Dark and Breakdown Currents Studies @ XBox2

M. Jacewicz, R. Ruber and V. Ziemann

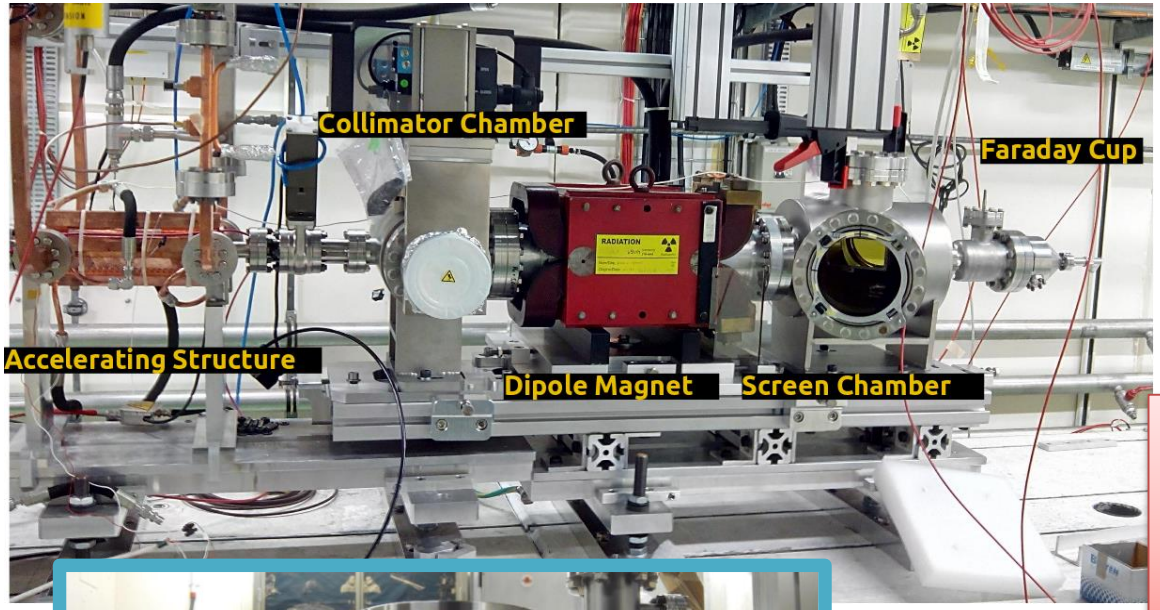
FREIA Laboratory, Uppsala University

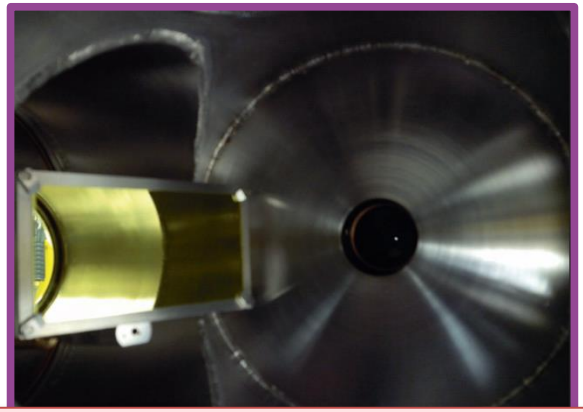
Outline

- Dark and breakdown currents at XBox
  - XBox2 instrumentation
  - Measurements
    - BD position
      - Longitudinal
      - Transversal
    - BD energy spectra
    - Dark current
- Summary and Outlook

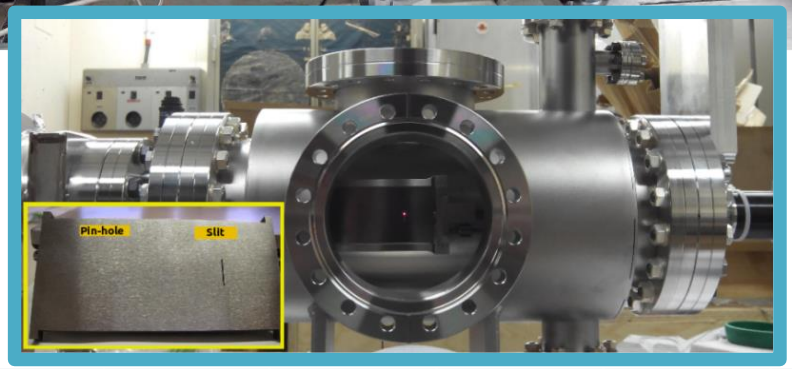
Uppsala/CLIC X-band Spectrometer (UCXS)

general-purpose system for detection and measurements of dark and breakdown currents during structure conditioning





Screen (100x50x0.5 mm YAG:Ce)
linear actuator (fully retractable)
30 degrees angle w.r.t. the beam axis
2M pixel, 50fps camera with focuser

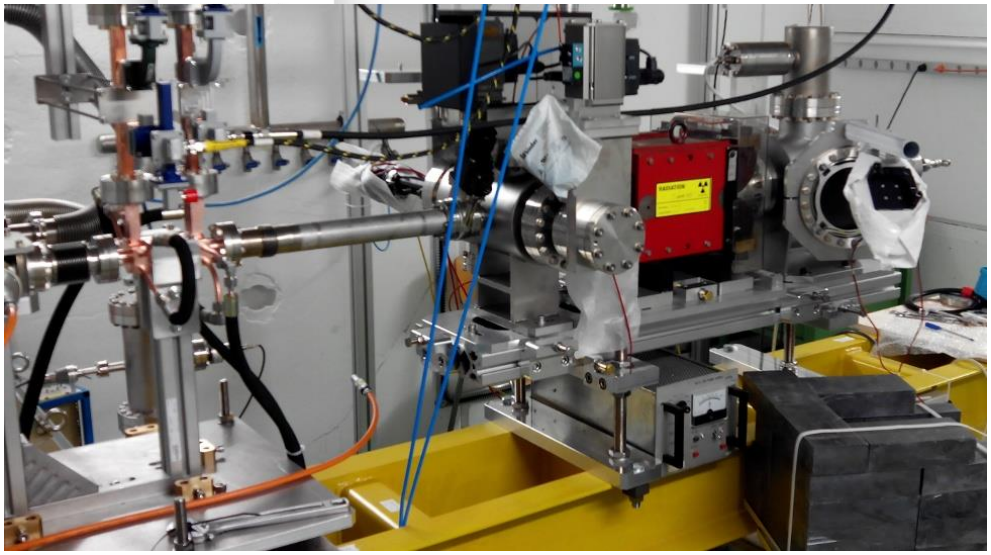


Energy resolution with dipole magnet

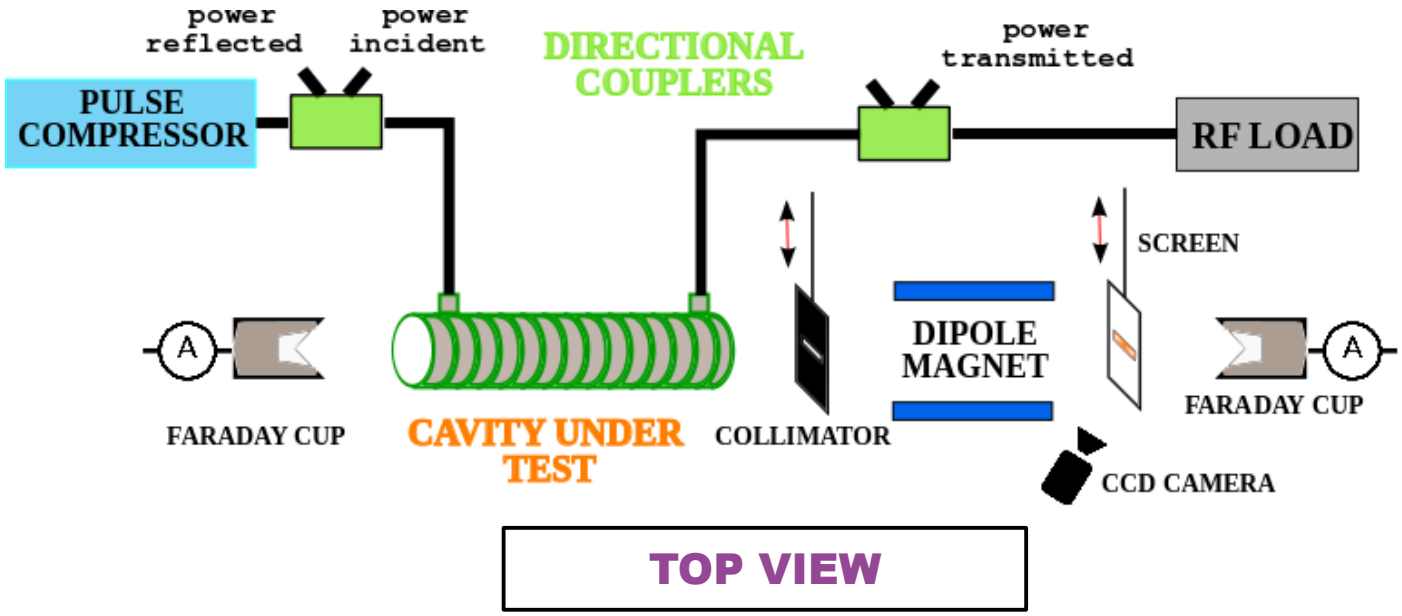
Maximum expected electron energy	~20MeV
Rel. energy spread (single slit)	10% - 25%
Full energy coverage with magnetic field scan	

Collimator (5 mm tungsten plate)
linear actuator (retractable), place for two patterns,
presently: **pin-hole** 0.5mm and **slit** 10x0.5mm

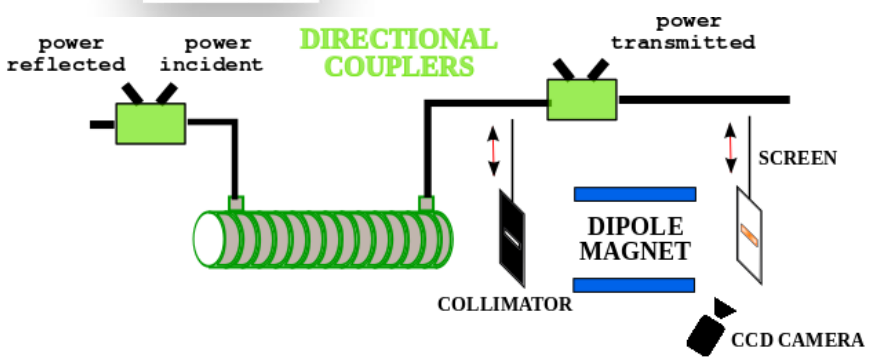
Instrumentation at XBox2



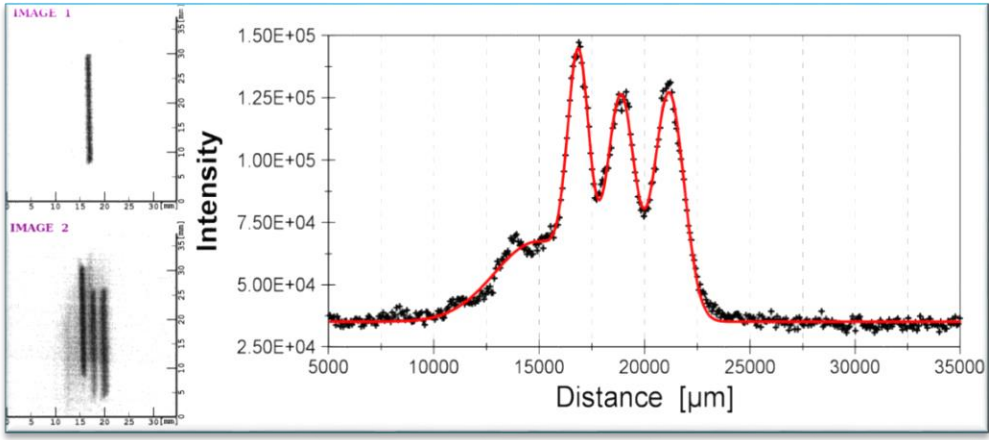
- All diagnostics information available for the BD events is combined with images from the camera
- Routinely saving images from before and after BD (dark current and no-RF bkg)
- 50 Hz operation

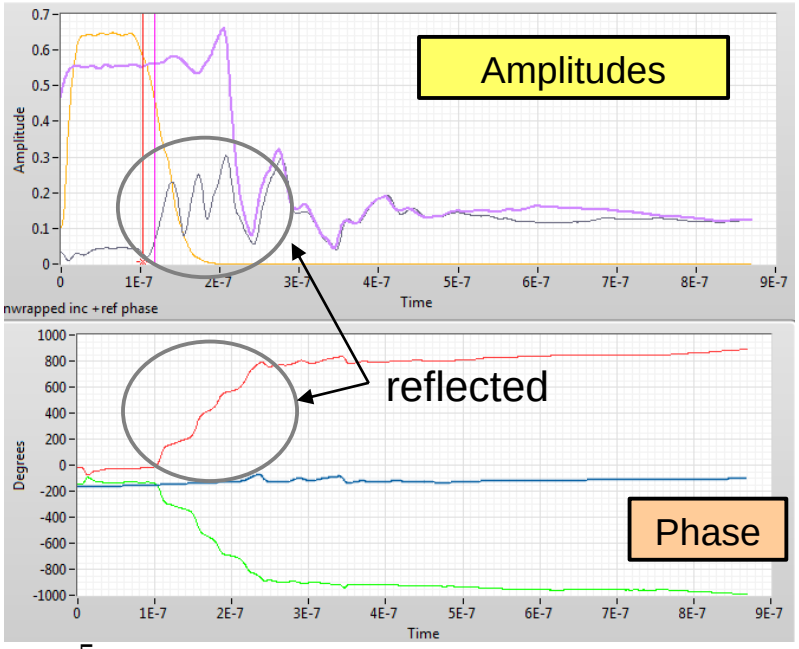


Example of collected signals – BD events



Example of images after the slit





LEGEND

Amplitudes:
RF In
RF Transmitted
RF Reflected

Phase:
RF In
RF Reflected
In - Reflected

Often rich structure of the reflected signal

From amplitude spectrum we conclude that the energy is lost

→ **breakdown is "feeding" from the RF power**

For the same events we see more features on the screen

BD longitudinal position

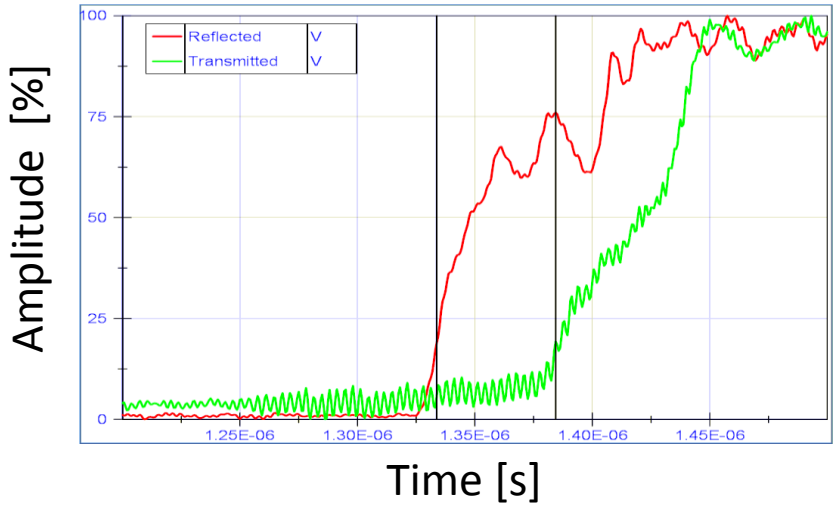
Time and phase differences in RF give us information about position of the BD site

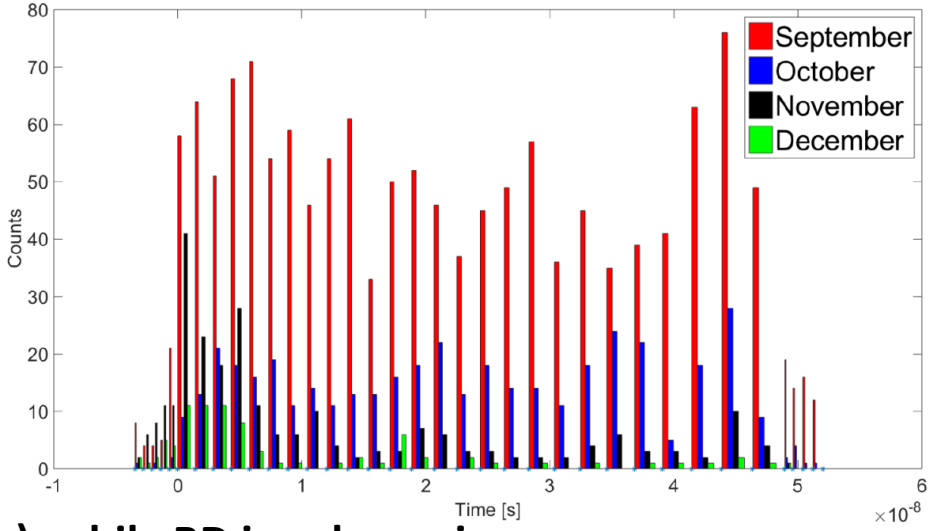
BD detected when:

1) Drop in transmitted power due to plasma formation
2) Power reflected back

Difference in time between the transmitted power and the reflected power is related to BD cell location. *)

The phase of the reflected signal is used to pinpoint cell location.





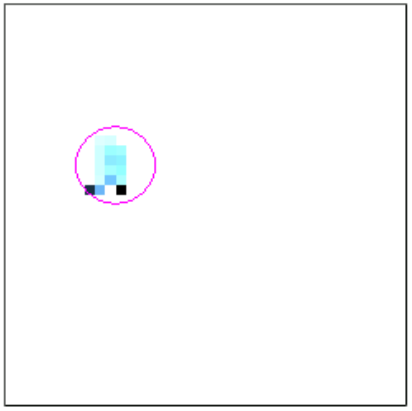
Static information (single value per pulse), while BD is a dynamic process…

*)There are other methods that use RF signal timing to extract BD position.

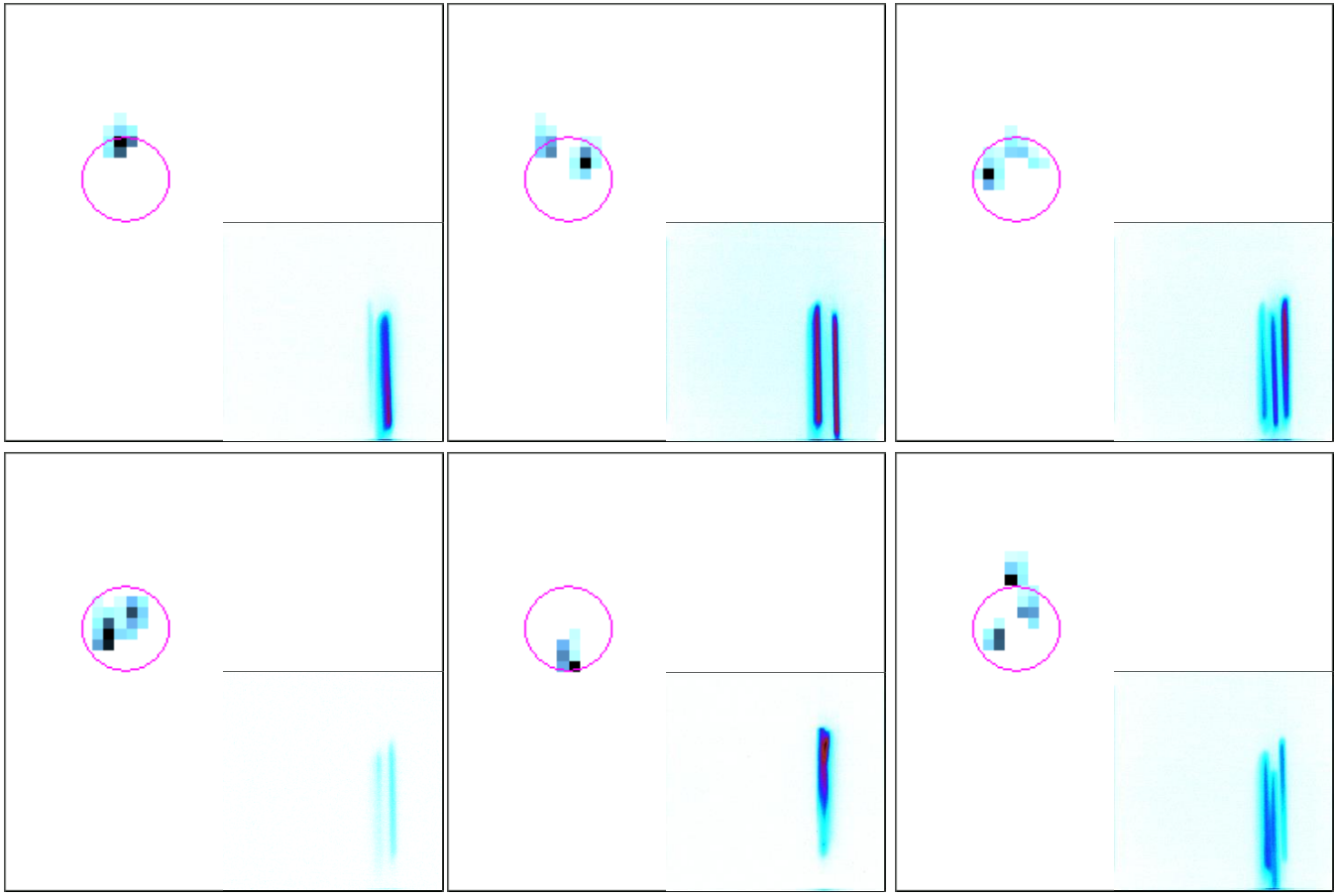
BD transverse position – SLIT

Magnet off, 75 ns pulses

- Deconvolution with slit transfer function
- Single events - recorded images and reconstructed source positions



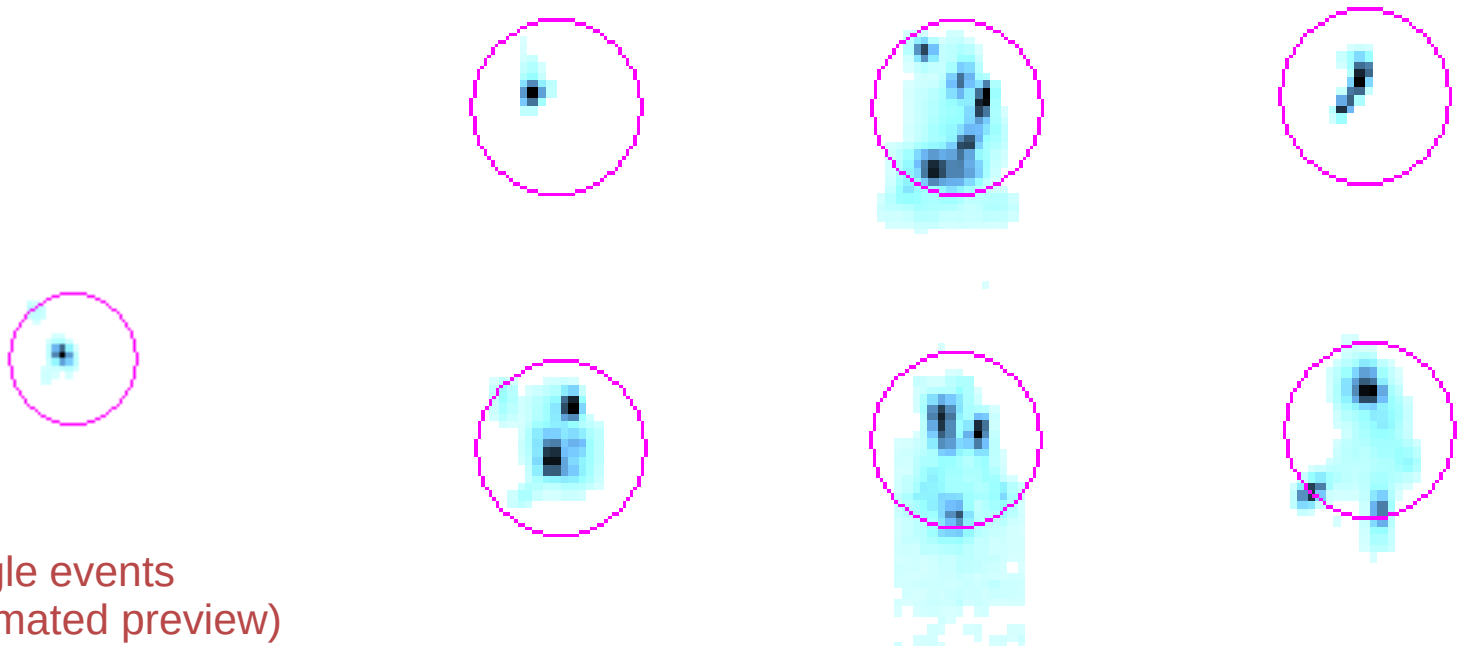
Single events
(animated preview)



BD transverse position – PINHOLE

Magnet off, 200 ns pulses

- Deconvolution with slit transfer function
- Single events - recorded images and reconstructed source positions

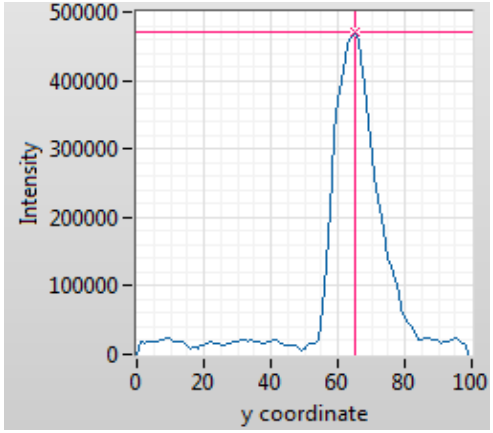


Single events
(animated preview)

Qualitatively more features in data –
longer pulse, more time to develop new breakdown

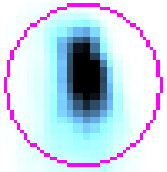
BD transverse position – PINHOLE

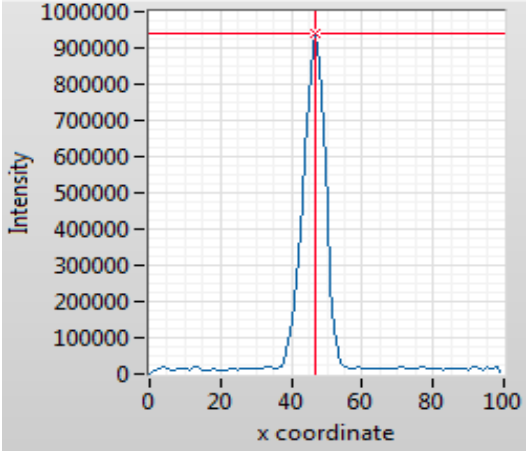
Magnet off, 200 ns pulses



- Combined image from 199 events

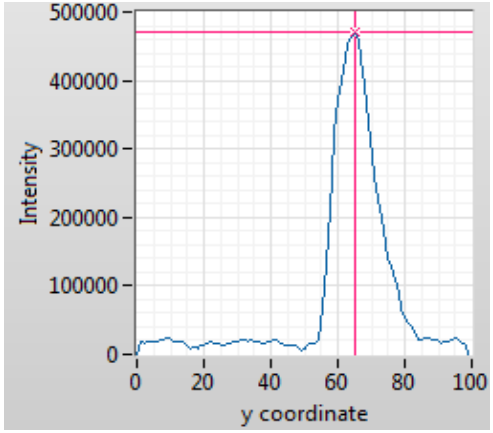
Asymmetry and excess events in vertical direction





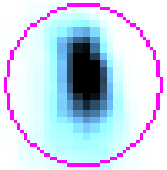
BD transverse position – PINHOLE

Magnet off, 200 ns pulses

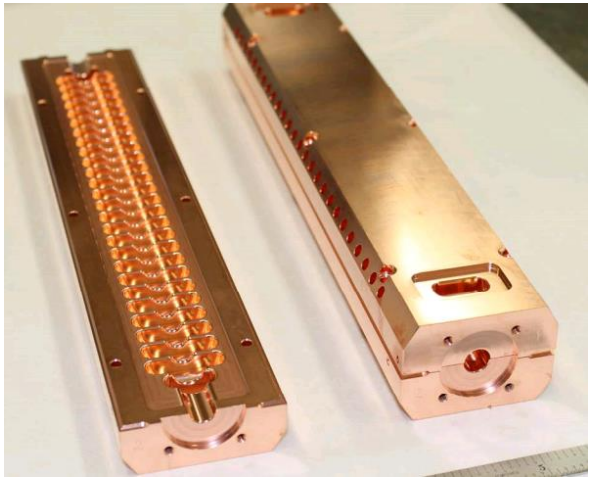


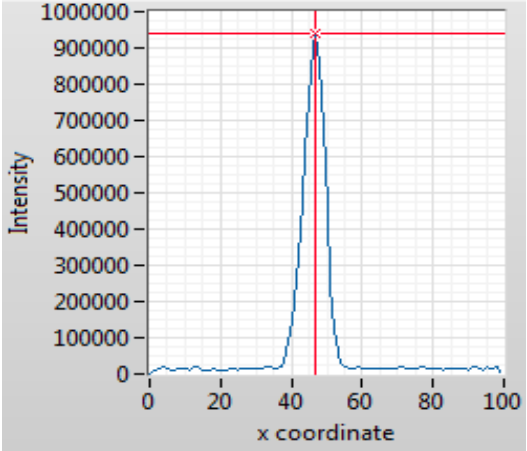
- Combined image from 199 events

Asymmetry and excess events in vertical direction

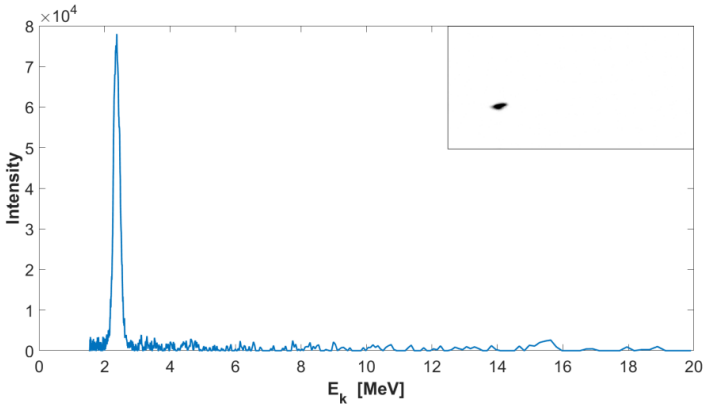


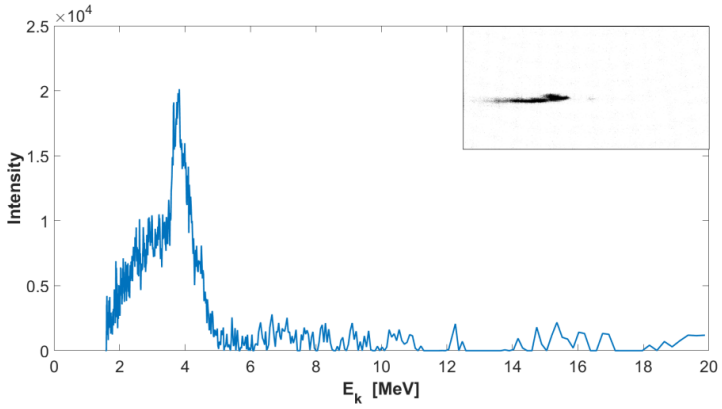
Due to special type of structure under test?



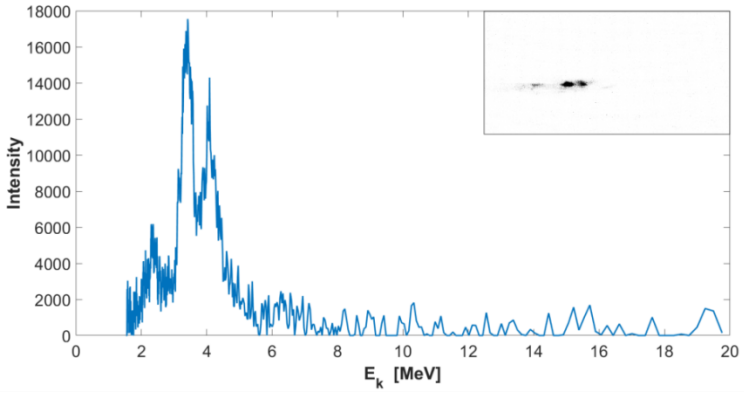


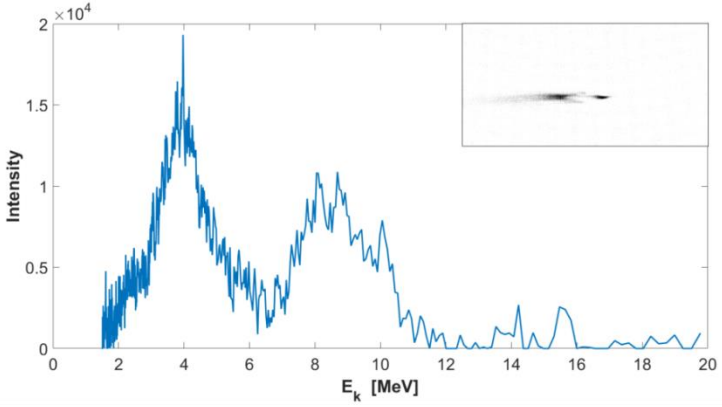
Energy spectra from BD events





Preliminary





Electrons with well defined energies

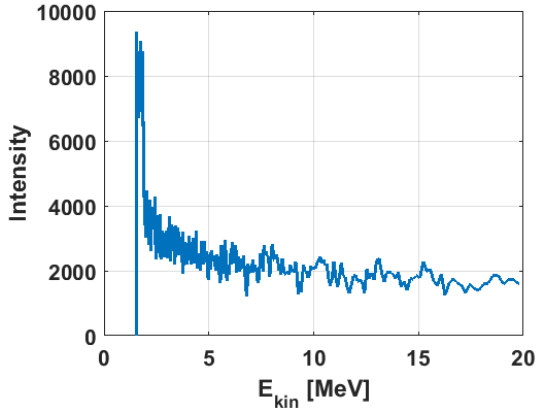
→ maximum in agreement with the given power/gradient in the structure

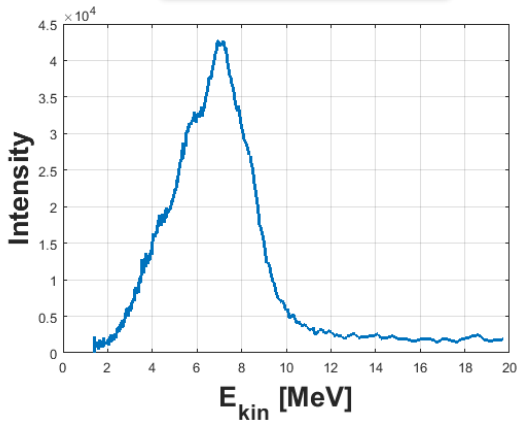
Next step:

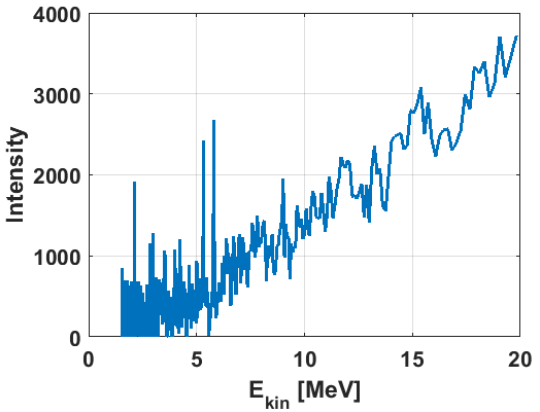
combining energy information with other signals and compare with simulation

Preliminary

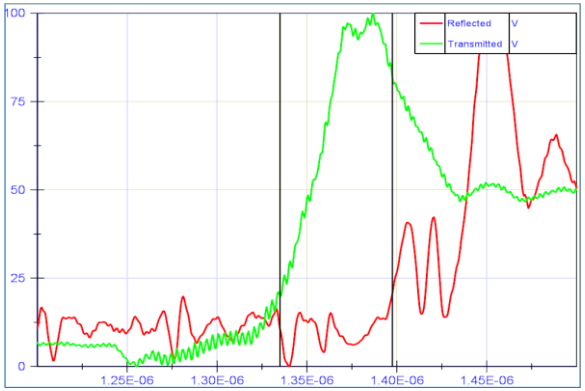
Energy vs BD position



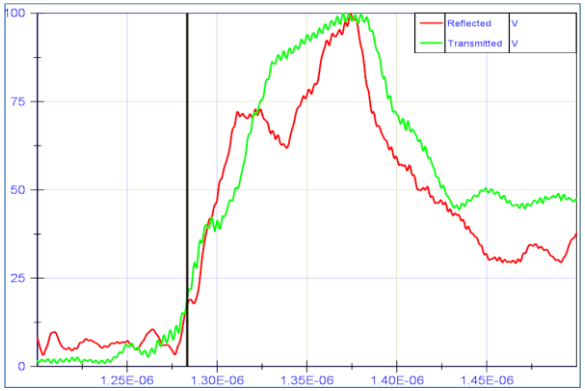




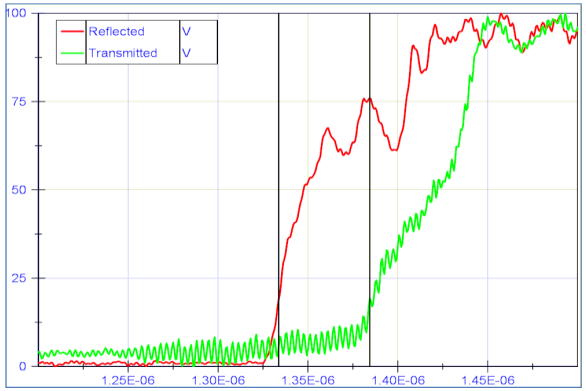
ΔT=62 ns → end of structure



ΔT=0 ns → middle of structure



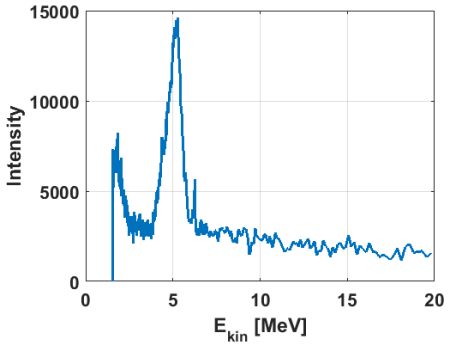
ΔT=-50 ns → start of structure



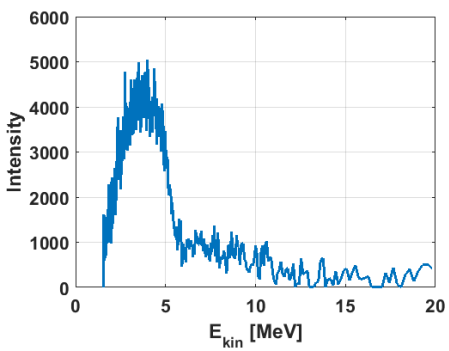
Preliminary

Analysis of BD clusters

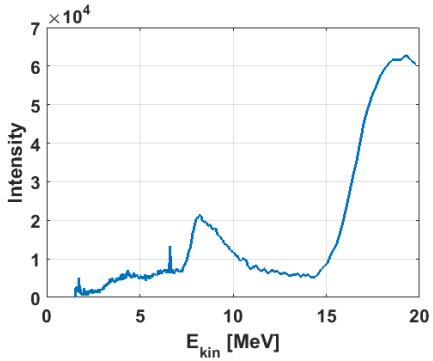
ΔT = 40 ns



ΔT = -38 ns



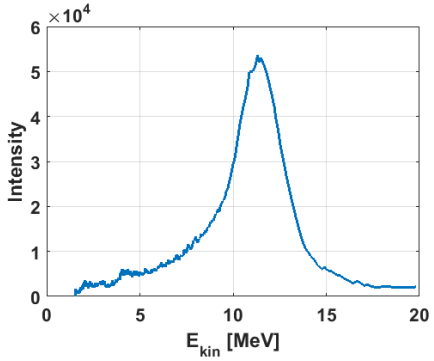
ΔT = -4.5 ns



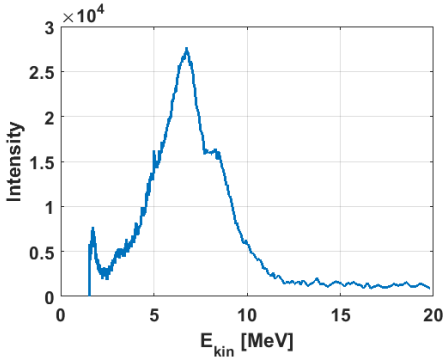
ΔT = -11 ns

?

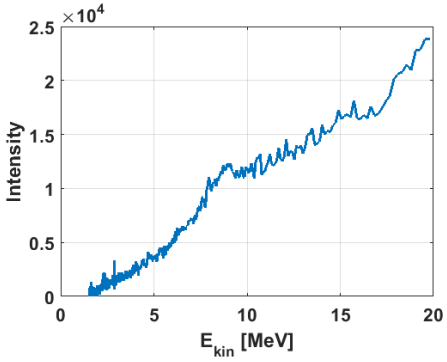
ΔT = 4.5 ns



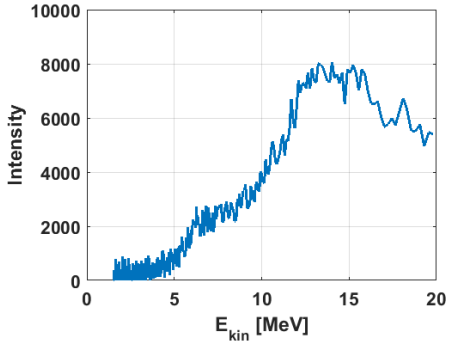
ΔT = 2.5 ns



ΔT = -27 ns



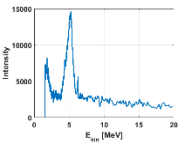
ΔT = -54 ns



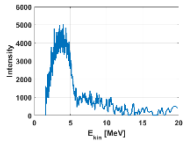
Preliminary

BD clusters

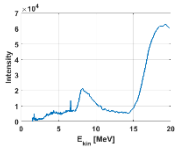
ΔT = 40 ns



ΔT = -38 ns

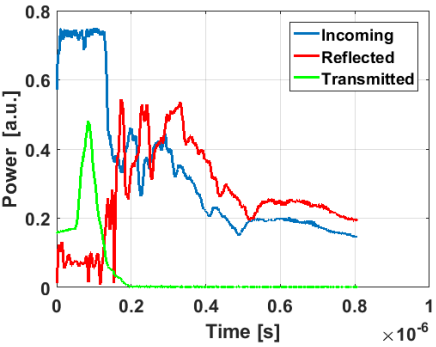


ΔT = -4.5 ns

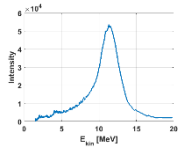


ΔT = -11 ns

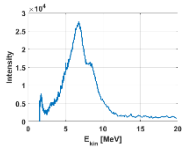
?



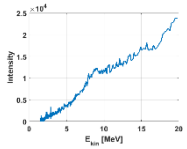
ΔT = 4.5 ns



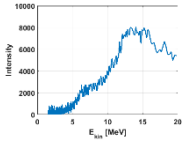
ΔT = 2.5 ns



ΔT = -27 ns



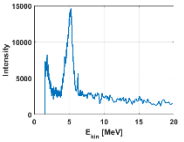
ΔT = -54 ns

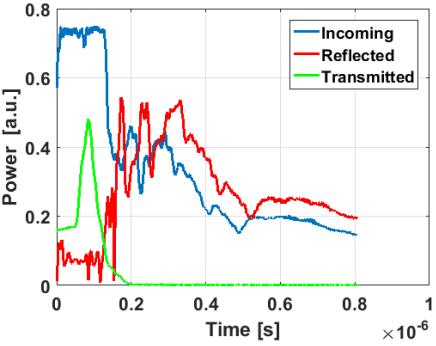


Preliminary

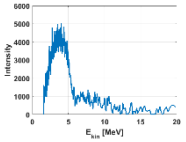
BD clusters

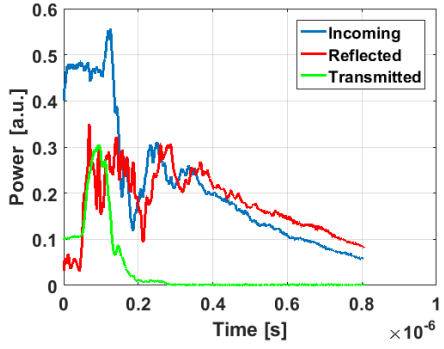
ΔT = 40 ns



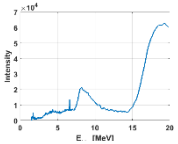


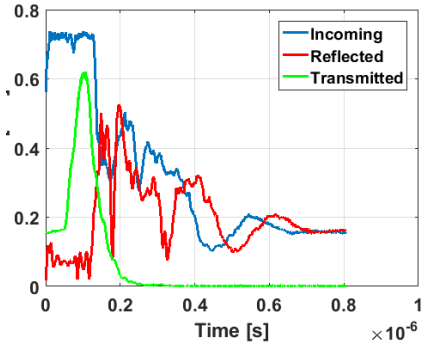
ΔT = -38 ns





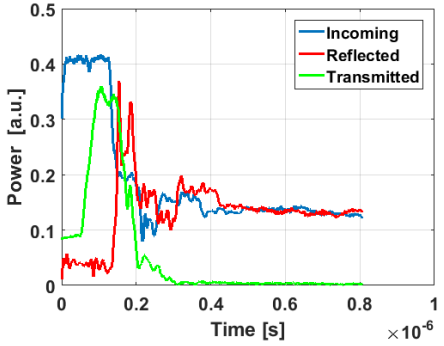
ΔT = -4.5 ns



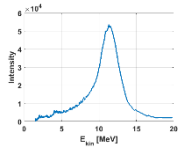


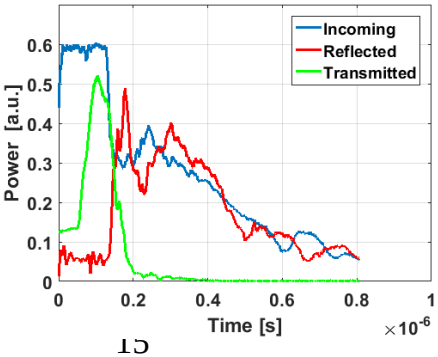
ΔT = -11 ns

?

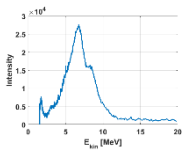


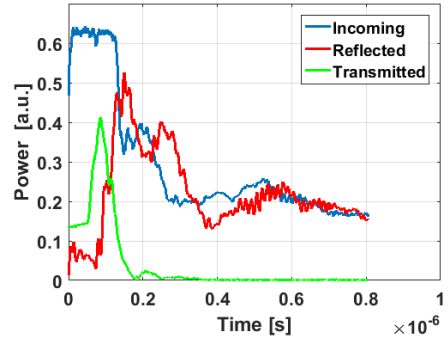
ΔT = 4.5 ns



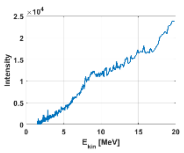


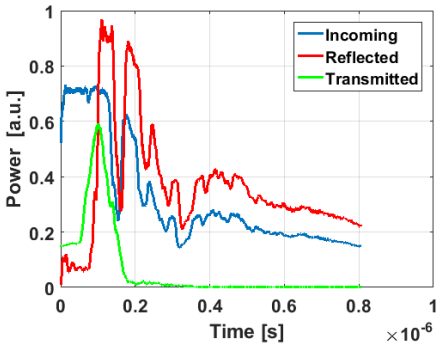
ΔT = 2.5 ns



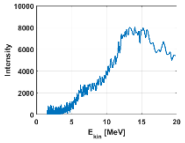


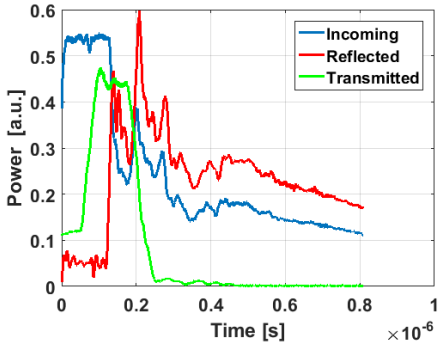
ΔT = -27 ns





ΔT = -54 ns

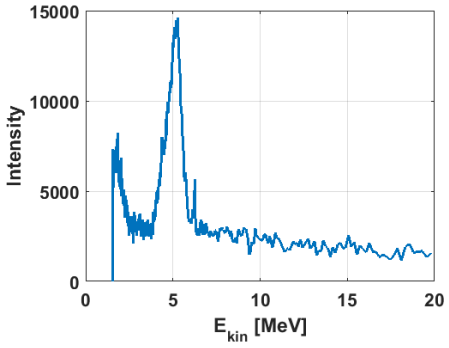




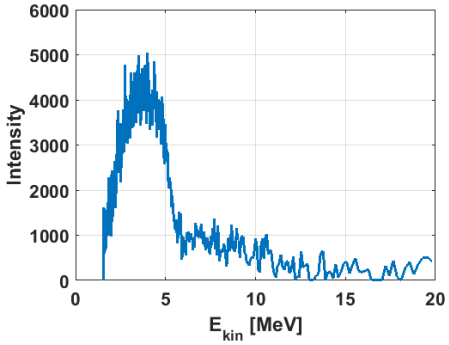
Preliminary

BD clusters

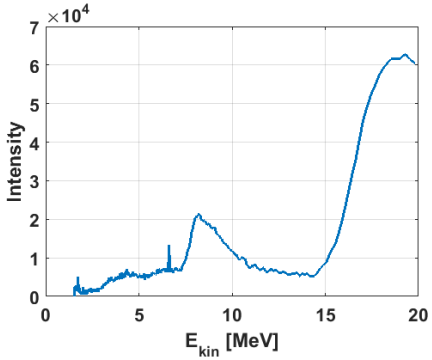
ΔT = 40 ns & P=100%



ΔT = -38 ns & P=65%



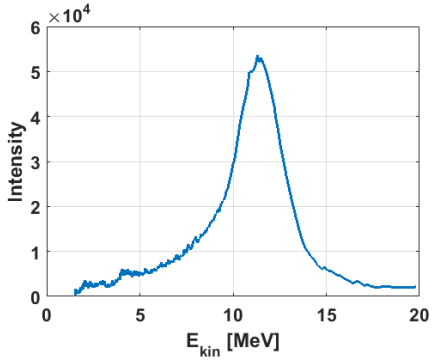
ΔT = -4.5 ns & P=95%



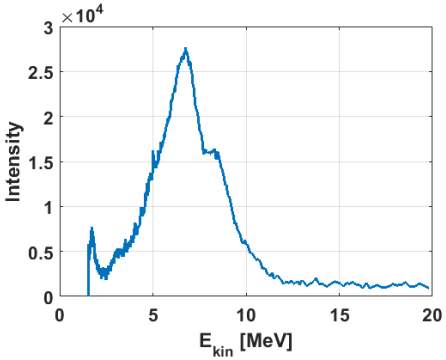
ΔT = -11 ns & P=55%

?

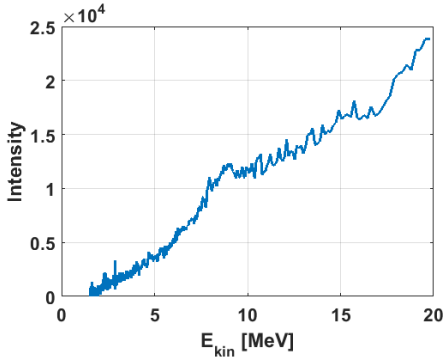
ΔT = 4.5 ns & P=80%



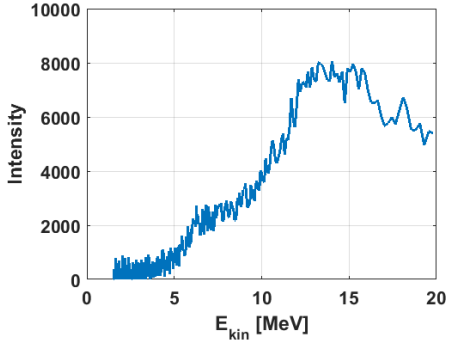
ΔT = 2.5 ns & P=85%



ΔT = -27 ns & P=95%



ΔT = -54 ns & P=75%

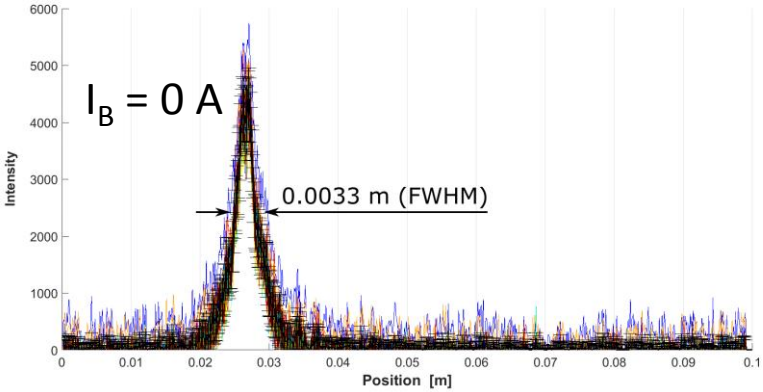


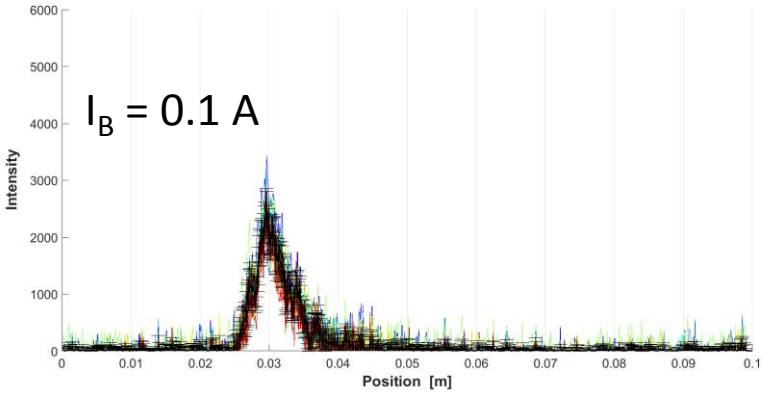
Dark current

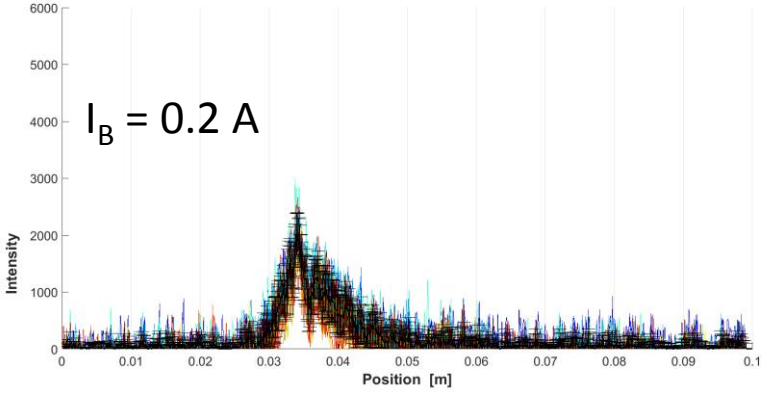
20 pulses + average

Dark current :

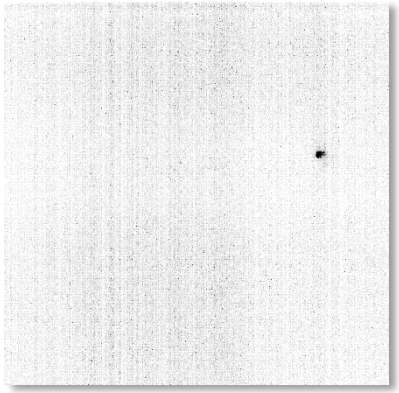
- precursor of RF breakdown, input to many models→can we predict when BD approaches?
- Information about structure hardening process
- Causes RF power loss, radiation, possible backgrounds





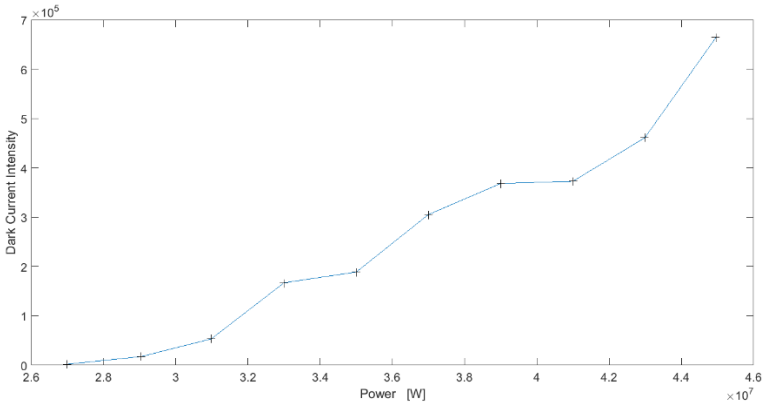


DC through pin-hole on screen (50 consecutive pulses)



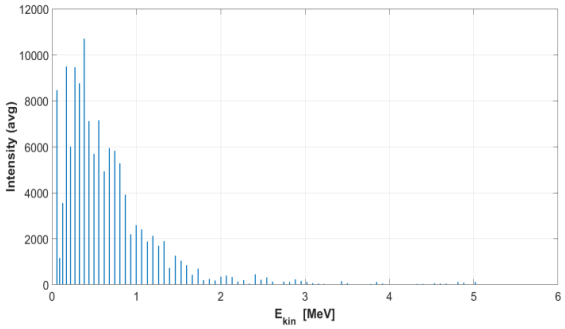
Dark current scans

DC scan with power

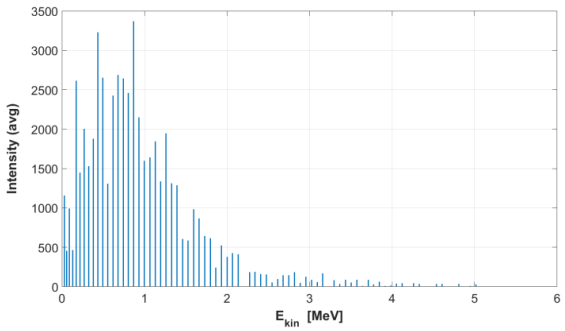


Preliminary

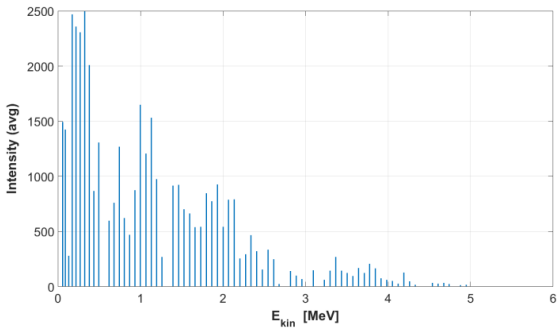
@ 21 MW inc. power



@ 26 MW inc. power



@ 30.5 MW inc. power



- No indication of single emitting spot inside the cavity
- Isotropic transverse distribution
- Broad energy spectrum – continuum from electrons in dark current

example here from 50 consecutive pulses (1 second)

Next step: comparison with other detectors i.e. Cherenkov fiber detectors, Faraday cup to look at which structure parameters affect the dark current production

Outlook

Xbox experiments status:

- Analysis in progress
- Many BD and DC data from Xbox on disk:
  - Correlate BD RF signals with energy spectra
  - Study dark current behavior (trends and before/after breakdowns)

Spectrometer plans:

- Probably needs to relocate to Xbox1 due to radiation problems
- Possibility for improvements of the setup , e.g.:
  - Another camera (splitter mirror) dedicated to DC measurements
  - New collimator with different patterns

Many thanks to XBOX team !

Xbox 2 @ CERN

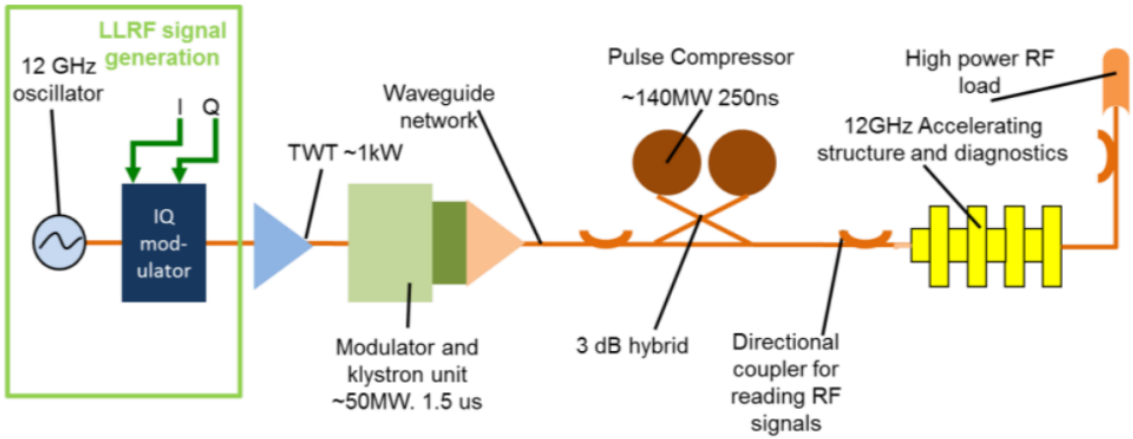
CLIC ACS tests require:

→ 40-45 MW power

→ pulse length ≤ 250 ns

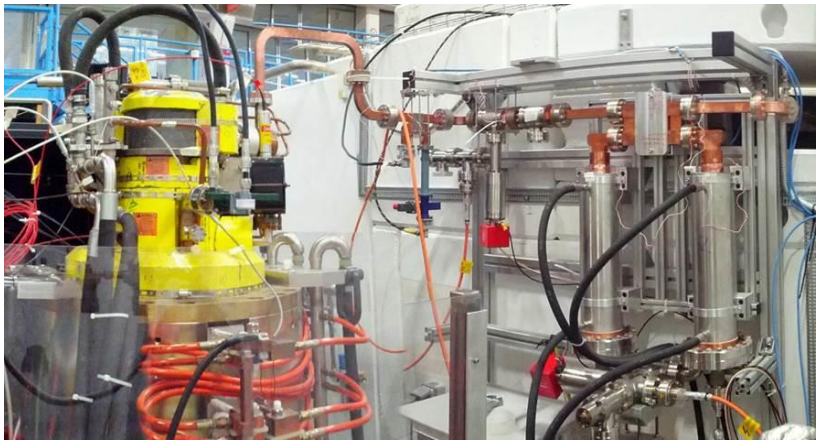
Conditioning process speed related to number of pulses:

→ high rep rate ≥ 50 Hz



XBox2

Solid state modulator +
a single 50 MW klystron +
pulse compressor



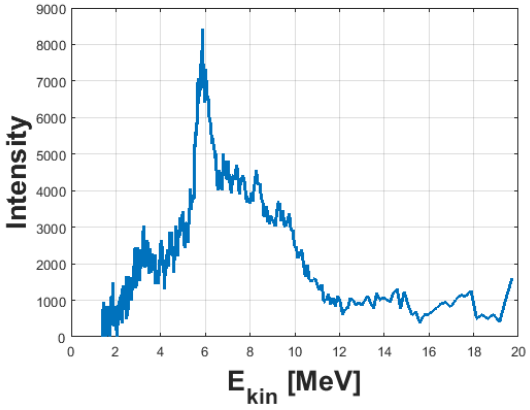
B. Woolley

Preliminary

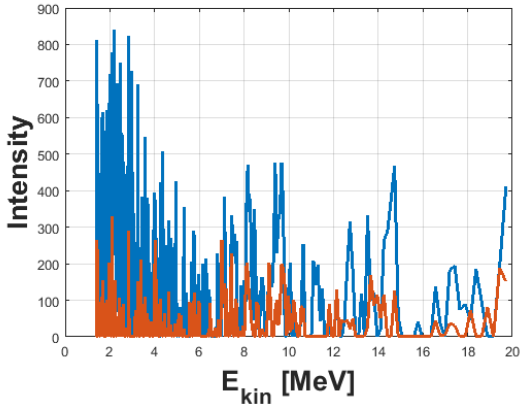
BD clusters

Data from 7 May

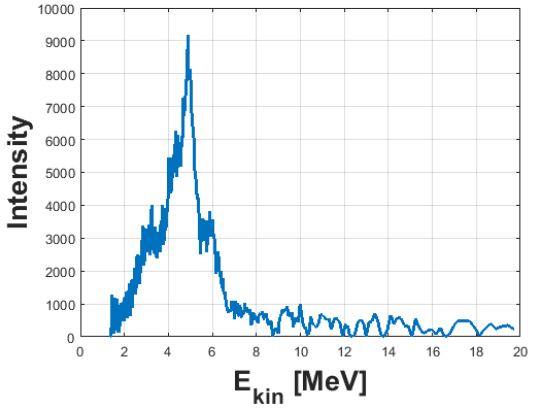
ΔT = -14 ns & P=100%



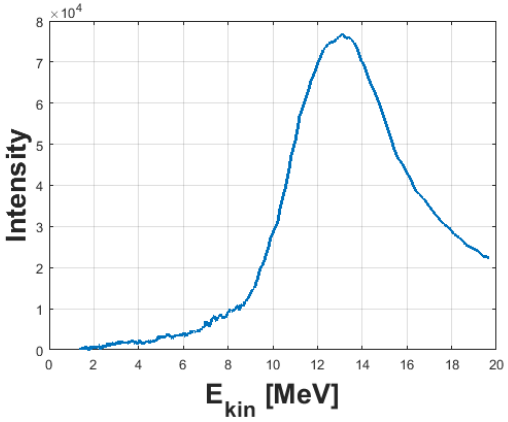
ΔT = -9.5 ns & 55%



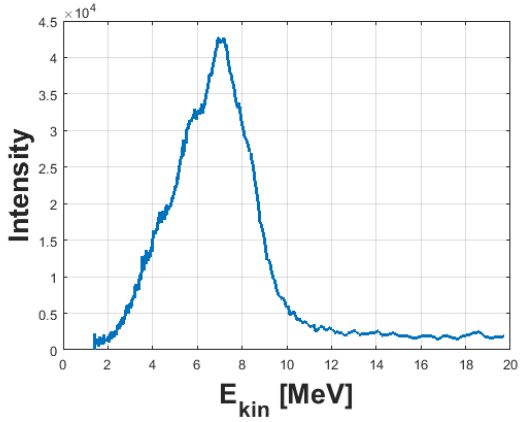
ΔT = 2.5 ns & 82%



ΔT = -4 ns & 92%



ΔT = 0 ns & 95%



ΔT = -5 ns & 100%