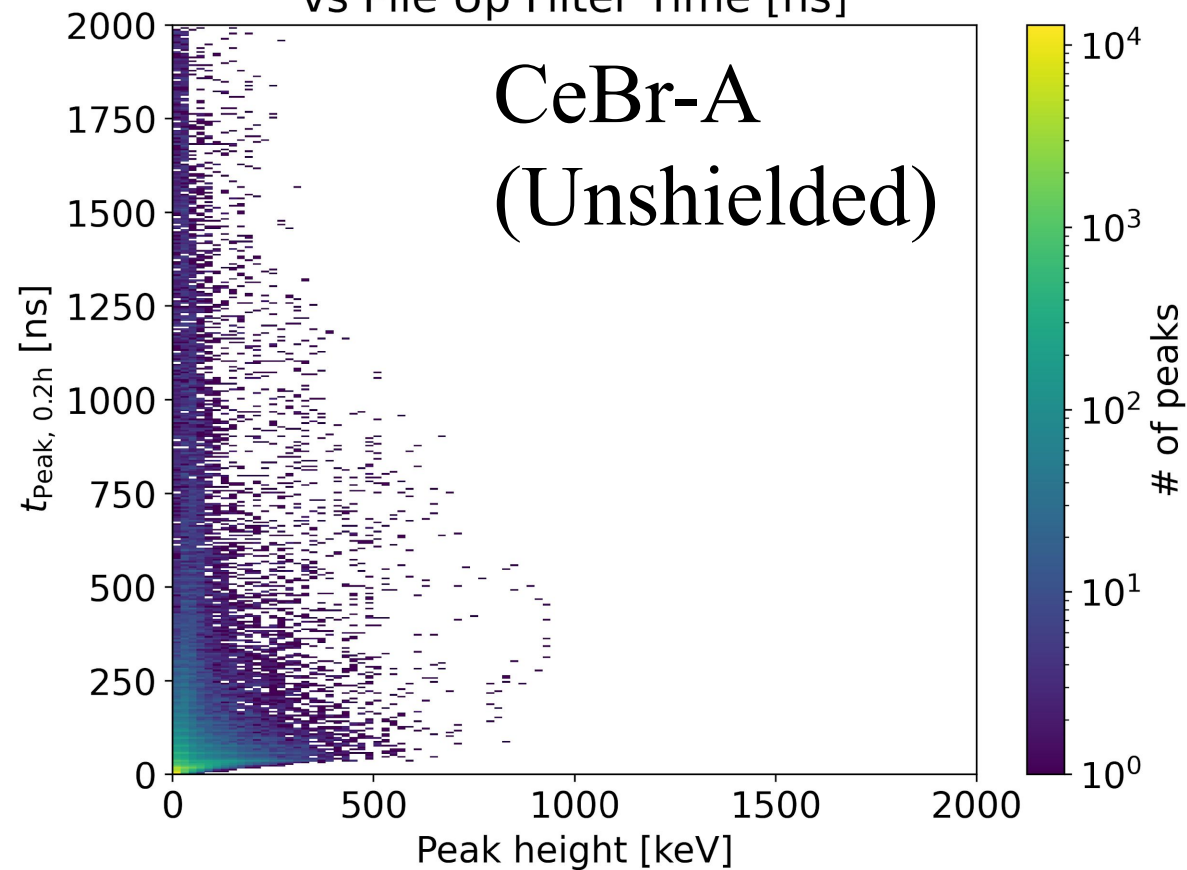




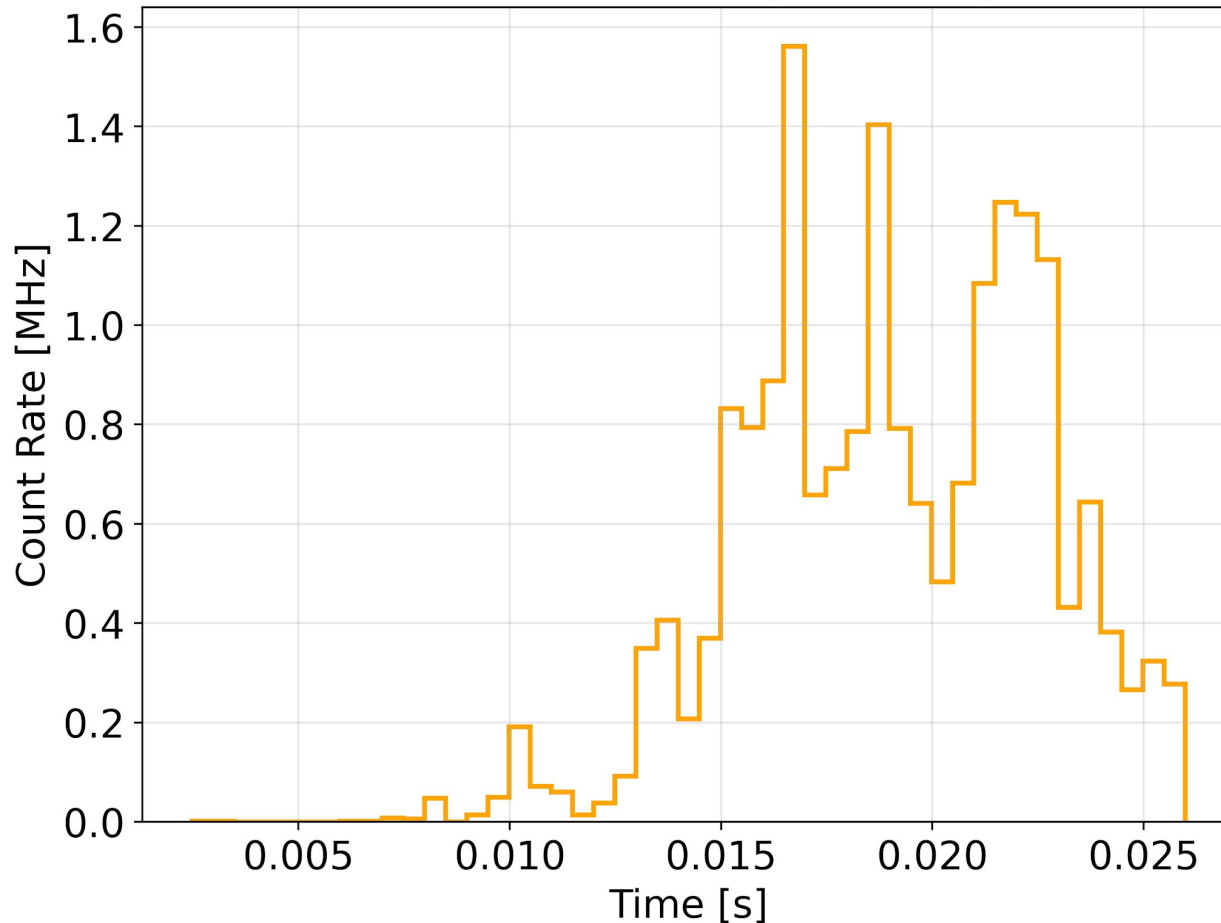
#49846 {t_start to t_end} Peak Height [keV]
vs Pile Up Filter Time [ns]



#49846 {t_start to t_end} Peak Height [keV]
vs Pile Up Filter Time [ns]



#49836 { t_{start} to t_{end} } Count Rate as a Function of Time for CeBr-A (Shielded)

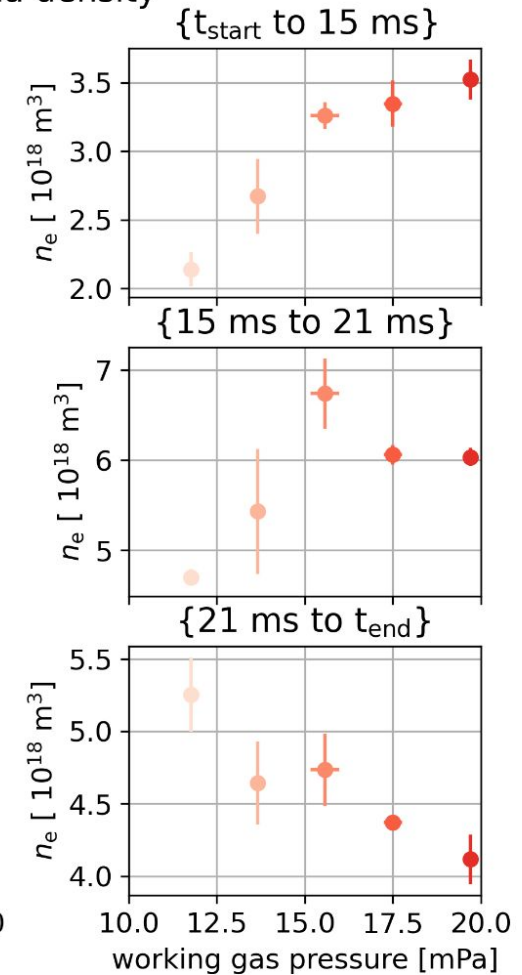
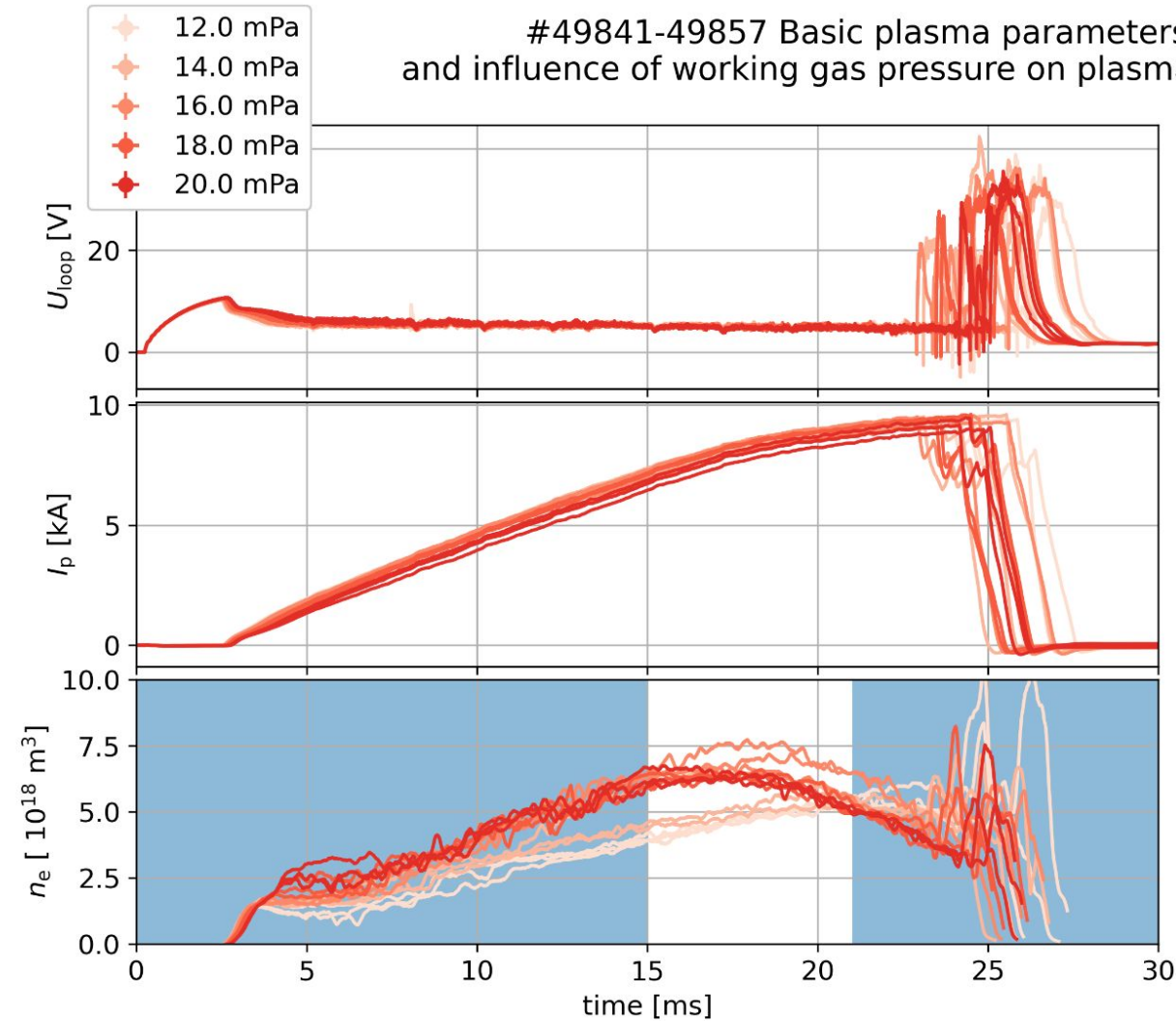


Count rate is how fast the detector is registering pulses (events per second).

$$\text{Count Rate [Hz]} = \frac{\text{Number of peak Counts}}{\text{bin_width (sec)}}$$

Where bin_width = 5e-4

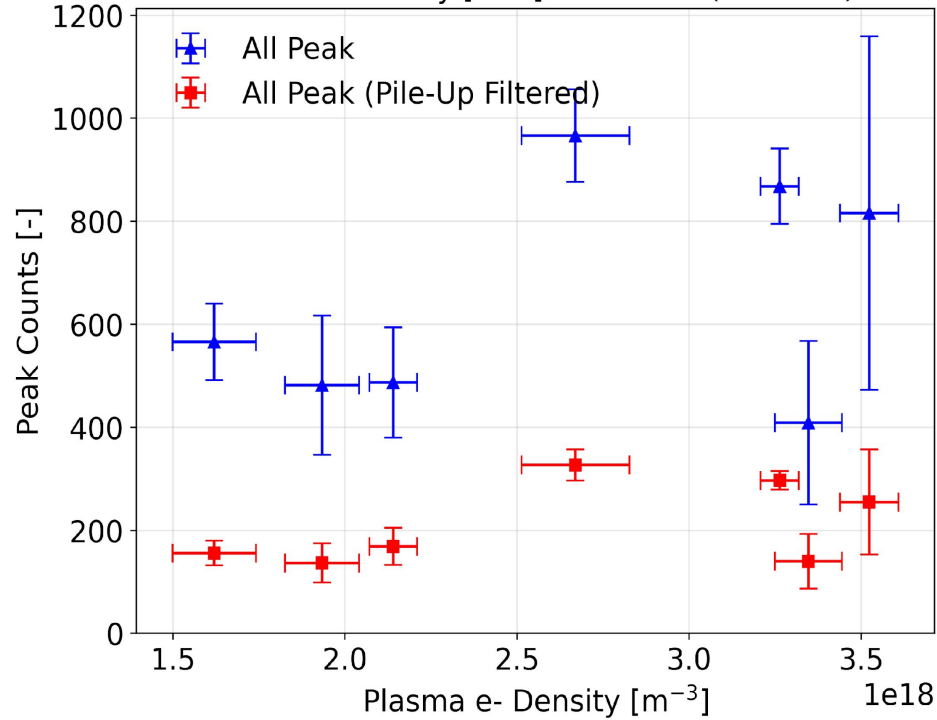
- ❖ Same discharge parameters apart from gas pressure
 - Repeatable
 - U_{loop}
 - I_p
- ❖ Gas pressure dictates plasma density only on beginning of discharge



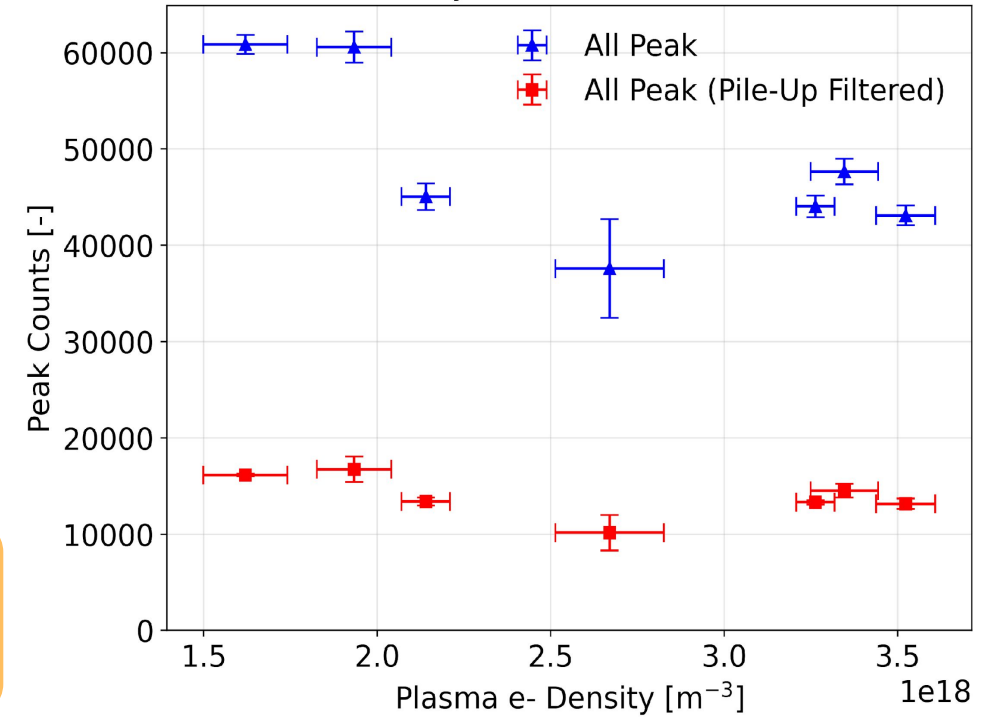


Peak Counts on Plasma Electron Density

#49835-49857 { t_{start} to 15ms} Dependence of Peak Counts on Plasma Electron Density [m^{-3}] for CeBr-A (Shielded)



#49835-49857 { t_{start} to 15ms} Dependence of Peak Counts on Plasma Electron Density [m^{-3}] for CeBr-B (Unshielded)



Removing offset from Energy vs time spectrum

Counting peaks of every shot

Plotting

Calculating mean & SDE

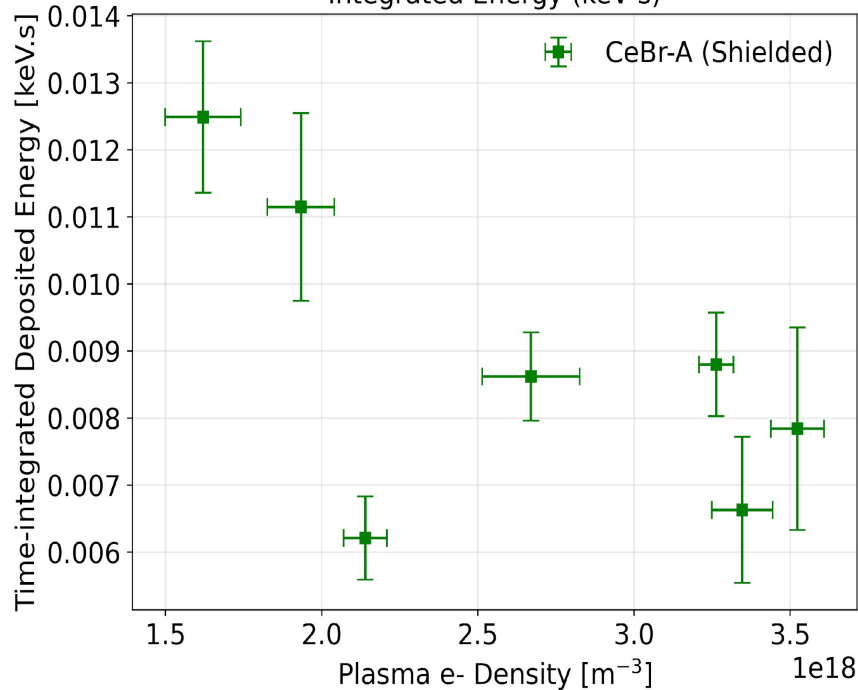
Plasma e- Density for every shot

t_{start} to 15 ms

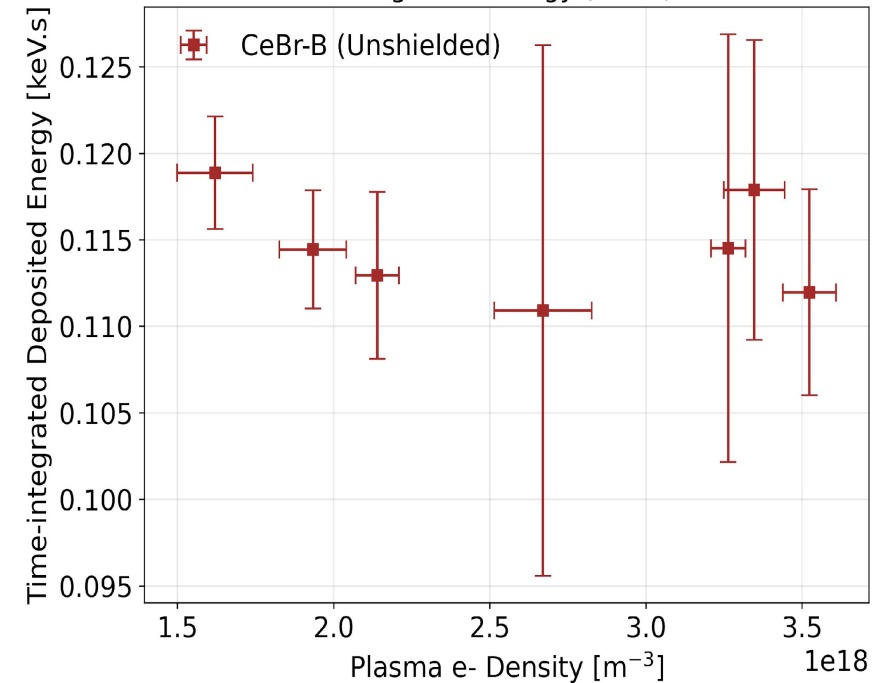


Total Energy on Plasma Electron Density

#49835-49857 { t_{start} to 15ms} Plasma e- Density [m^{-3}] dependence on Integrated Energy (keV.s)



#49835-49857 { t_{start} to 15ms} Plasma e- Density [m^{-3}] dependence on Integrated Energy (keV.s)



Plotting

Calculating mean & SDE

Removing offset from Energy vs time spectrum

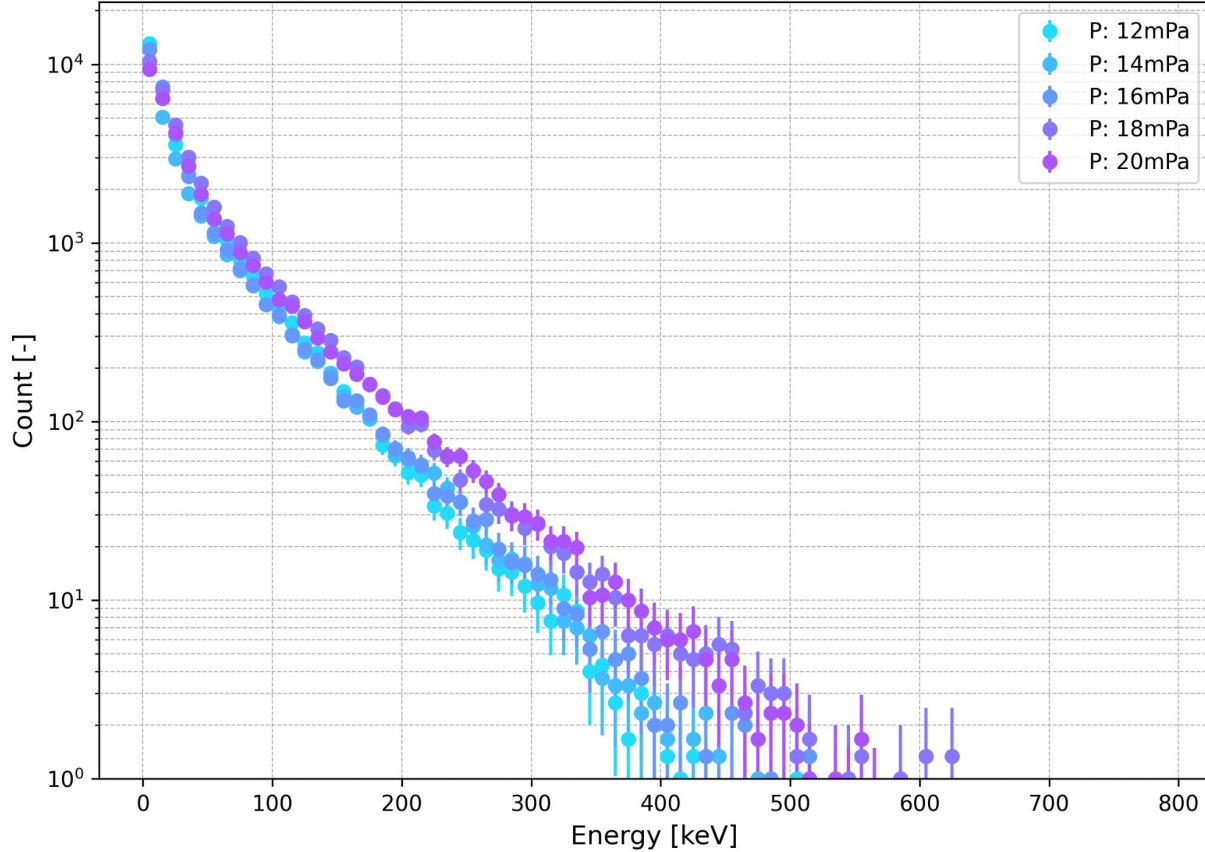
Integrating every shot with time

t_{start} to 15 ms

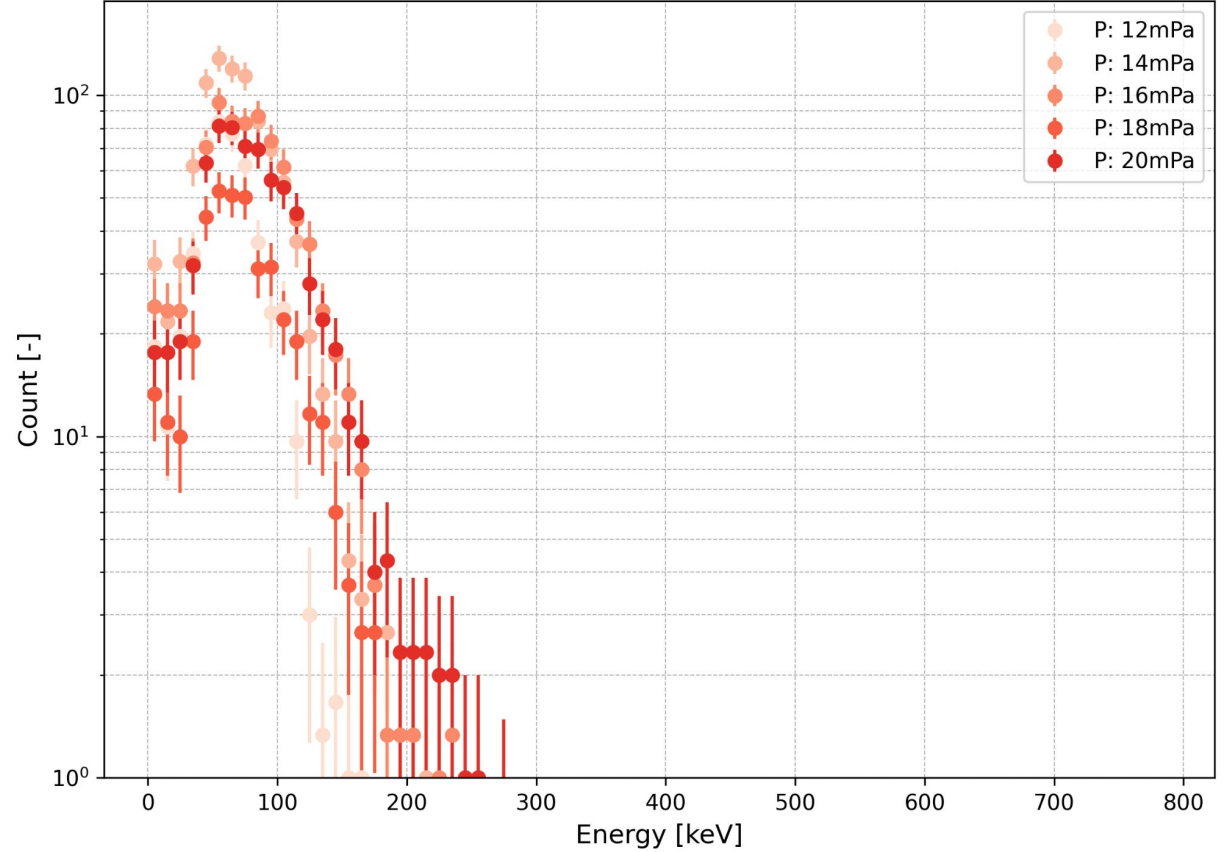
Plasma e- Density for every shot

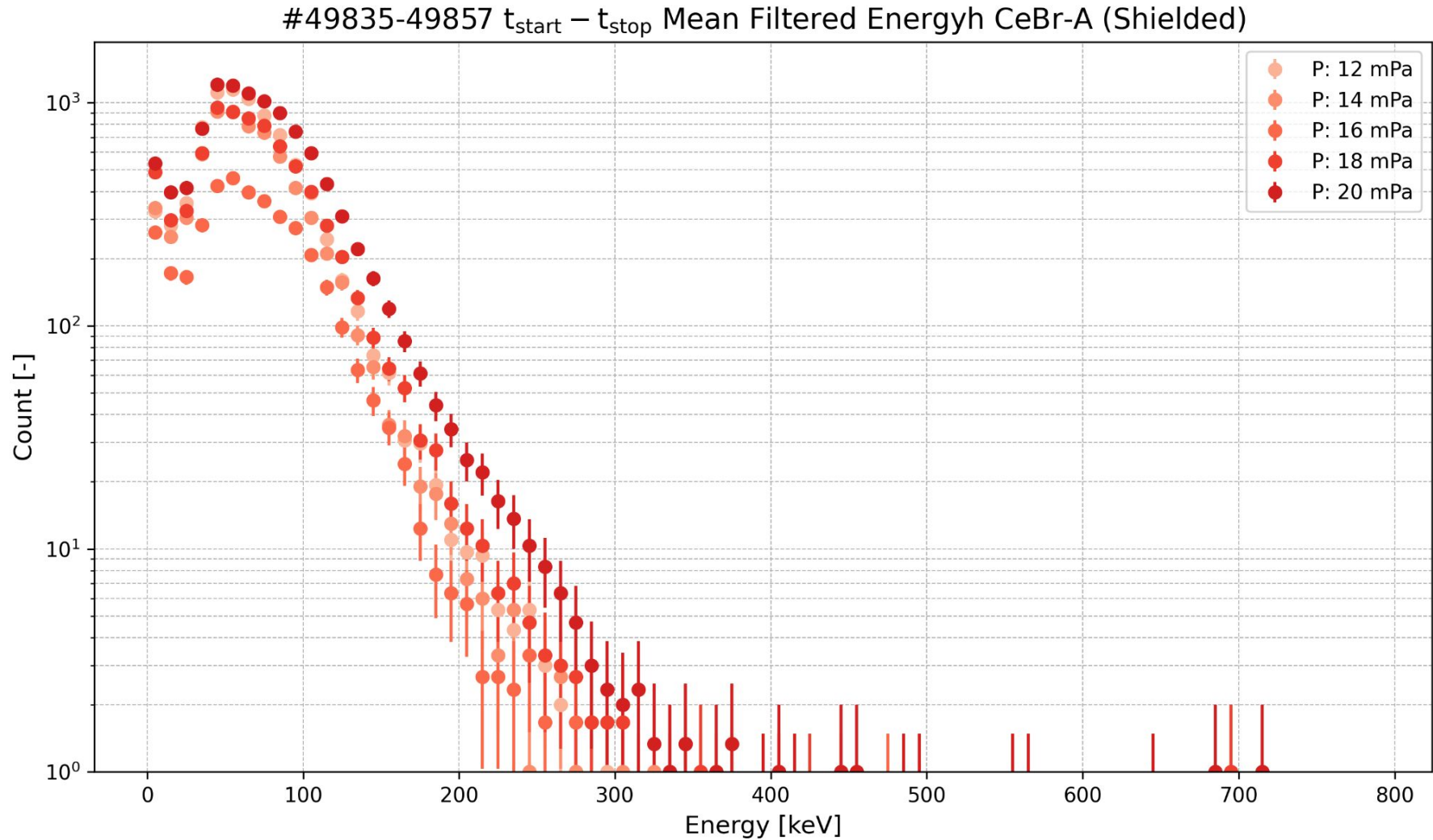


#49835-49857 { $t_{\text{start}}=15\text{ms}$ } Mean Filtered Energy CeBr-B (No-shielding)



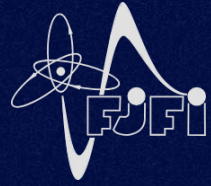
#49835-49857 { $t_{\text{start}}=15\text{ms}$ } Mean Filtered Energy CeBr-A (Shielded)







- ❖ Detector successfully calibrated.
- ❖ Pileup reduced through filtering to get reliable signals. PSD analysis demonstrated clear signal discrimination.
- ❖ Time vs. count rate analysis confirmed detector stability and response.
- ❖ Plasma density validation confirmed measurement accuracy.
- ❖ Peak count showed consistent dependence on plasma density.
- ❖ Integral vs density showed decreasing dependence. (as generally expected)
- ❖ Interesting result: Energy spectra seems to shift into higher RE energies with increasing density. (less expected, needs more detailed analysis for validation)



Backup slides



- Very high light yield ($\sim 60,000$ photons/MeV)
- Resolution for scintillators ($\sim 3\text{--}4\%$ at 662 keV)
- Low intrinsic background compared to LaBr₃(Ce)
- Decay Time = 18 - 25 ns
- Lower limit: $\sim 20\text{--}30$ keV
- Upper limit: up to 3–5 MeV
- Covers HXR ($\sim 20\text{--}200$ keV) and extends into γ -rays



<https://www.epic-crystal.com/scintillation-crystals/cebr3-crystal.html>

