Analysis of TBTS high-gradient testing and breakdown kick measurements

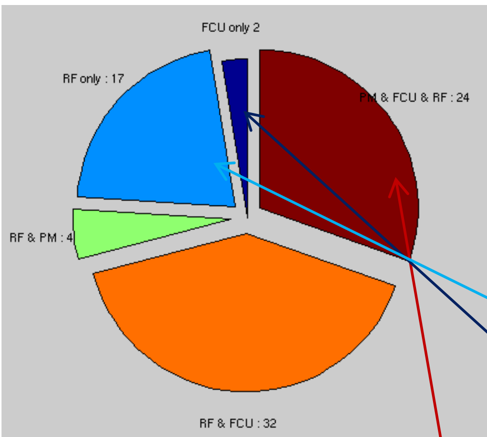
Overview of on-going studies

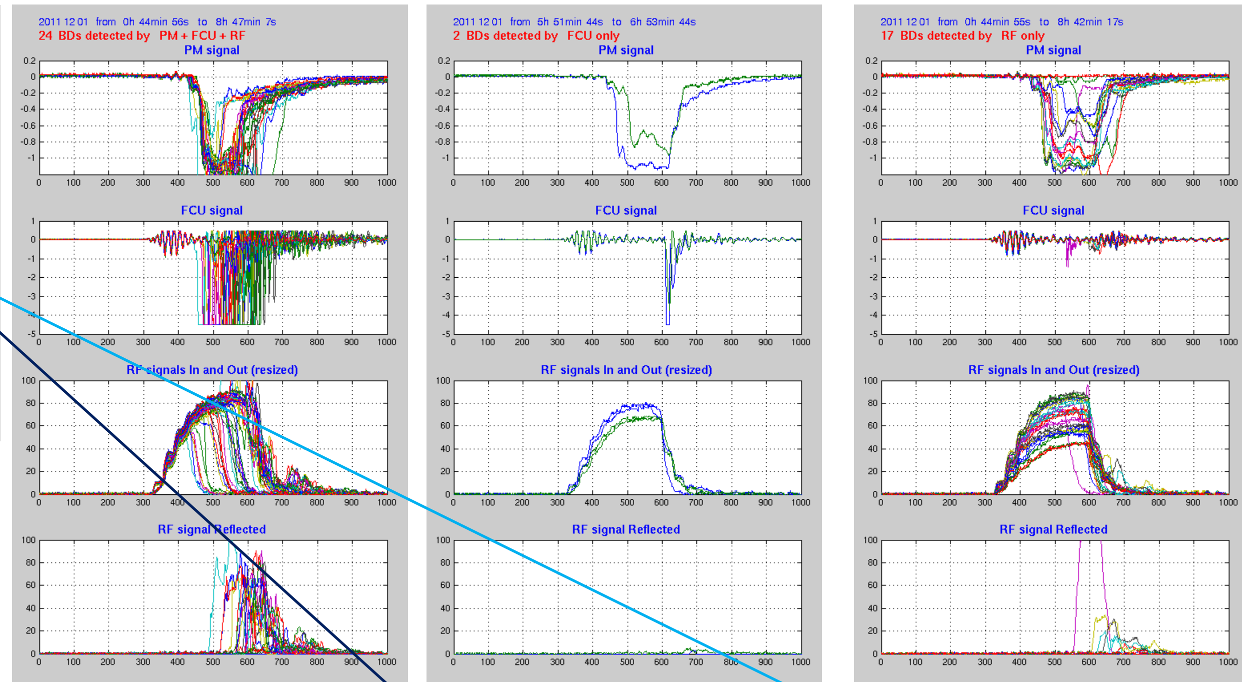
Preliminary results

Contents

- Statistical analysis
  - Various BDs detection channels
  - BDR – overview of recorded experiments
  - BD's time distribution and Poisson law
  - RF exposure time before BD and time power law
- Signal processing analysis
  - RF signals without BDs
  - BDs signatures – RF input reaction
  - BDs locations – possible migration of BDs
- New diagnostics and possible improvements

BDs detection triggering data storage





1st Dec 2011 record

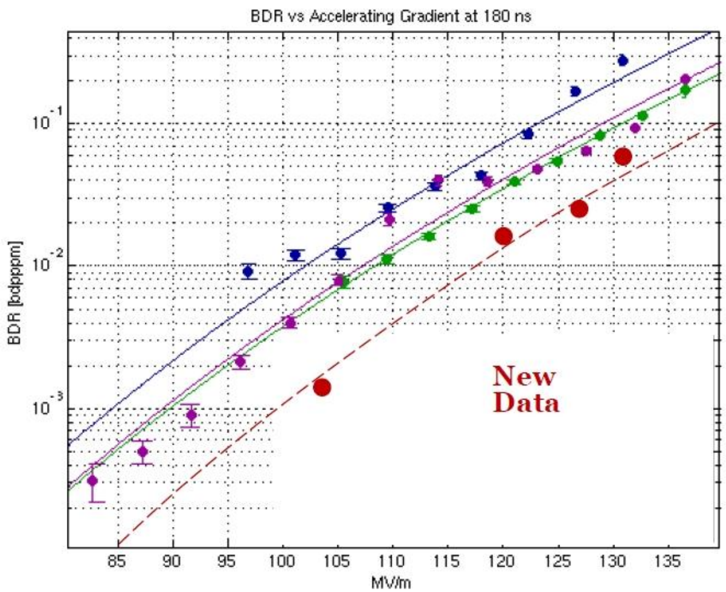
BDs detected by all 3 diagnostics

Rare cases of FCU detection only

Frequent cases of RF detection only

- With the present instrumentation set, most of the BDs are detected by RF signals (Reflected RF and Missing Energy).
- PM is jammed by noise (dark current, X-rays ?)
- FCU is sensitive to RF noise (like BPMs) and not always inserted (probe beam)

BDR from the last experiments

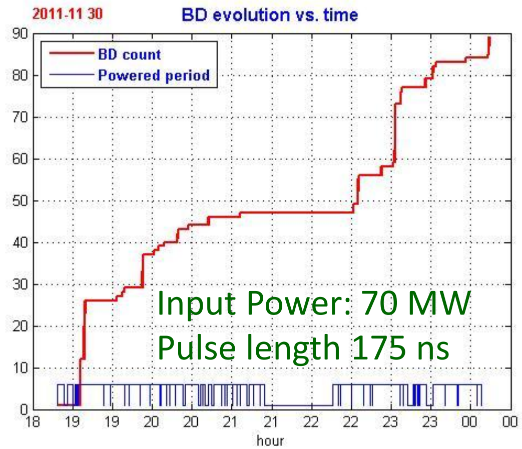


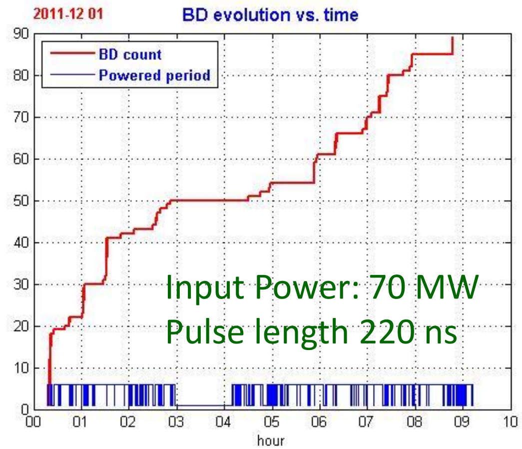
R. Corsini – CLIC Project Meeting, 9 Dec. 2011

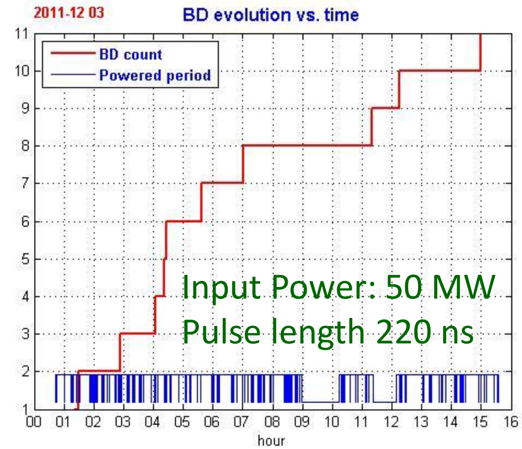
Date	Start time	Stop time	Power (MW)	Pulse (ns)	BDR
21 Nov.	22.24	22.26	70	160	0.88
22 Nov.	14.56	9.51	60	240	1.7 10^{-2}
23 Nov.	18.41	23.20	70	220	1.9 10^{-2}
24 Nov.	00.13	9.29	80	200	1.3 10^{-2}
30 Nov.	18.48	00.16	70	175	7.4 10^{-3}
1 Dec.	08.55	9.09	80	220	4.0 10^{-3}
3 Dec.	01.21	14.58	50	220	3.0 10^{-4}
6 Dec.	19.42	08.25	80	220	5.8 10^{-3}
7 Dec.	20.00	21.15	>100	120	0.8
8 Dec.	12.59	16.58	>100	150	0.15

- Only few records are meaningful for statistics

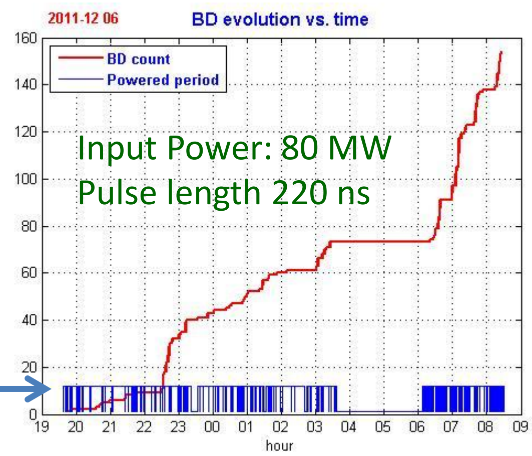
BD count vs. time

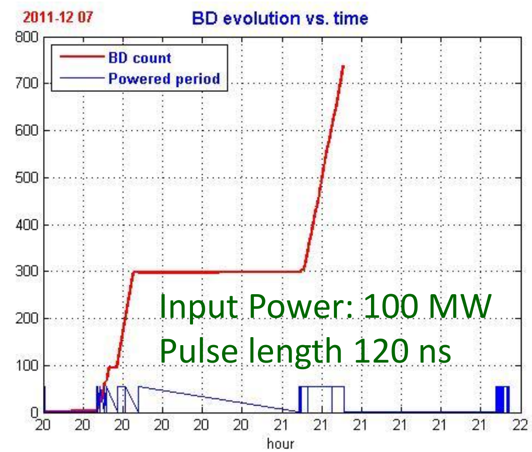






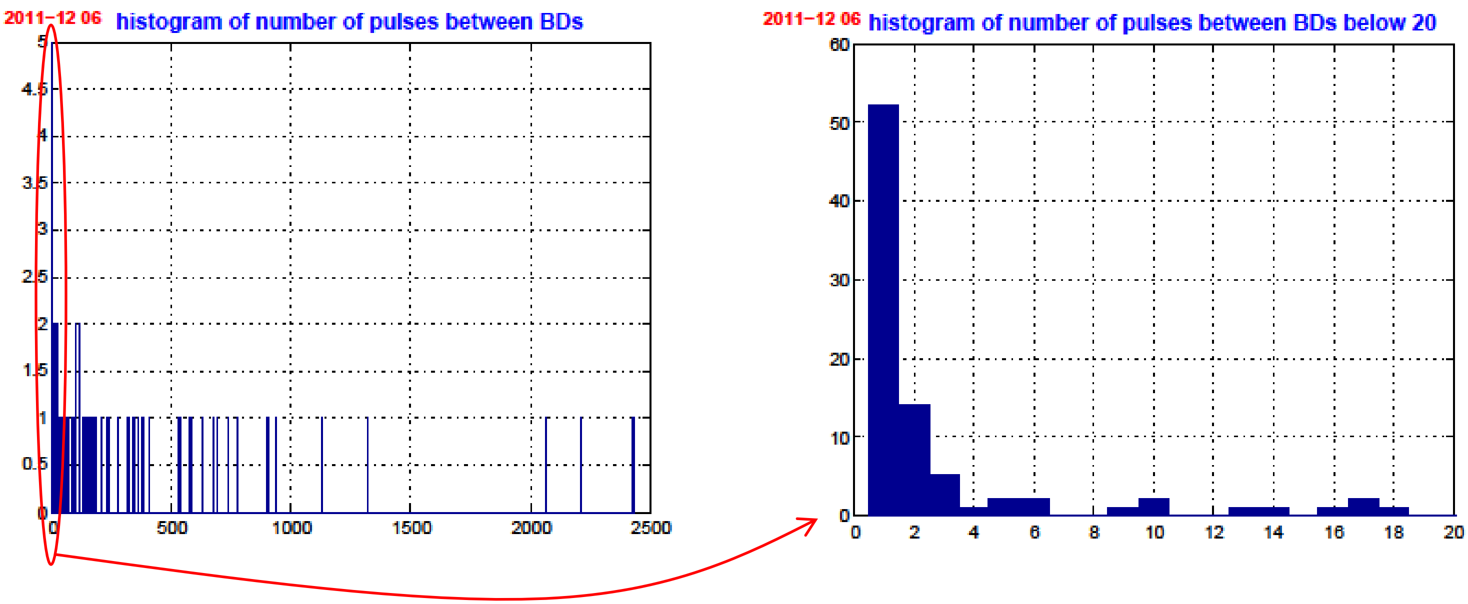
RF power ON





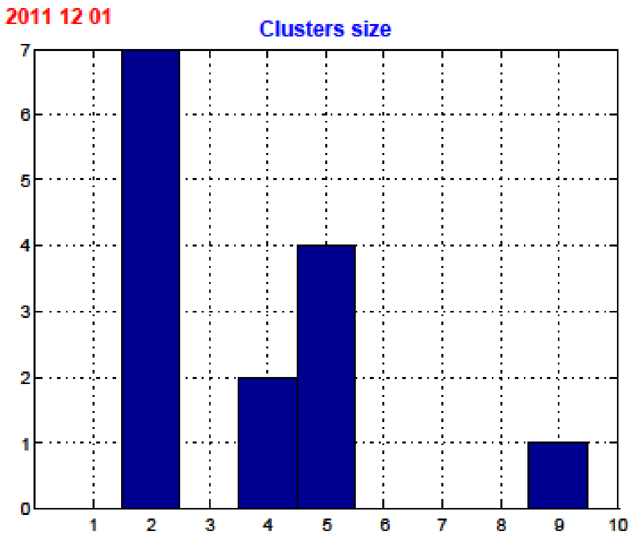
- Due to Drive Beam trips only *BDs count vs. "nominal" RF pulses number* is meaningful.

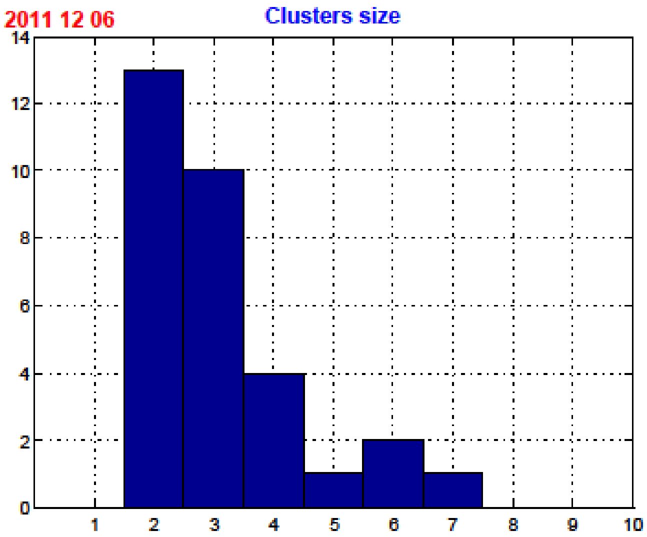
Numbers of RF pulses before a BD



Histogram and zoom on bins below 20 showing the presence of clusters.

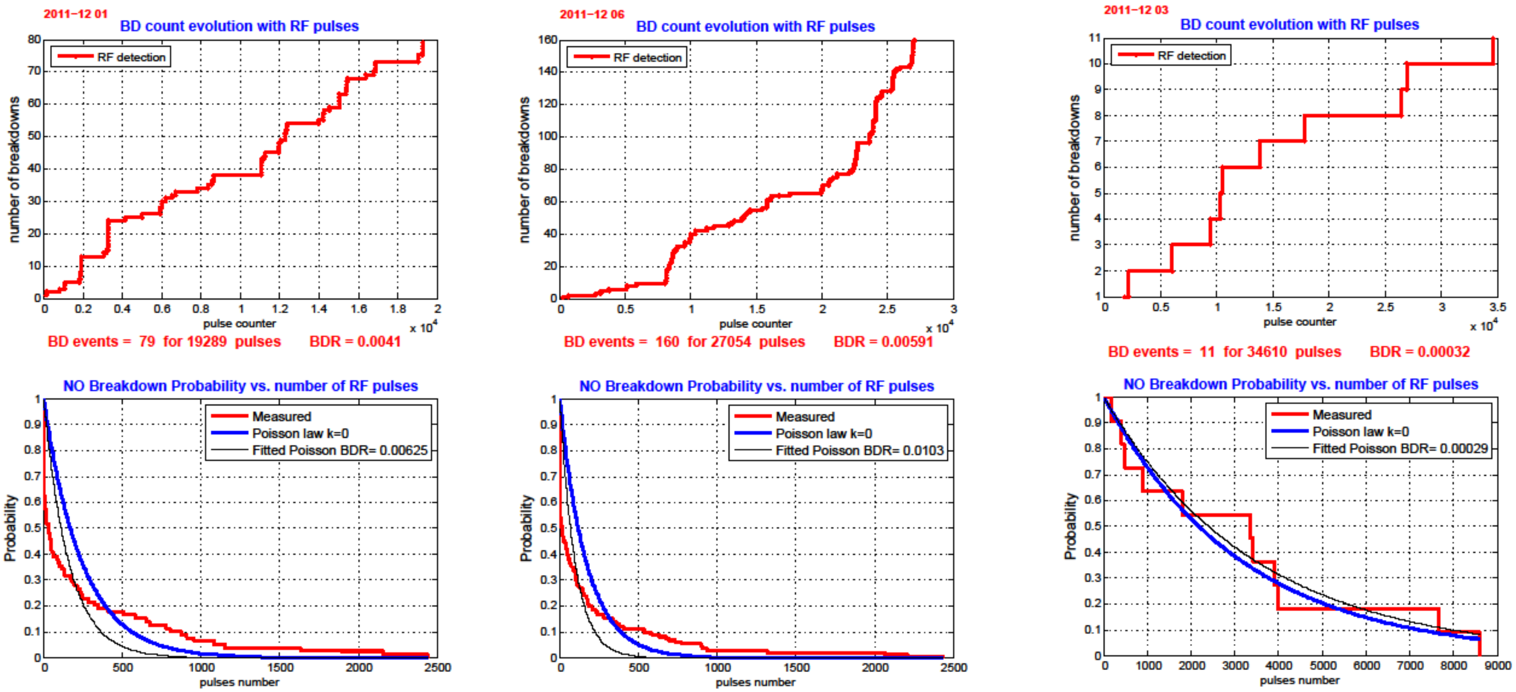
Clusters size distribution





However long series of consecutive BDs are rare

BDs time distribution and Poisson law



High BDR

Low BDR

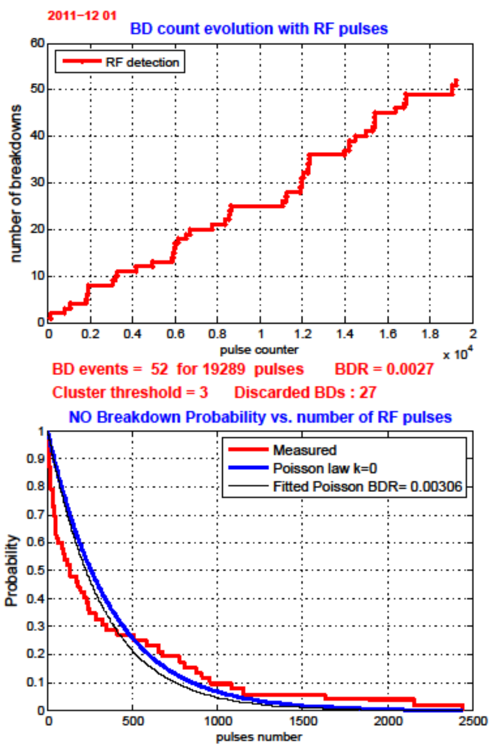
- Randomly distributed events should follow the Poisson law.

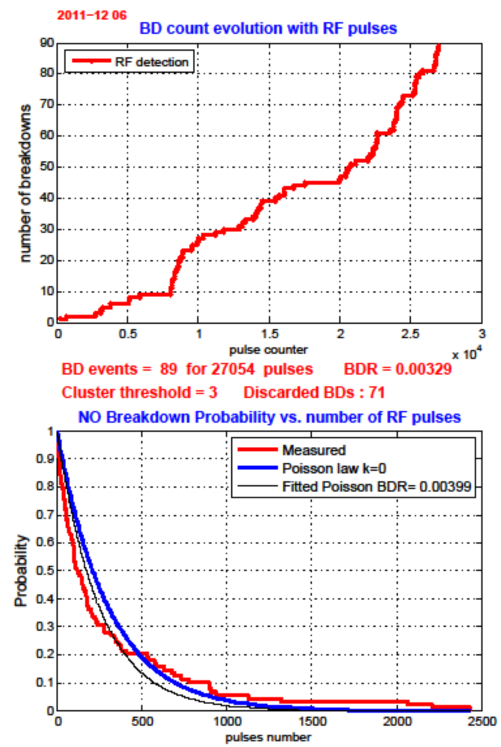
$$P(k,\lambda) = \frac{\lambda^k}{k!}\exp(-\lambda)$$

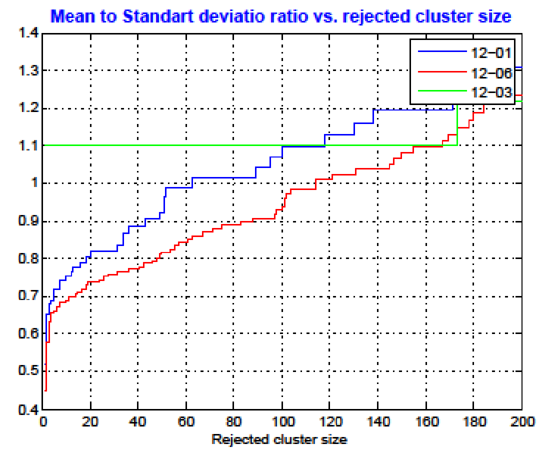
k : number of BDs, λ : BDR x number of pulses

- Clusters make the BD probability (BDR) non stationary

Discarding the cluster events







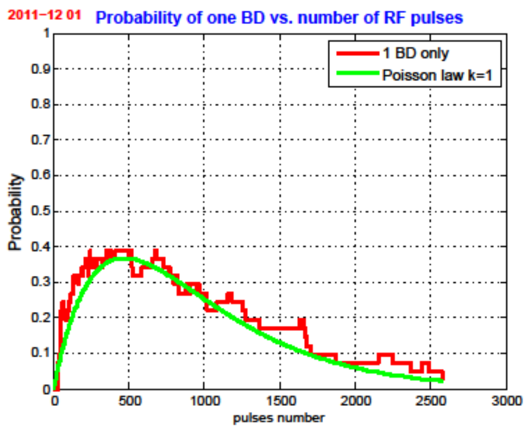
Evolution of mean/σ with the cluster size rejection

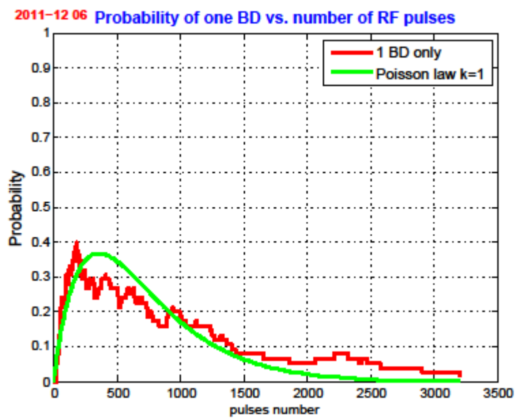
(1 for a Poisson distribution)

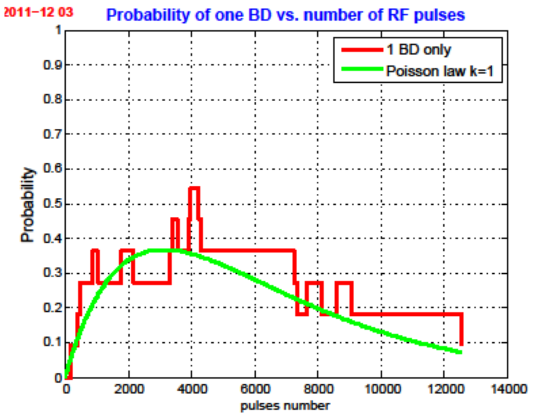
Rejecting clustered BDs leads the BDs events to be more "Poisson Like"

- Discarding successive BDs can be considered like ramping the power after a BD (not done in the TBTS)

Probability of one single BD within a given number of RF pulses







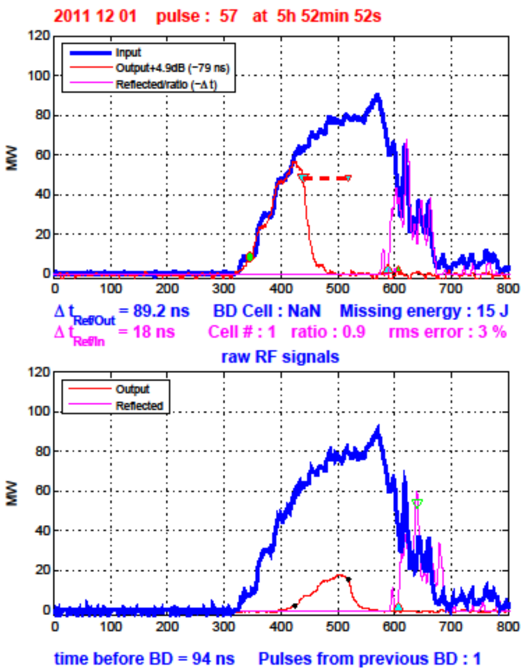
Clusters rejected up to 20 pulses between BDs

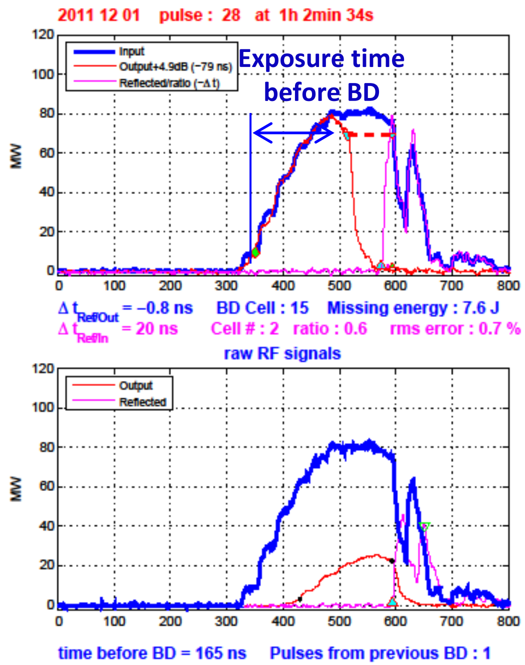
No clusters rejection needed at low BDR

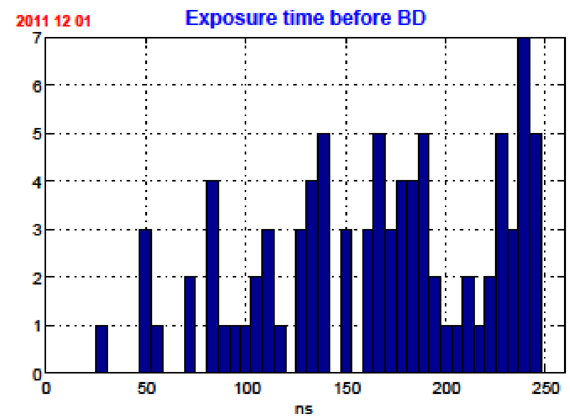
- Poisson law for k = 1 and plotted using the raw BDR for λ (not a fitted one)

$$P(k,\lambda) = \frac{\lambda^k}{k!}\exp(-\lambda)$$

RF exposure time before BD



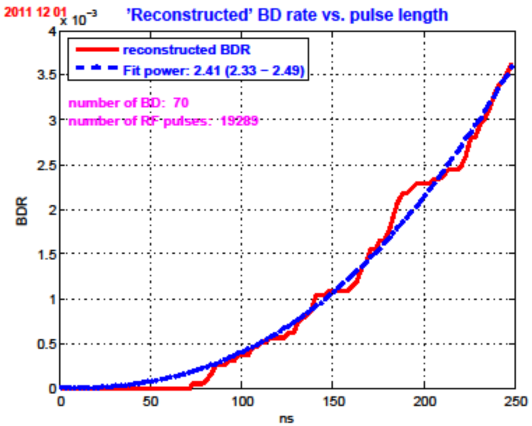


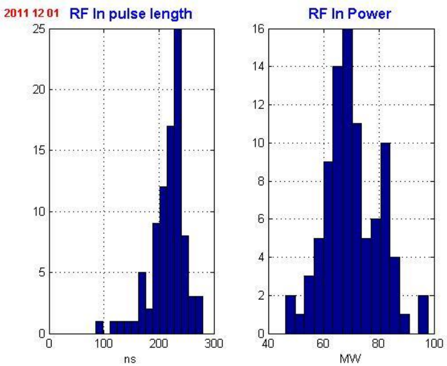


Histogram of exposure time before BD

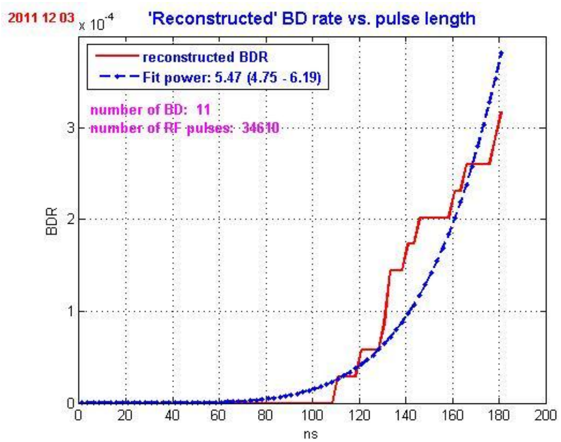
- Exposure time measured on transmitted RF signal
  - Dependent on edge definition (particularly sensitive with recirculation pulse shape: no steep edges)

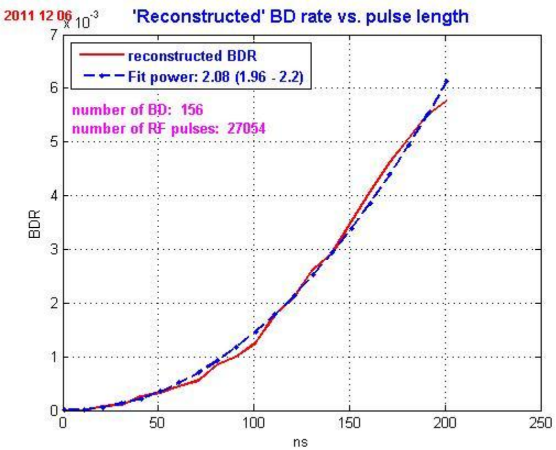
BDR as function of exposure time





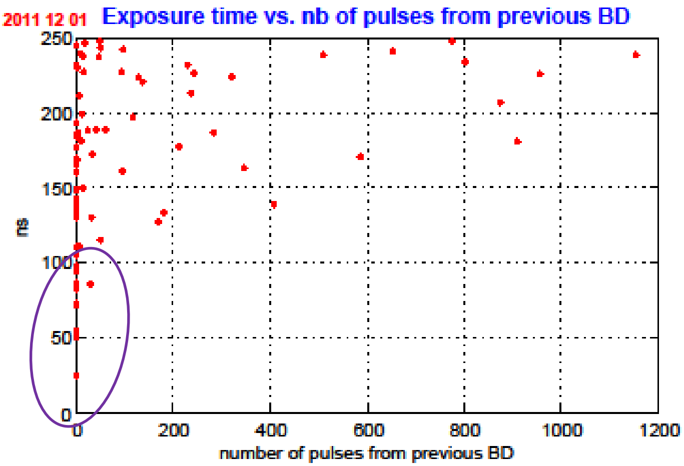
Pulse length and energy stability checking



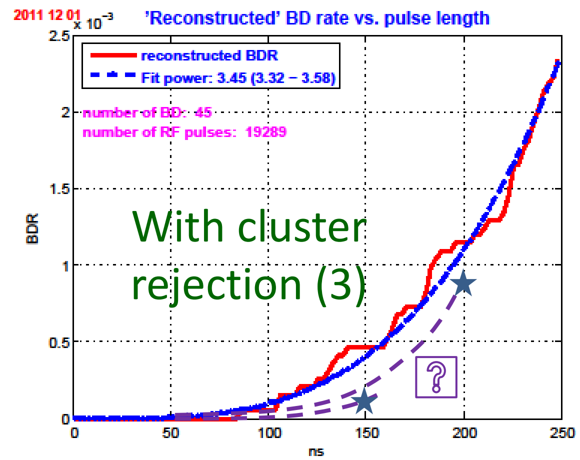


- Assumption : BDs occurred before a given time have the same statistic as if the pulse length would have been this time: NO MEMORY EFFECT CONSIDERED

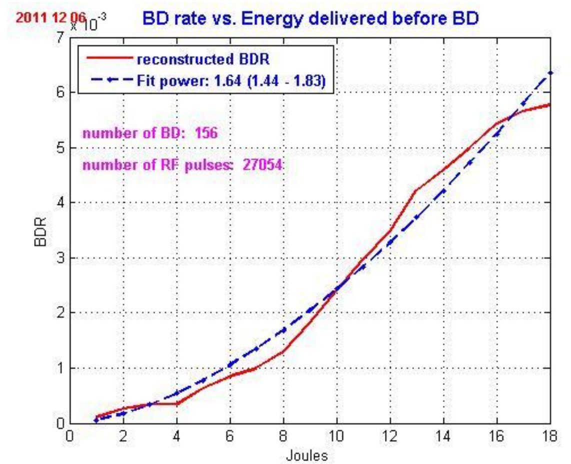
Influence of clusters



All BDs occurring before 100 ns exposure time are inside clusters

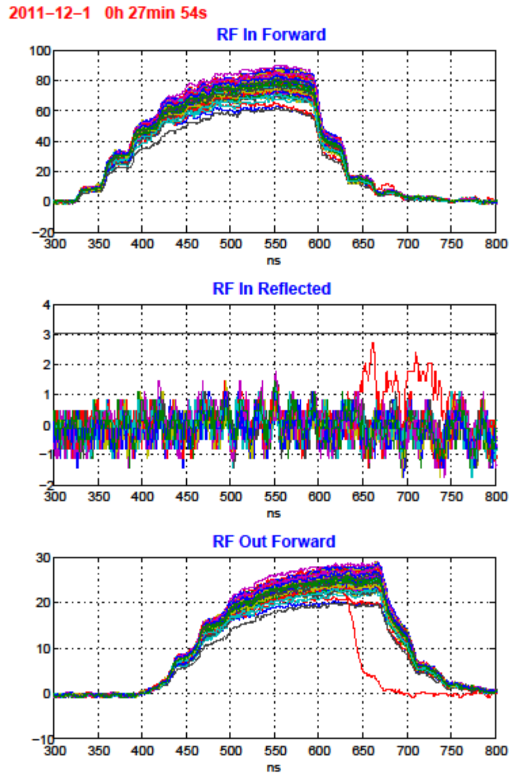


Alternative dependence law: "Energy delivered before BD" to avoid rising edge problem (thanks to Jan Kovermann)

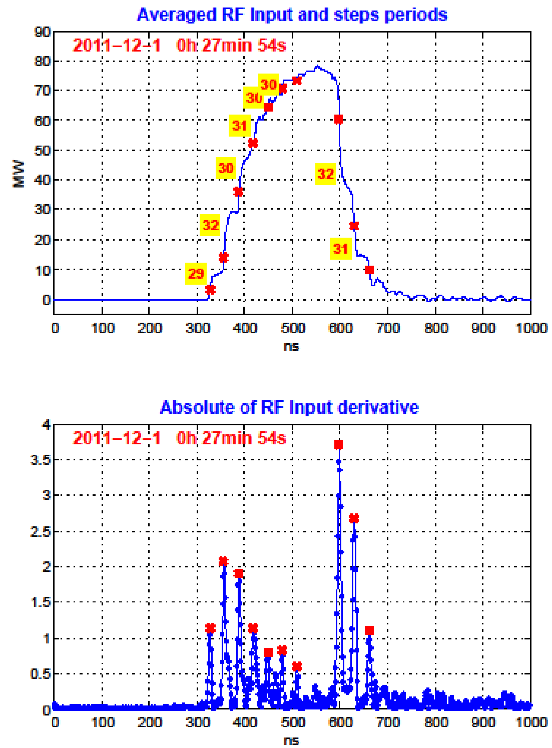


- It will be very interesting to draw the same plot at various pulse lengths *at low BDR* (checking a possible "fatigue" effect function of the pulse length)

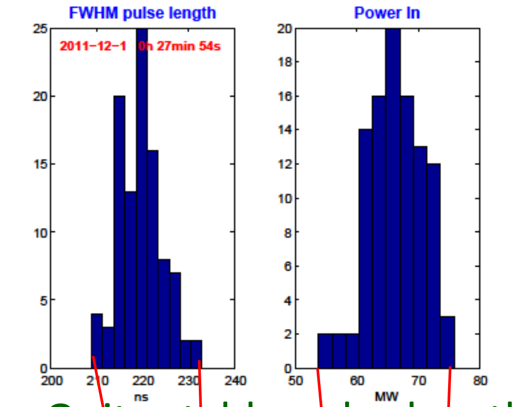
RF signals without BDs



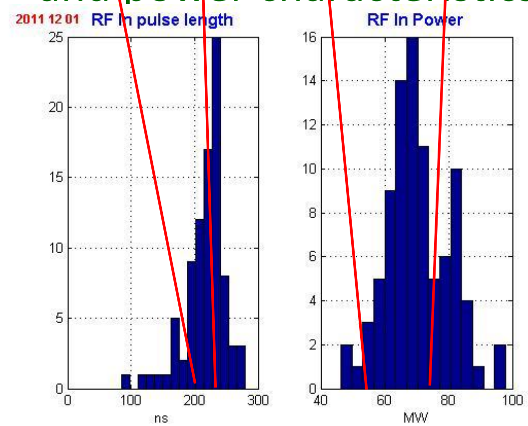
100 consecutive signals including 1 BD



Average input signal and steps detection showing the recirculation loop delay of 31 ns



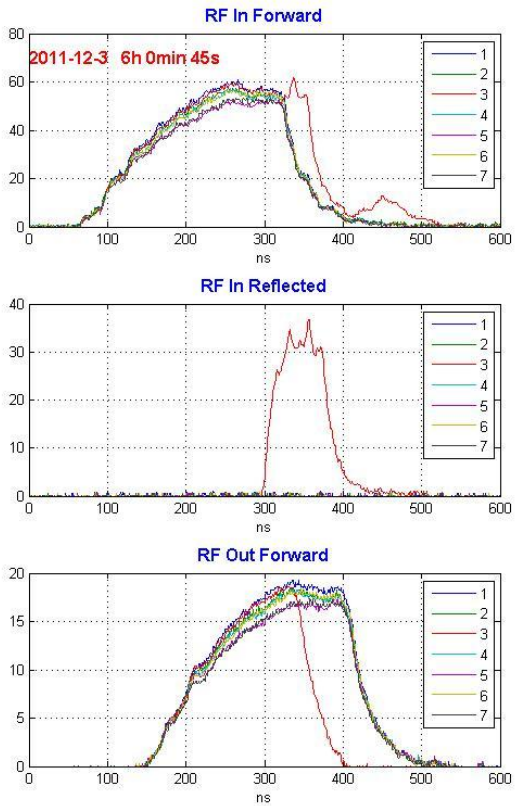
Quite stable pulse length and power characteristics



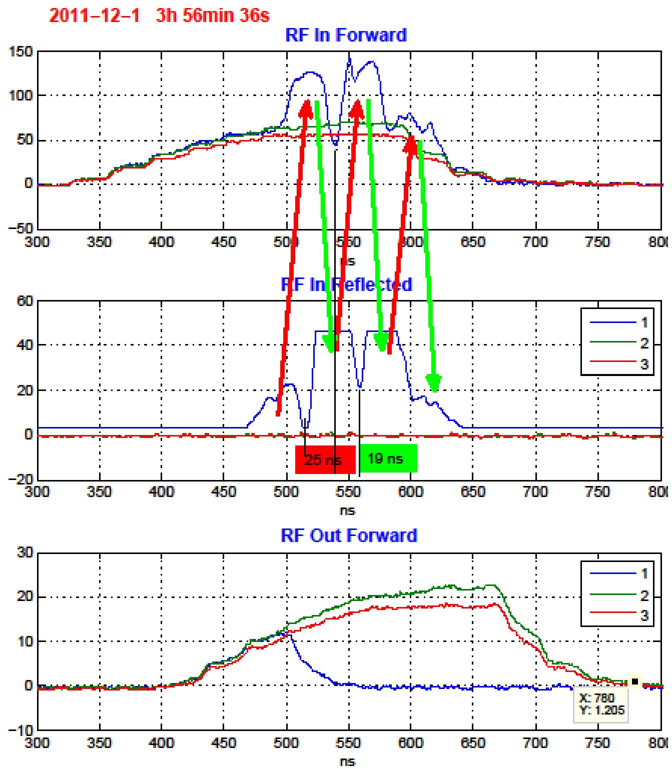
much less stable when ACS BDs !

- Without BDs all signals are quite stable: good RF power production by the Drive Beam

Evidence of ACS BDs effect on RF Input



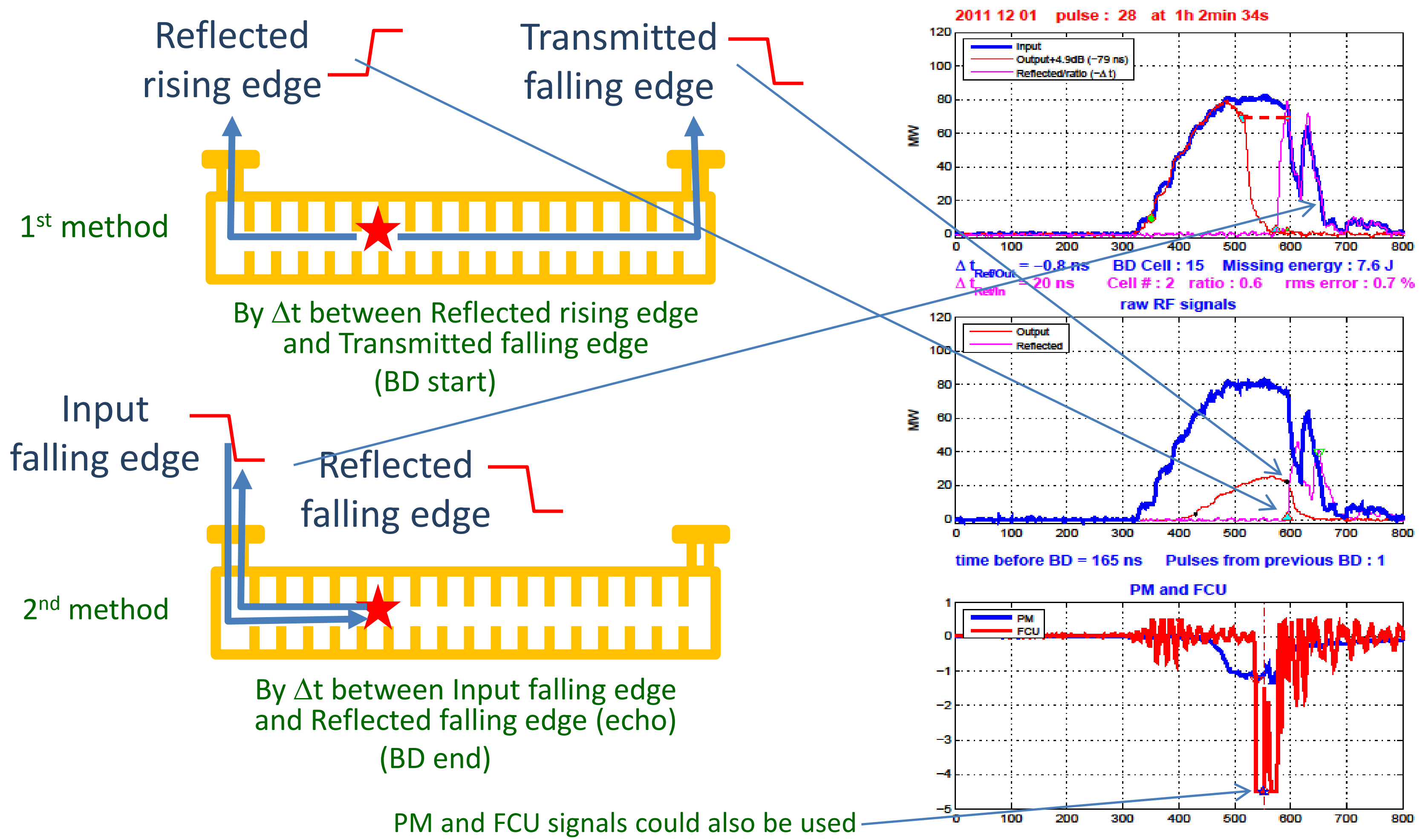
A BD in the ACS affect the PETS output



Possible bouncing of an early BD reflected power

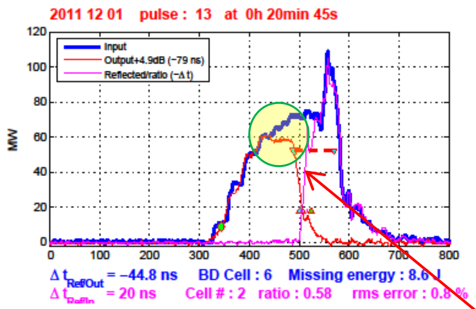
- The reflected power is likely to change the phase of the recirculation loop and consequently modify the PETS produced power

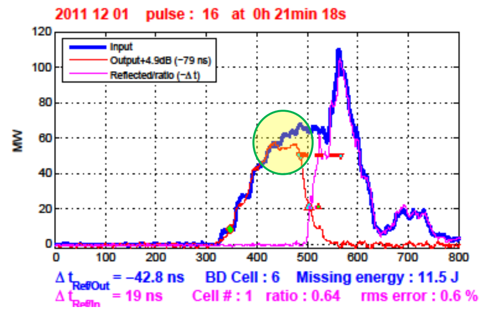
BD location determination

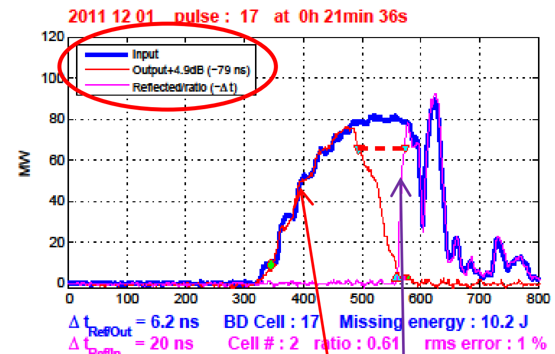


- Edge detection is always tricky especially for the transmitted signal (BD precursor)
- Cross-correlation method is much more robust

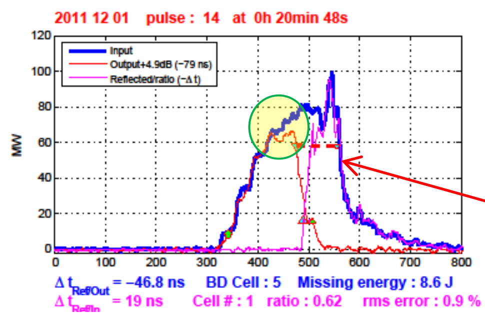
BD precursor on transmitted signal

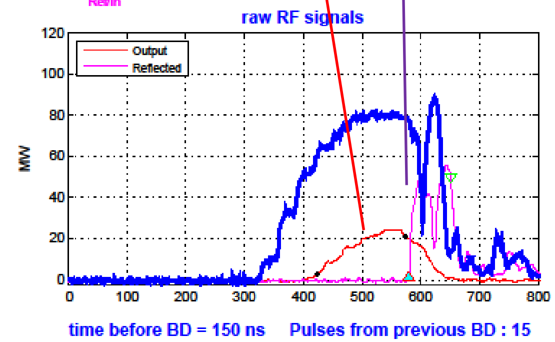




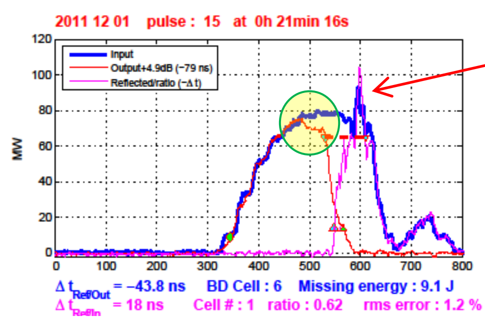


Uncertain falling edge location

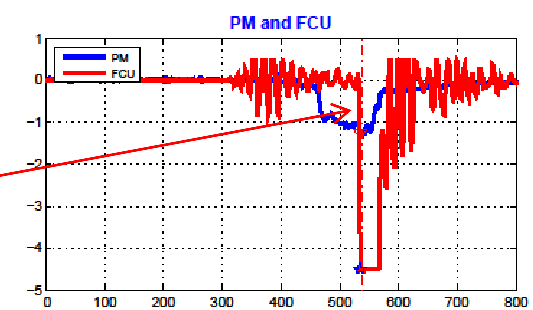




Very good cross-correlation



Glitch of extra PETS power

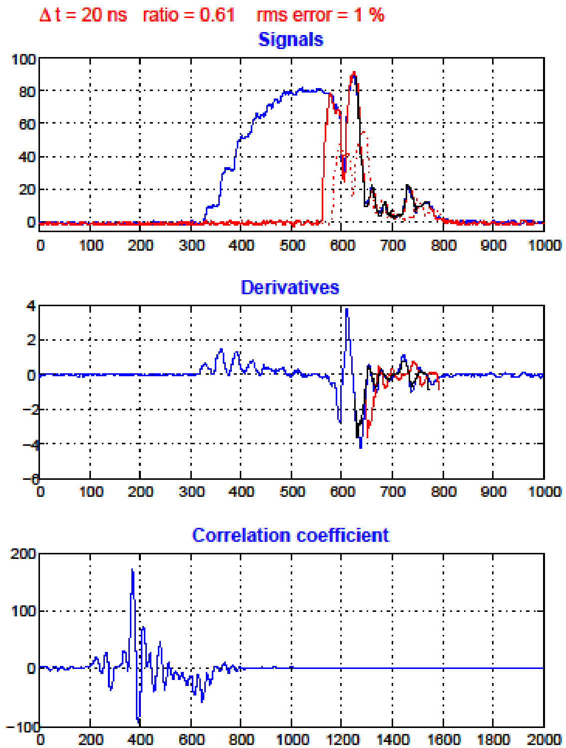


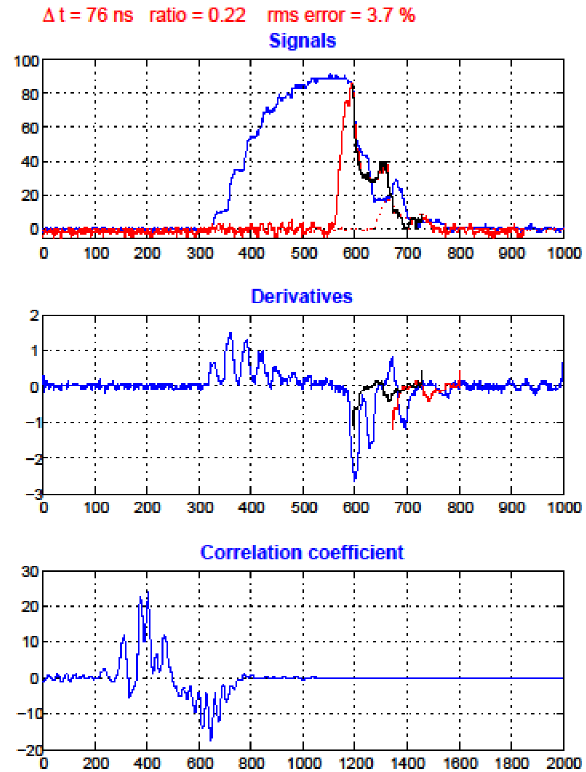
Excellent consistency with FCU detection (unfortunately rather rare)

Consecutive BDs

- BD development: RF power is absorbed before reflected power appears

Edge correlation Input - Reflected

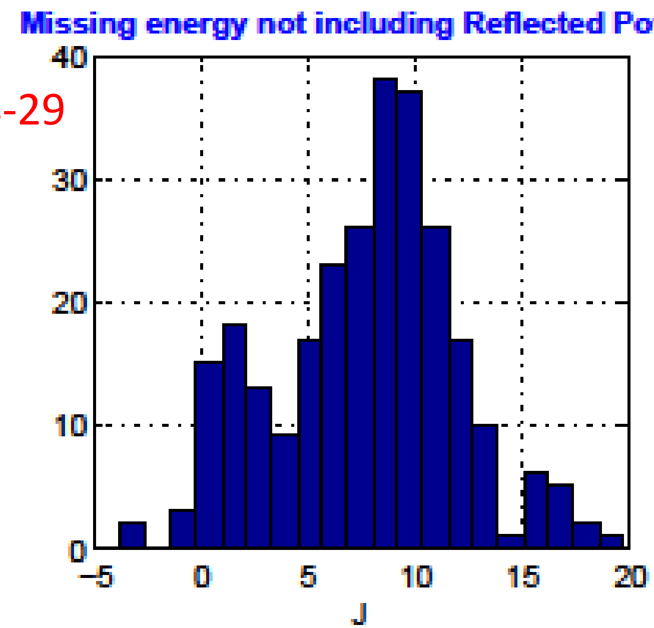


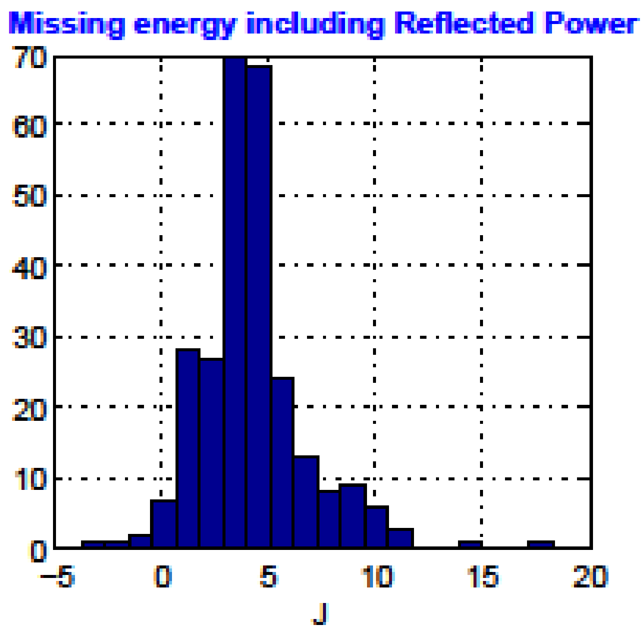


- Use of cross-correlation of the derivatives of the falling edge area to accurately determine the Δ time
- Then fit the amplitude for minimizing rms difference between shifted signals and to determine the attenuation
- ACS group velocity dispersion does not seem to affect the pulse shape

Missing energy

2011-08-29

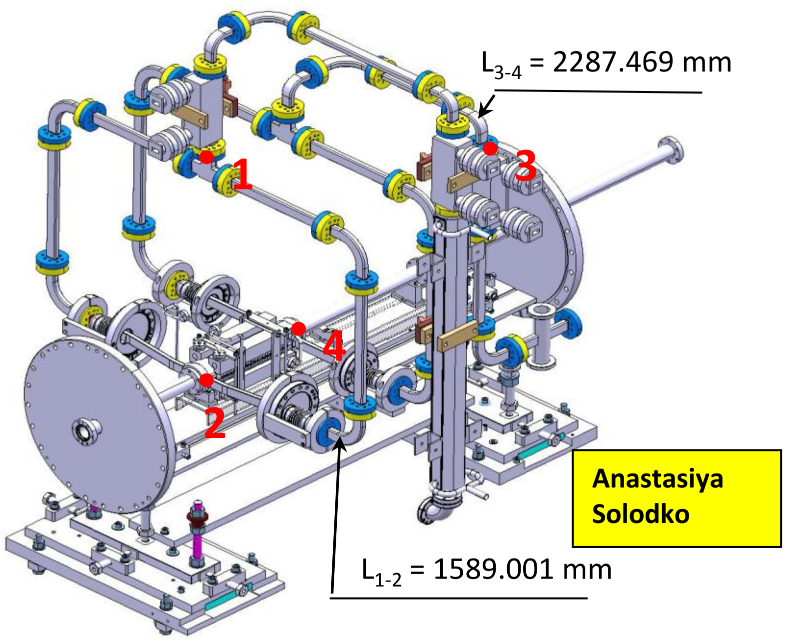


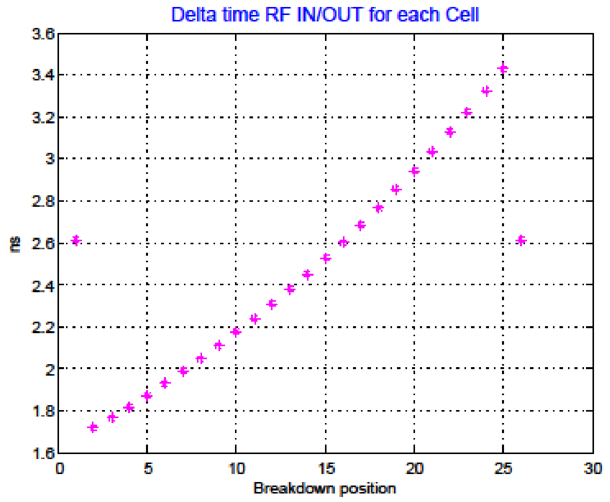


Subtraction of Reflected power taking into account the ACS attenuation up to the BDs location

- Missing energy is quite different if reflected power is subtracted

ACS in TBTS environment characteristics



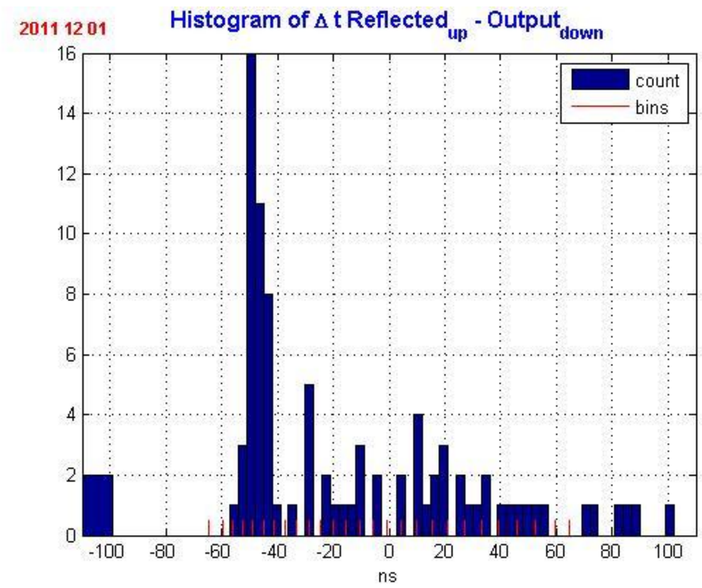


Travelling time for each cell

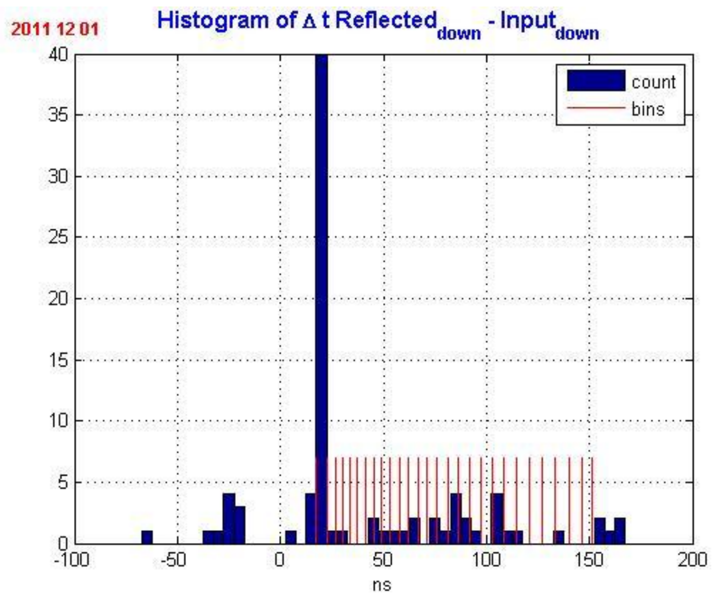
- WG lengths provided by Anastasiya
- RF cables characteristics from Stephane
- ACS network analyzer measurement from Jiaru
- ACS theoretical characteristics from Alexei *TD24_vg1.8_disk 12WDSDVG1.8 CLIC_G disk at 12 GHz A.Grudiev, 25/03/10*

- Flange attenuation was found to be 0.034 dB (to be measured independently)

BDs location histograms

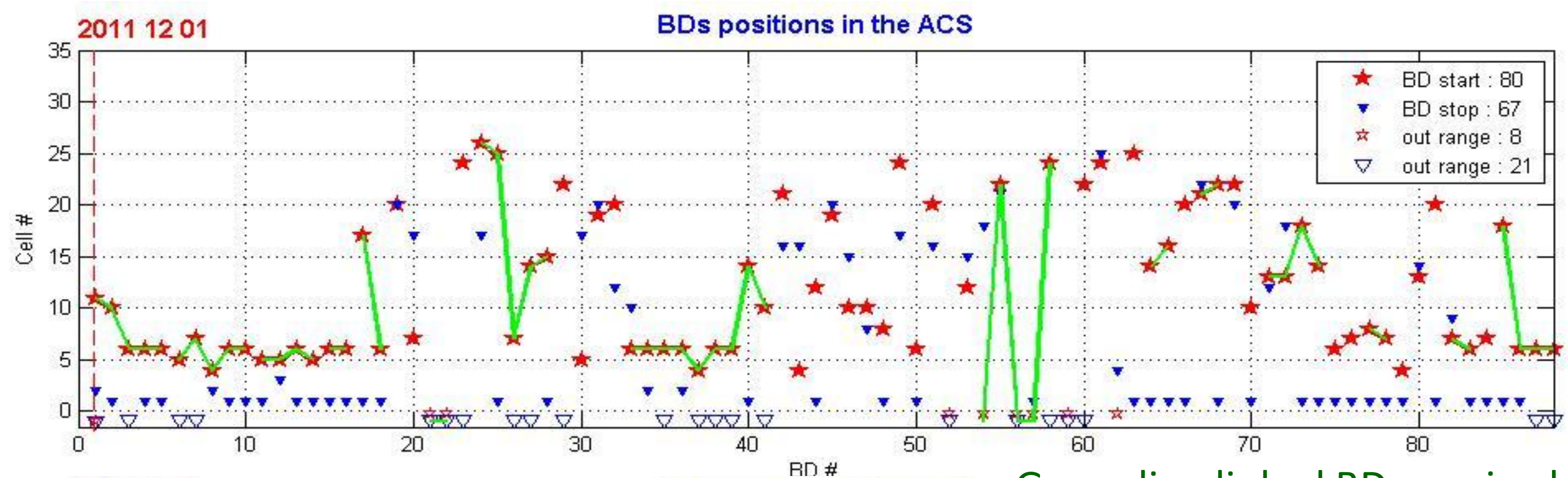


1st method : cell #5 seems more affected

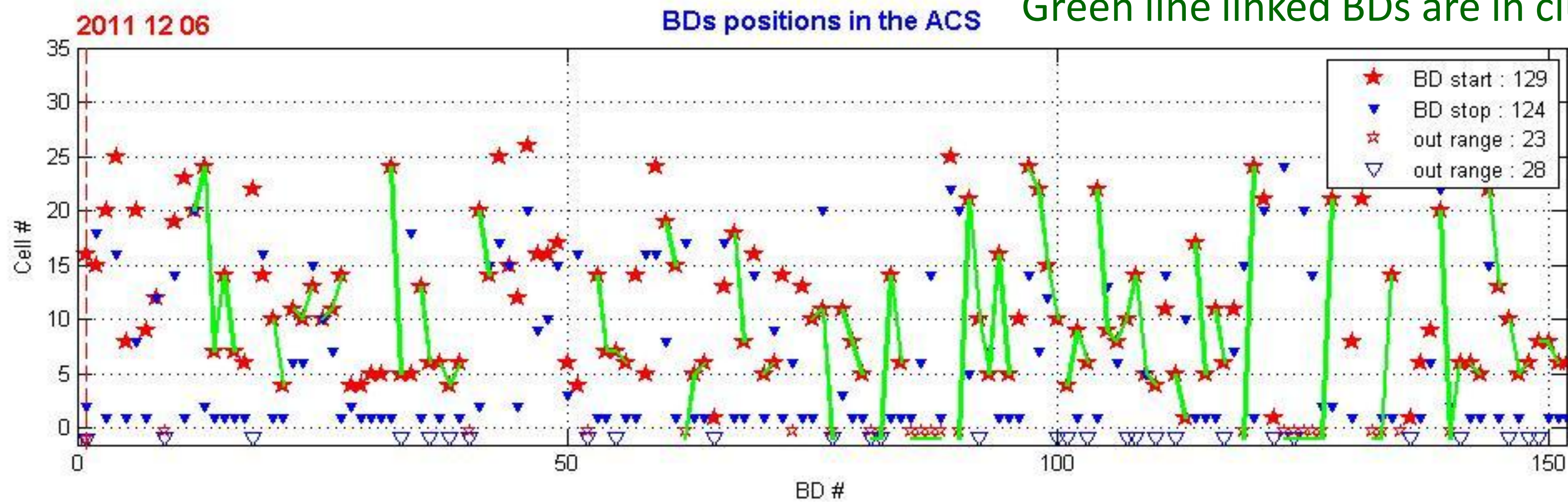


2nd method : cell #1 seems more affected

BDs location chart

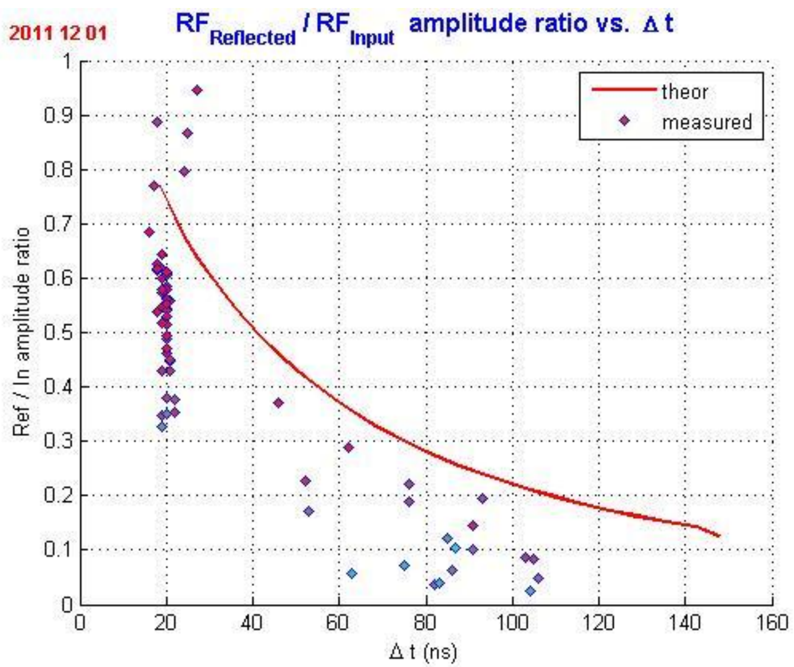


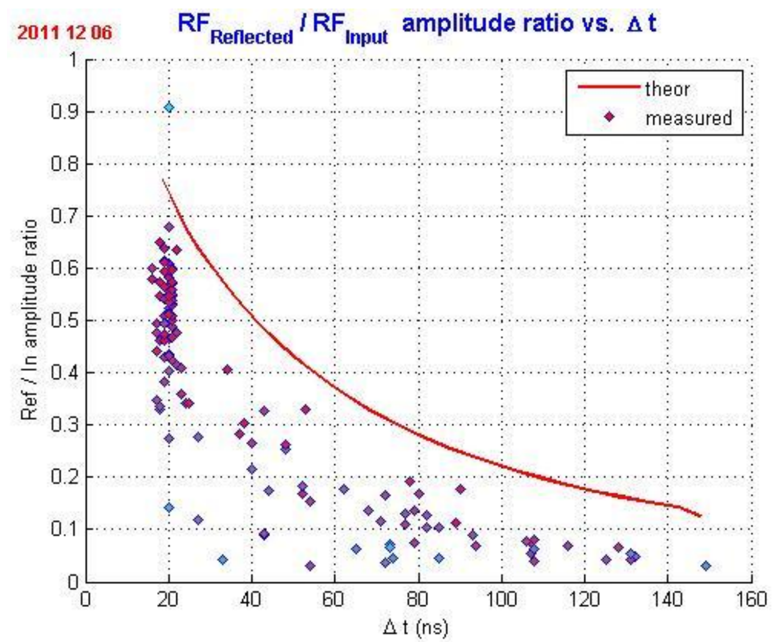
Green line linked BDs are in clusters



- BDs seems to migrate from the initial position to the first cell (from red star to blue triangle)

Attenuation vs. BD location

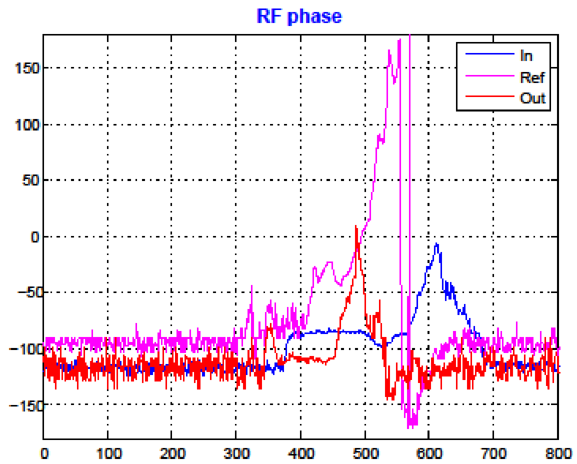


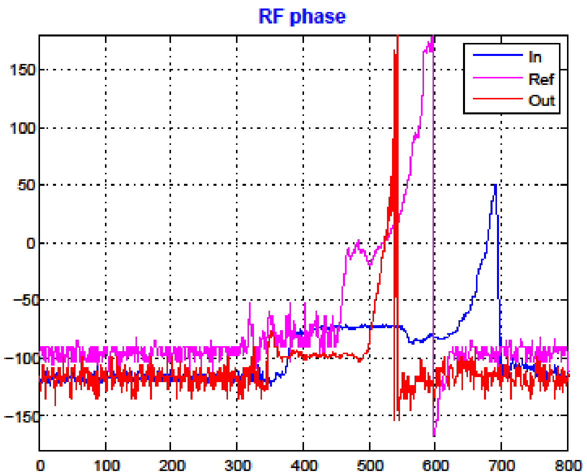


dots color code : rms error

- Reflected power is consistent with the detected position of the BD
  - BDs are not always 100% reflective
  - Still some uncertainties in the power calibration of the various signals

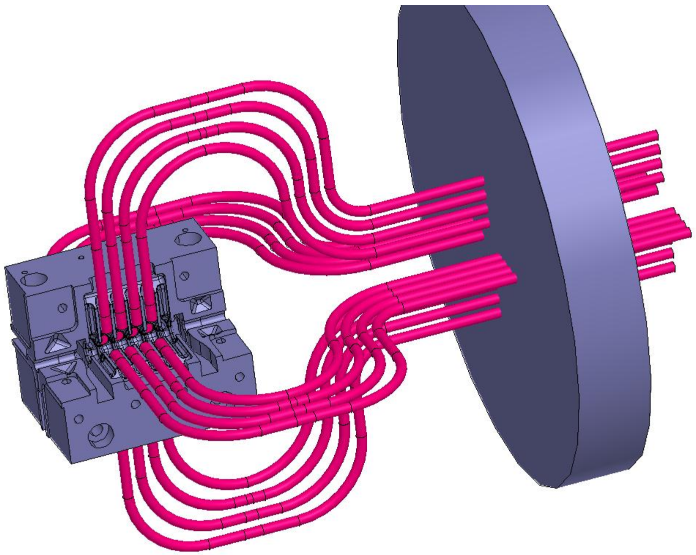
Phase information



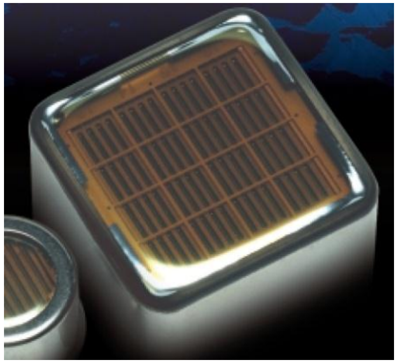


- Not yet fully processed
- No clear clue of BD migration
- Evidence of PETS reaction to reflected power

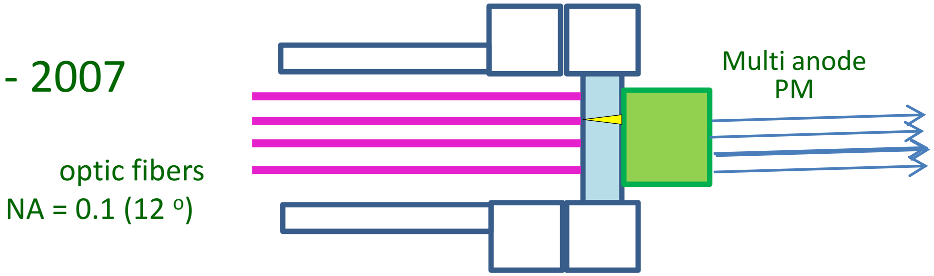
Diagnostic to localize BDs with time resolution



Franck Peauger - 2007



Hamamatsu H8711
16 channels PM

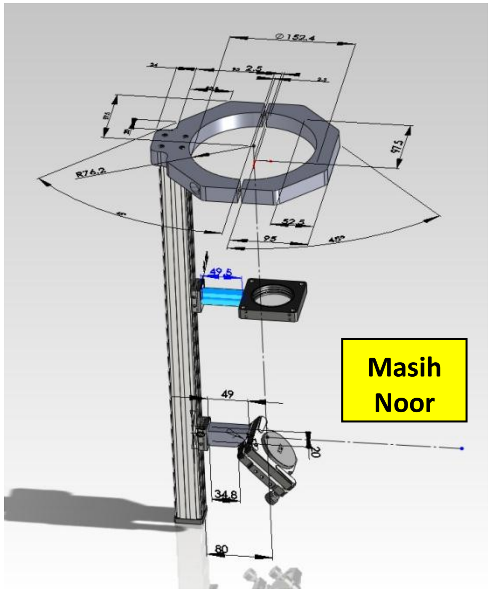


Viewport

- Use of a viewport instead of feedthrough (Jan K.)

The next run…

- Use other coupler signals (PETS)
- Use the RF phase information
- Collect more data at reasonable BDR
  - Long shift at stable power characteristics
  - Higher repetition rate
  - Fix the data acquisition / synchronization
- Additional diagnostics
  - PM looking inside the TD24 through FCU mirror
  - New re-entrant cavity BPMs
- Use of
  - the Flash Box (ions still to be detected)
  - the Wakefield monitor on Saclay ACSs
  - 2 ACSs powered by a single PETS (possible BDs cascading ?)



PM optical line