Analysis of TBTS high-gradient testing and breakdown kick measurements

CLIC RF structure development meeting
CERN, 29 Feb 2012

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Outline

- Influence of RF-breakdowns on the beam:
  what we expect and how we can measure it at TBTS
- Screen-based measurements of transverse beam kicks
- Correlation study of measured kicks with breakdown characteristics (cell number, missing energy, input power)

RF-breakdown influence on the beam

beam expected to get a transverse kick
in the structure when a breakdown occurs
(as measured by other experiments, cfr. Dolgashev, SLAC-PUB-10668)

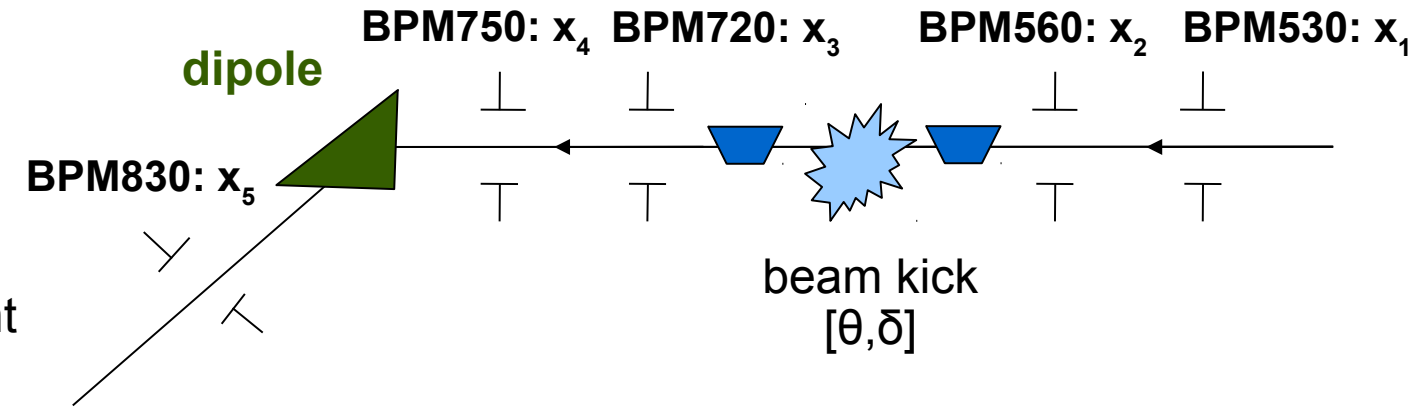
Assuming that the breakdown occurs “during” the pulse
(neither before nor after):

1. the whole beam pulse can be kicked (new orbit);
2. only part of the beam pulse can be kicked (only the kicked part follows a new orbit);
3. the beam can be completely lost;
4. the energy of the kicked beam changes.

BPM-based transverse kick measurement

4 BPMs for kick measurement (angle and offset)

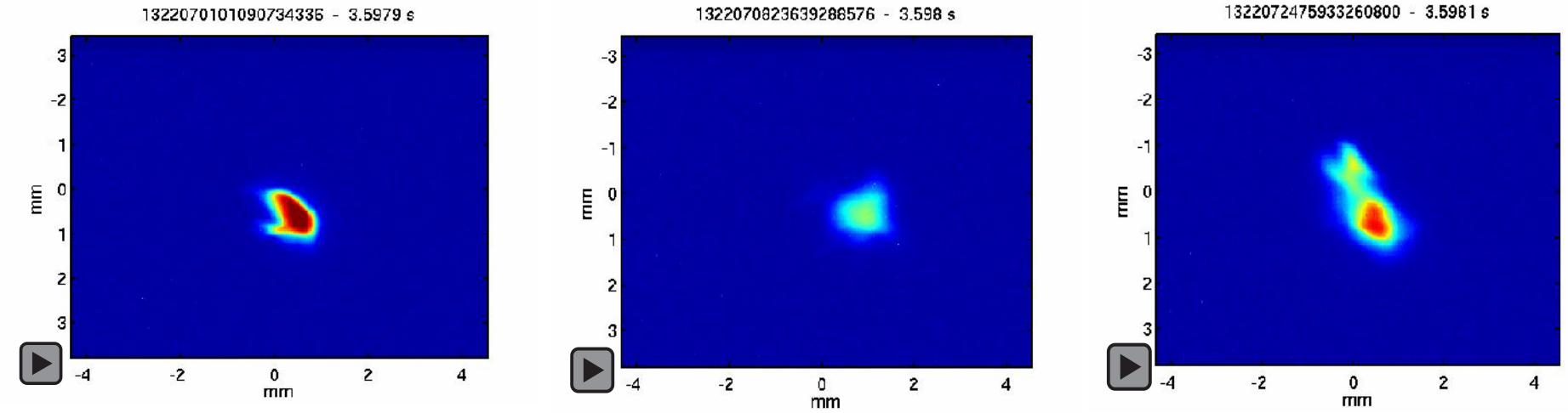
dipole + 1 BPM for energy measurement



- aiming at 10 μm BPM resolution to reach ~10 μrad angle resolution (cfr. Johnson, CLIC-NOTE-710)
- currently limited at ~300 μm due to to small signal-to-noise ratio and blinded by drive beam noise (below 100 MHz) induced on the diagnostics (cfr. Palaia, EDMS document 1175749)
- modifications to existing BPMs (inductive peak-ups), installation of new laser and two cavity BPMs (before April 2012), will improve BPM resolution → BPM-based kick measurements planned for CTF3 2012 run.

Screen-based kick measurements

how the beam looks like when a RF-breakdown occurs

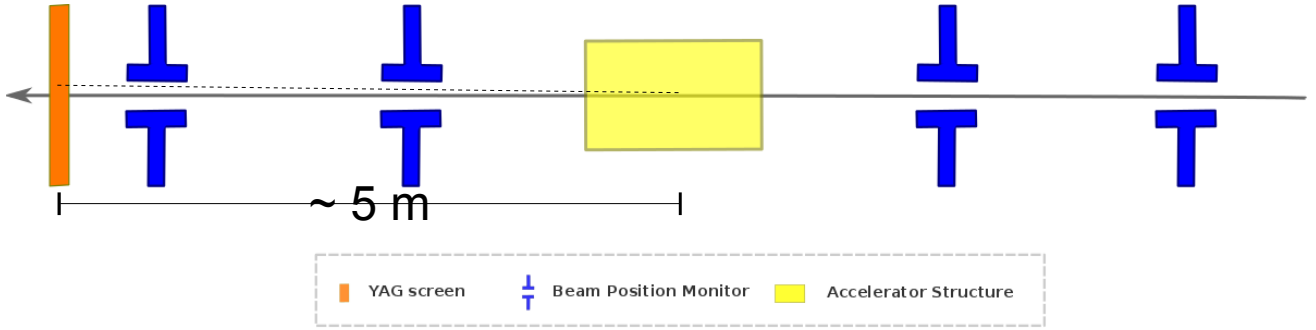


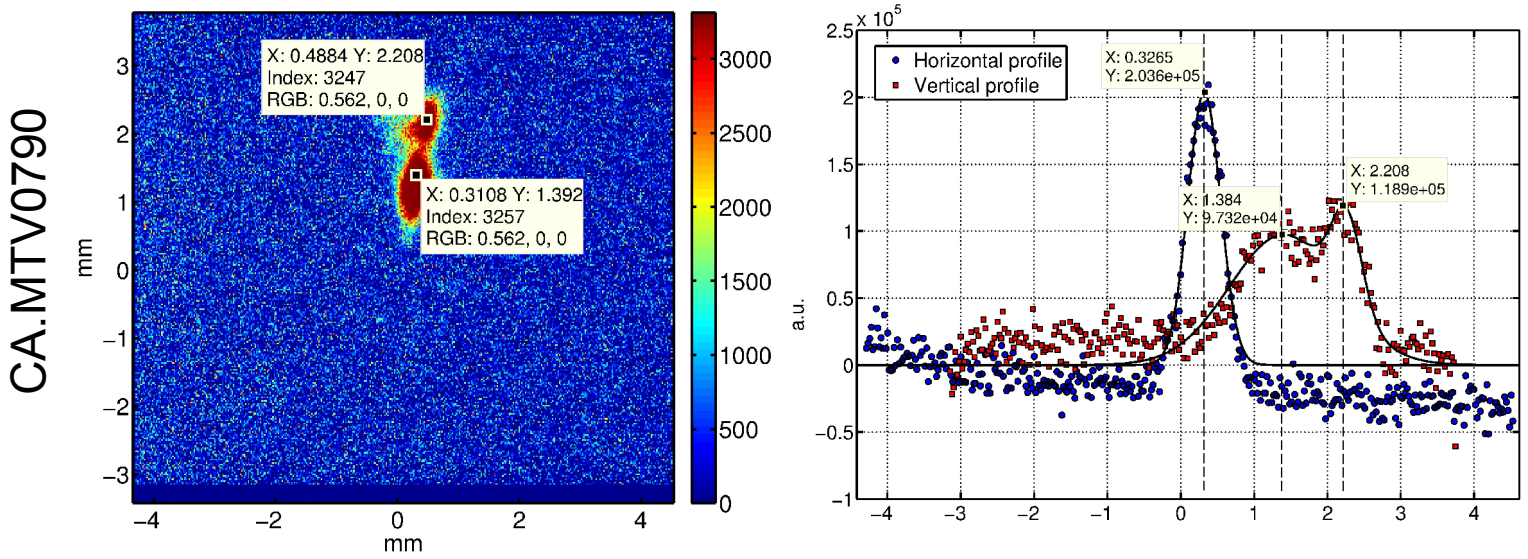
- the beam shape is affected by RF in the ACS even if no breakdown occurs
- due to the beam jitter (~1 mm) it is not possible to detect a whole kicked beam pulse

RF-breakdown kick to the beam

example of YAG screen based measurement

22 August 2011: first attempt to measure the effect of RF-breakdown on the probe beam

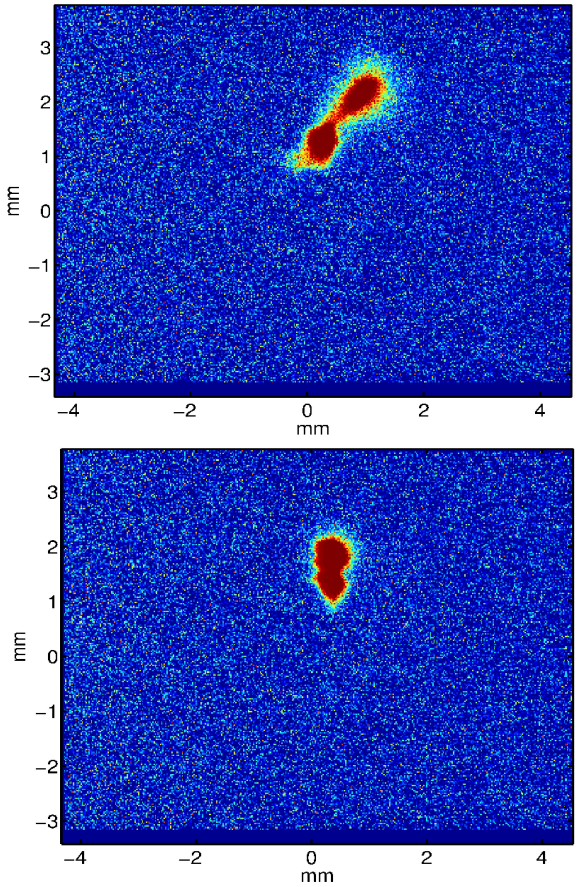


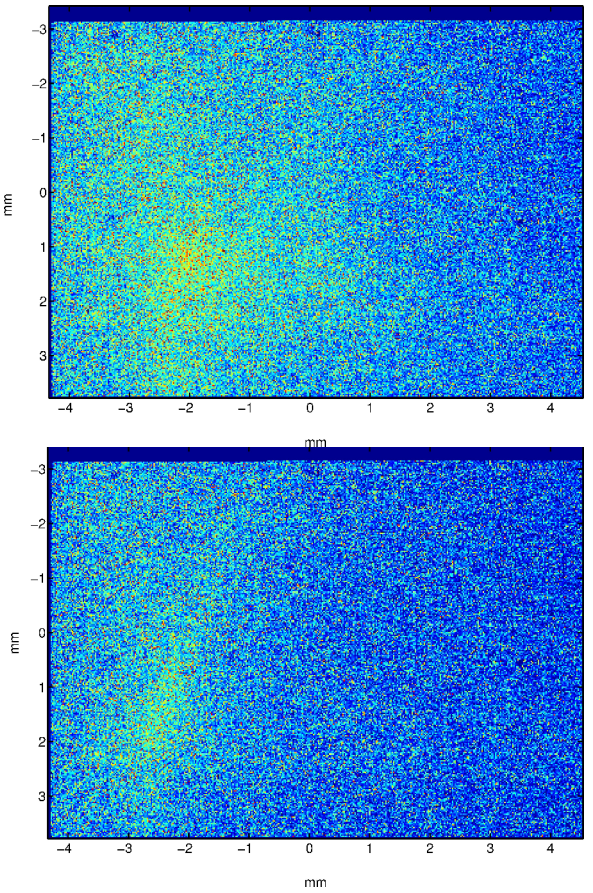


Kicked beam or breakdown current?

Measurements with (left) and without (right) probe beam,
same input power in the ACS (~80 MW)

kicked beam





breakdown current

REMARK: different filters used to prevent saturation with the beam

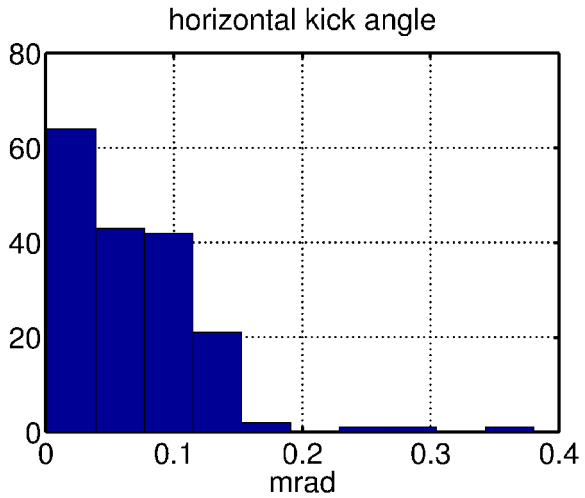
RF-breakdown kicks to the beam

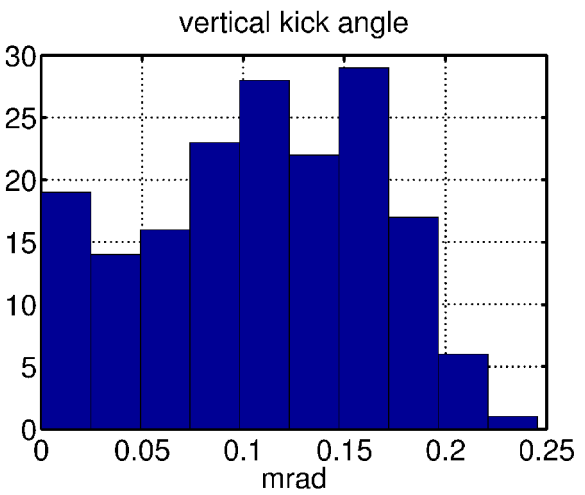
statistics of YAG screen based measurements

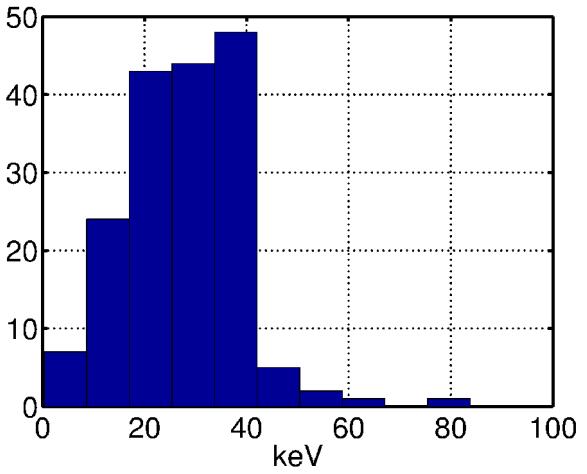
29 AUG 2011 data

analysis on ~170 BD events, 2-Gaussian fit on horizontal and vertical profile of the screen (separately)

- kicks on horizontal and vertical planes between 0.02 and 0.2 mrad;
- kicks corresponding to a transverse momentum between 10 and 40 keV/c (measurements at NLCTA within 30 keV/c, cfr. Dolgashev, SLAC-PUB-10668);







REMARK: preliminary results based on a larger data-set
with respect to what used so far (cfr. Palaia, CTF3 working meeting)

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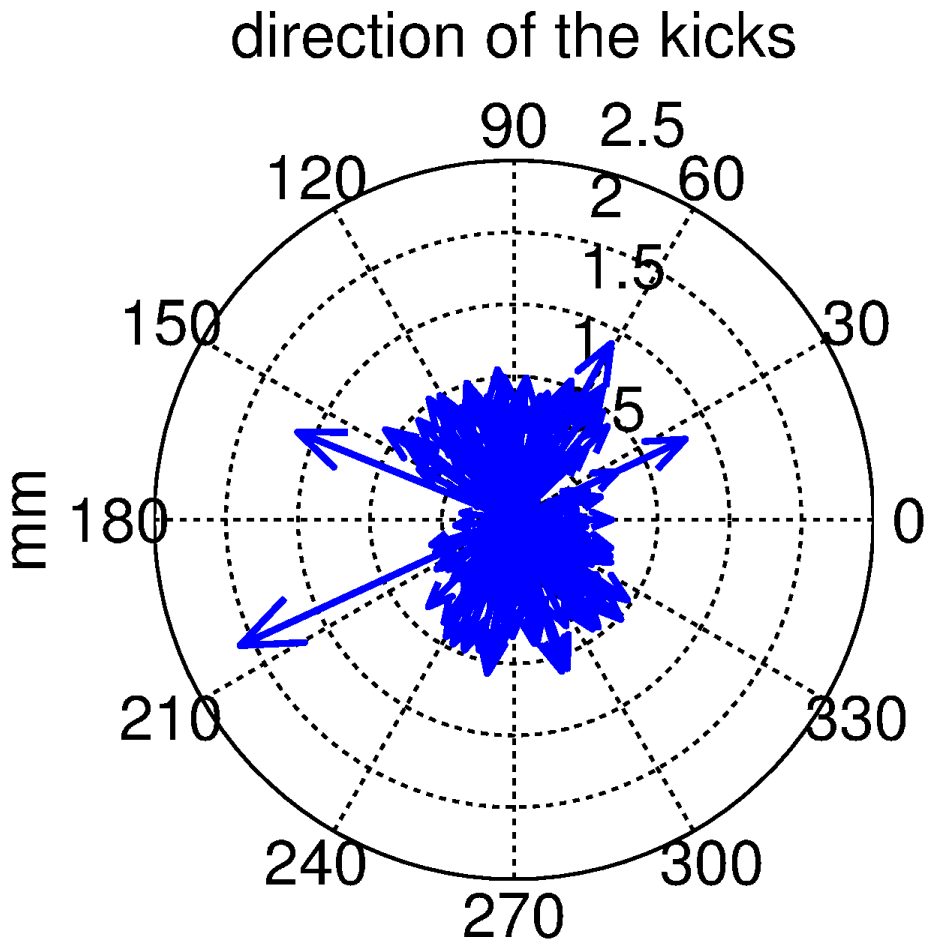


29 AUG 2011 data

REMARKS:

1. preliminary results based on a larger data-set with respect to what used so far (cfr. Palaia, CTF3 working meeting)

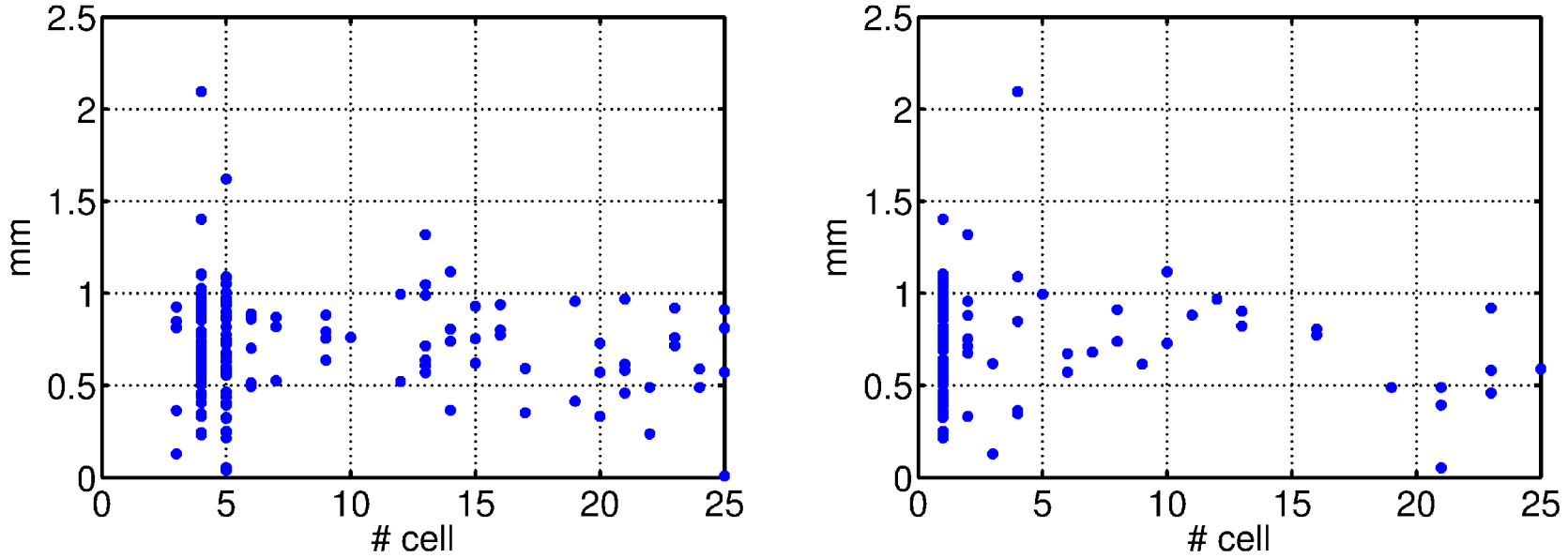
2. the kick direction is somehow “guessed” due to the unavailability of the non-kicked beam pulse

RF-breakdown kicks to the beam

correlation with breakdown position in the accelerator structure

analysis on ~170 BD events, 2-Gaussian fit on horizontal and vertical profile of the screen (separately)

distance between the peaks (measured on the screen) vs BD cell number



Estimation of BD cell:

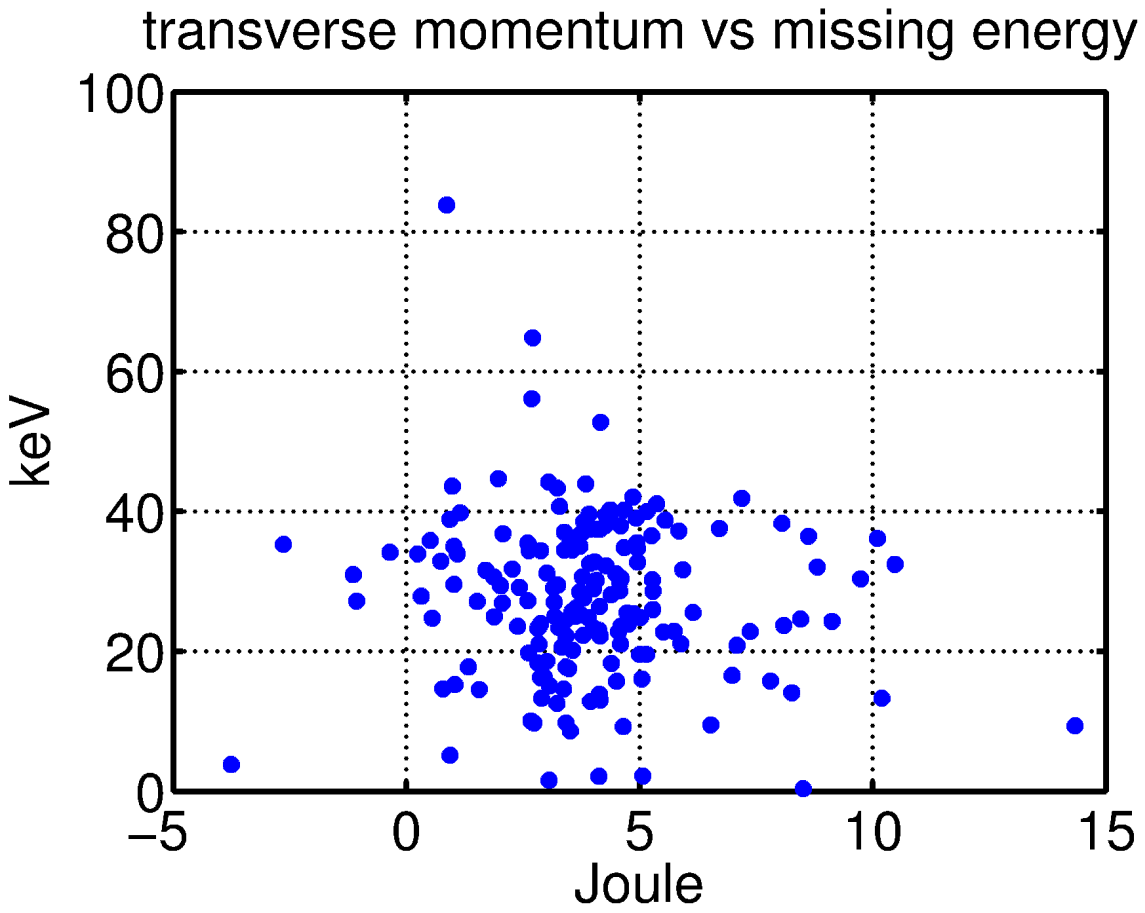
- method 1 (left): time between appearance of reflected RF and disappearance of transmitted RF;
- method 2 (right): time between forward and reflected RF.

REMARK: data consistency (synchronization of RF and screen) still not 100% sure

RF-breakdown kicks to the beam

correlation with missing energy

analysis on ~170 BD events, 2-Gaussian fit on horizontal and vertical profile of the screen (separately)



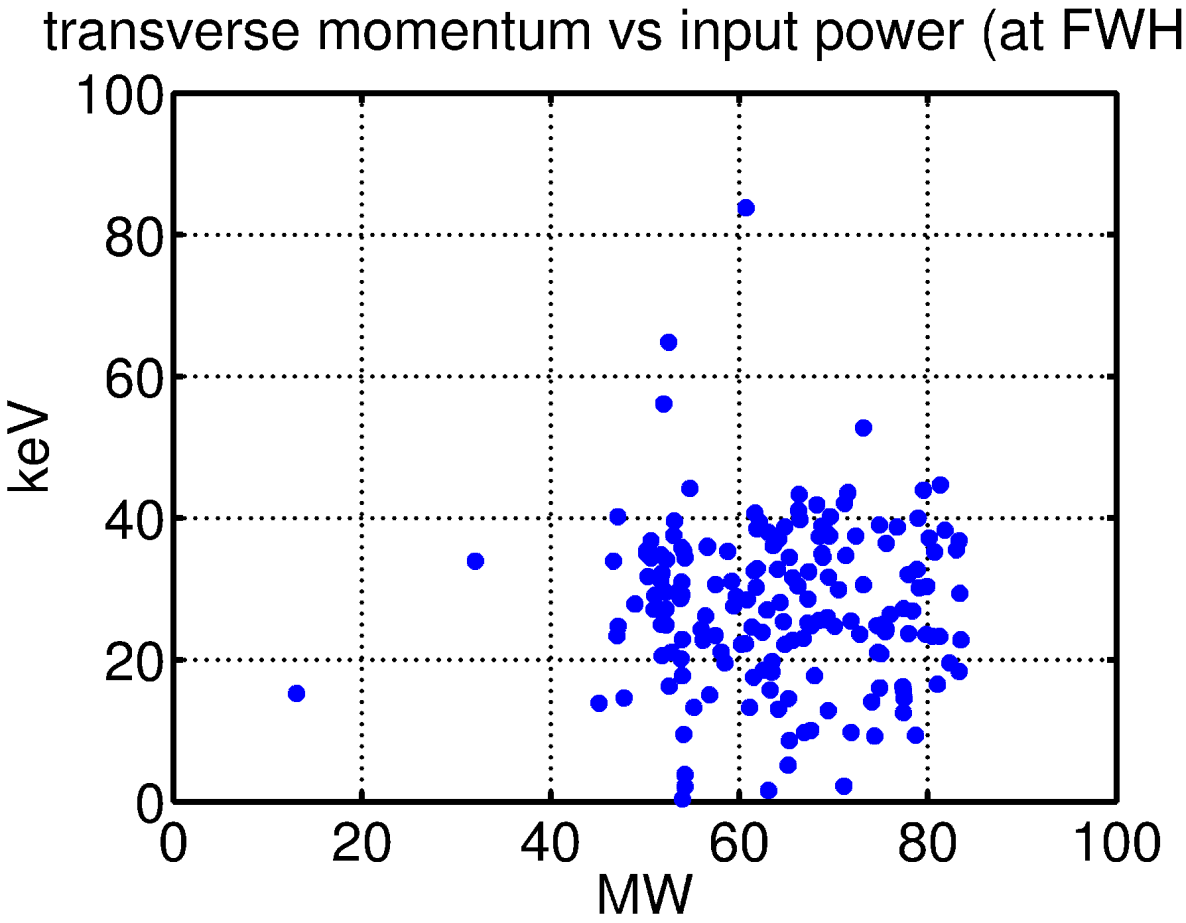
REMARKS:

- missing energy is estimated integrating over the whole RF pulse;
- missing energy estimation takes into account attenuation in WG and ACS;
- missing energy estimation is sensitive to BD cell estimation (reason for negative energies)

RF-breakdown kicks to the beam

correlation with input power

analysis on ~170 BD events, 2-Gaussian fit on horizontal and vertical profile of the screen (separately)



Conclusions

RF-breakdown kick to the beam so far:

- first results kick within 40 keV/c
- poor statistics, difficult to correlate with RF measurements due to data format

For 2012 Run

- More screen-based kick measurements
- BPM-based kick measurements
- Data acquisition consistent with the physics we are interested in (correlation with RF measurements)

Spare slides

RF-breakdown kick to the beam

statistics of YAG screen based measurements

AUG 2011

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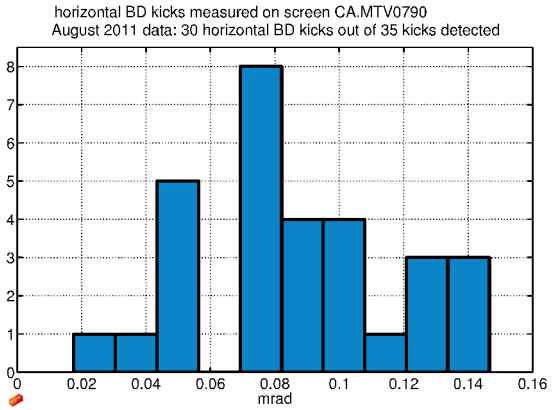
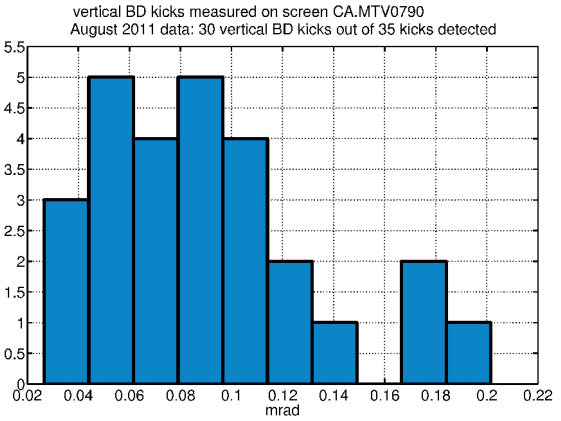
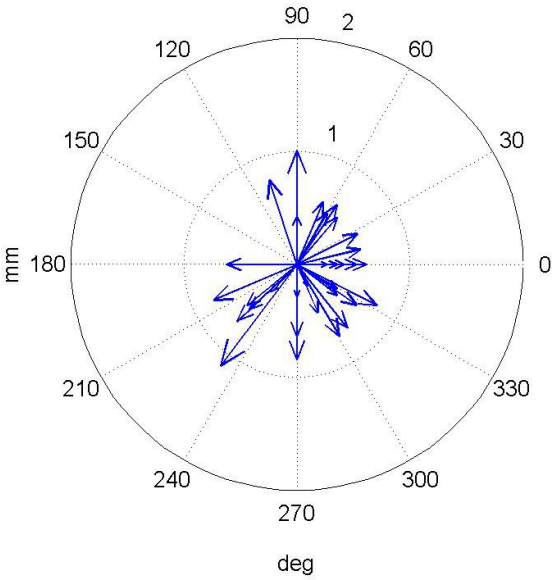
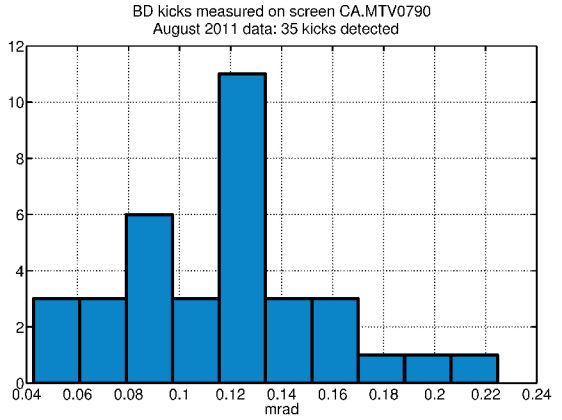
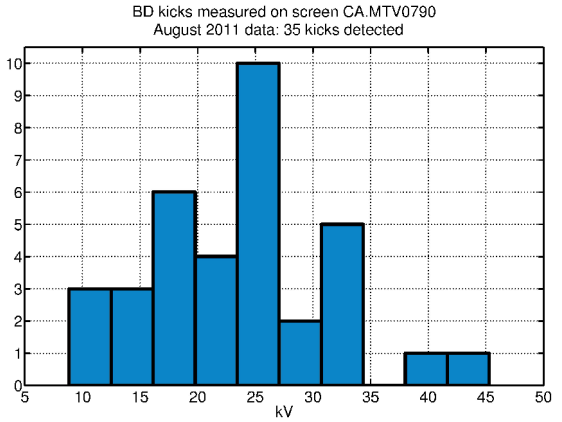




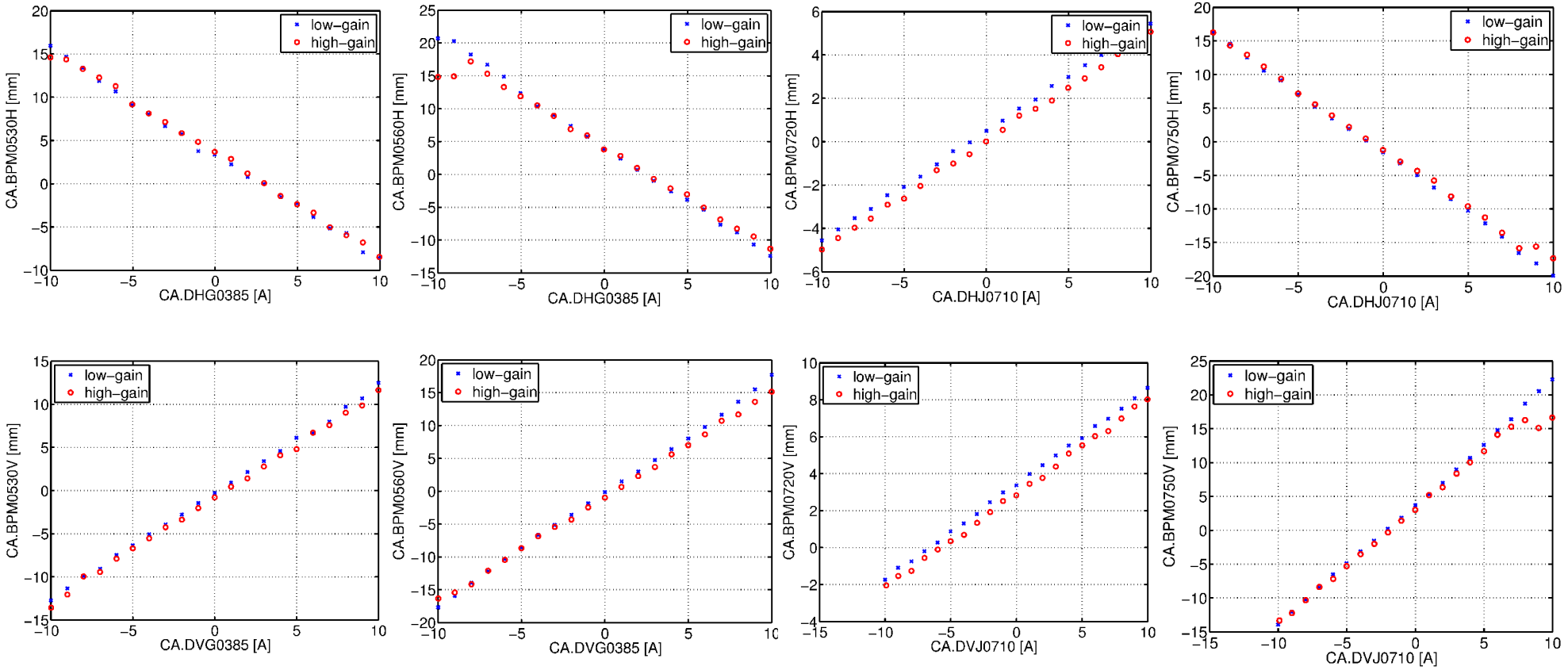






BPMs: linear response and calibration

- consistency between high-gain and low-gain calibration;
- BPM response linear in the whole range (beam pipe diameter is 40 mm);



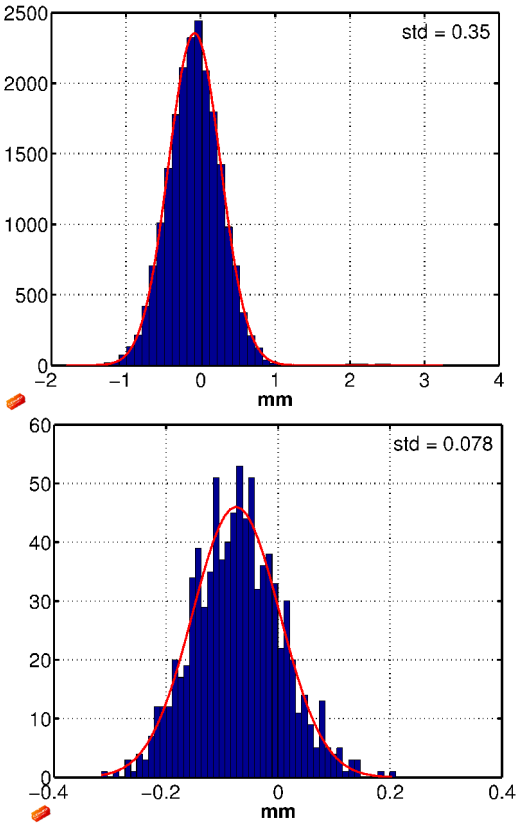
BPMs: resolution

Resolution = standard deviation of the distribution of the residuals given by comparing the beam position measured at one BPM with the beam position expected at the same BPM

Two methodologies used:

1. beam position *sample-by-sample* (interesting for the kick measurement);
2. *average* beam position over a beam pulse (always give a resolution smaller by a factor √beam pulse length in #samples)

Best resolution *sample-by-sample* measured so far is ~0.35 mm (August 2011);

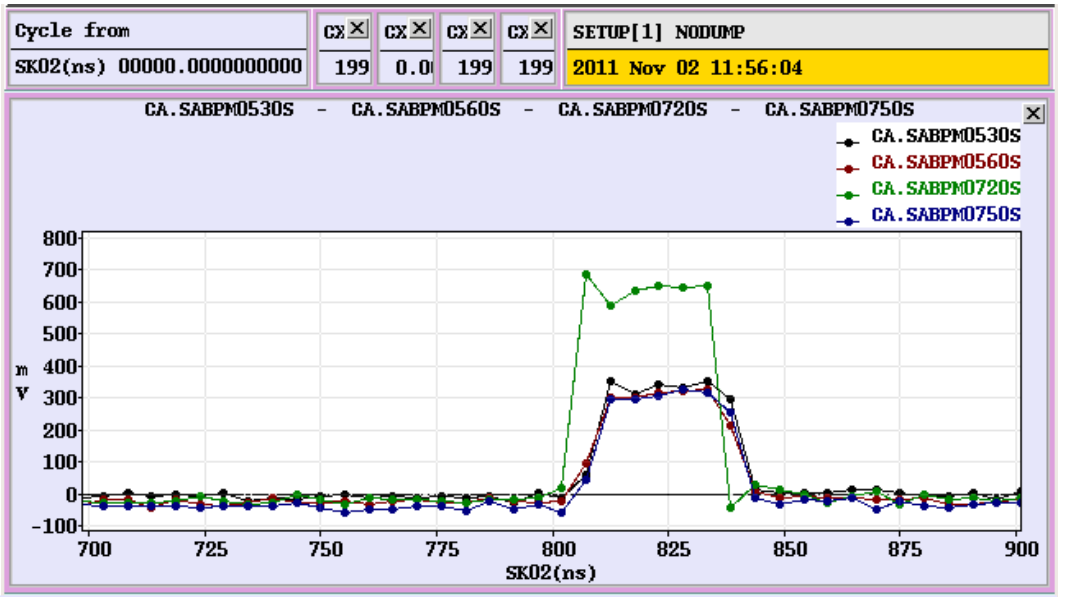


Reference: EDMS document 1175749

TBTS BPMs: modifications Nov2011

- Limitation to the resolution identified in a too small signal-to-noise ratio (SNR)
- Modification on BPM CA.BPM0720 (downstream of the ACS) results in a bigger SNR (Nov 2011)

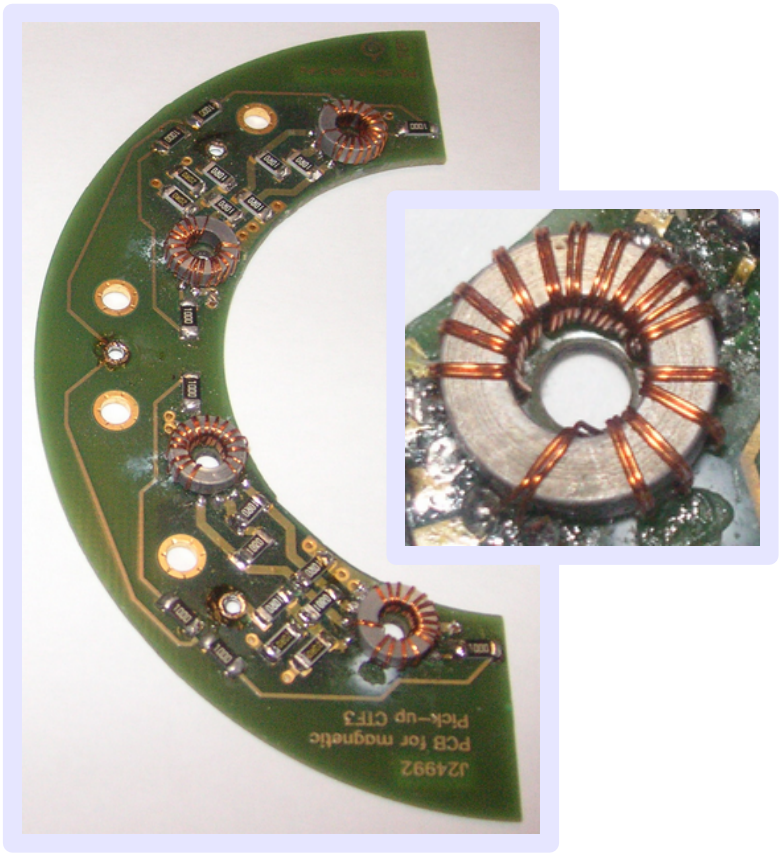
Number of turns in the secondary winding of the transformer of CA.BPM0720 reduced from 30 to 16, gives a SNR higher by a factor ~1.8, keeping the noise level unaltered (~8 mV)



Reference: CTF3 e-log on 2 Nov 2011 at 11.54

TBTS BPMs: on-going modifications

Improvement of the signal-to-noise ratio for all five probe beam BPMs reducing the number of turns in the secondary winding of the transformer



- 40 new toroids (8 toroids per BPM x 5 BPMs) with 10 turns each (currently 30) are being produced at Uppsala and will be assembled at CERN on the existing PCBs
- we expect a signal-to-noise ratio 3 times higher, (noise unchanged) with a slightly higher low cut-off frequency

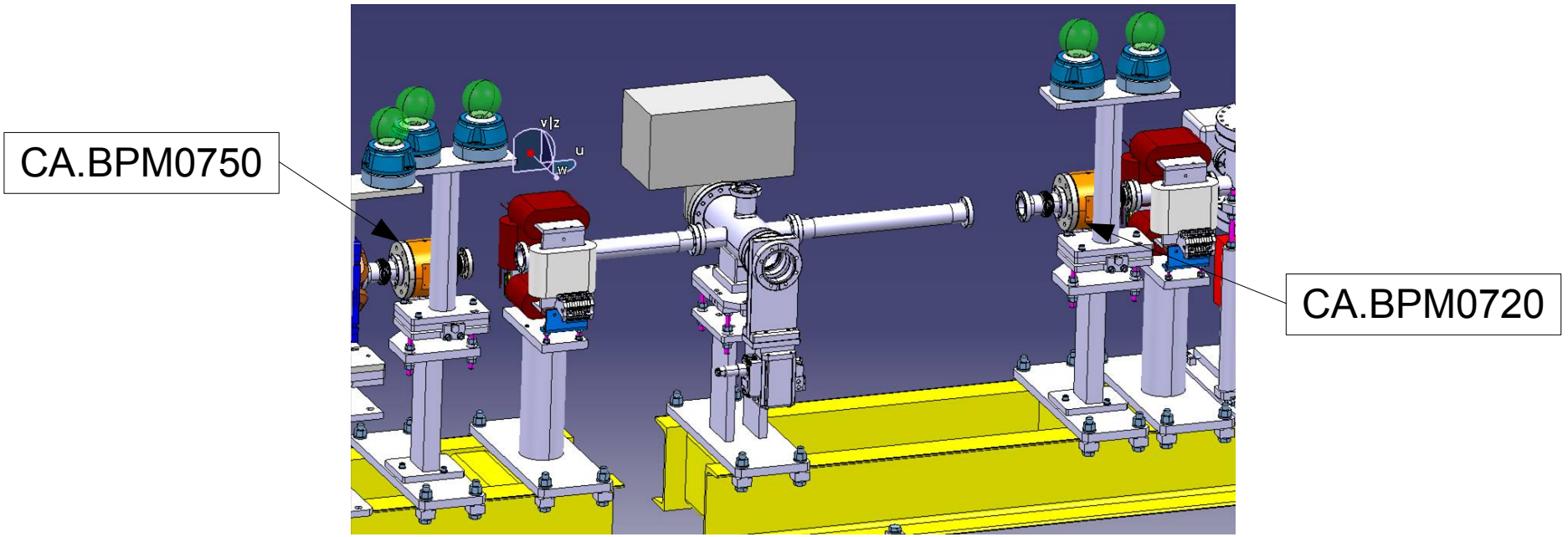
	Σ	Δ
currently	150 Hz	10 kHz
expected	1.35 kHz	90 kHz

Expected droop at percent level, tolerable as we are looking for fast signals in the BPM trace

TBTS BPMs: cavity BPMs

Installation of 2 re-entrant cavity BPMs (CALIFES spares) in TBTS

- Cabling needed (6 cables from CLEX to the gallery for 5 GHz signals)
- Read-out with CALIFES electronics (down-mixing and ADCs)

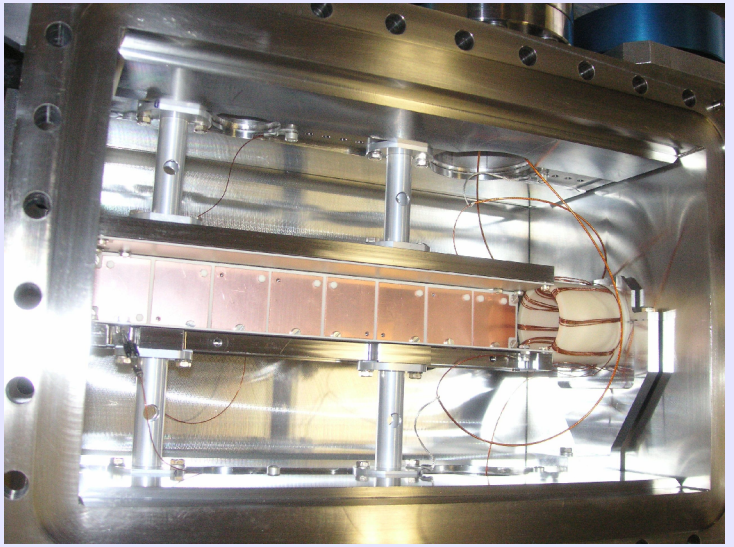


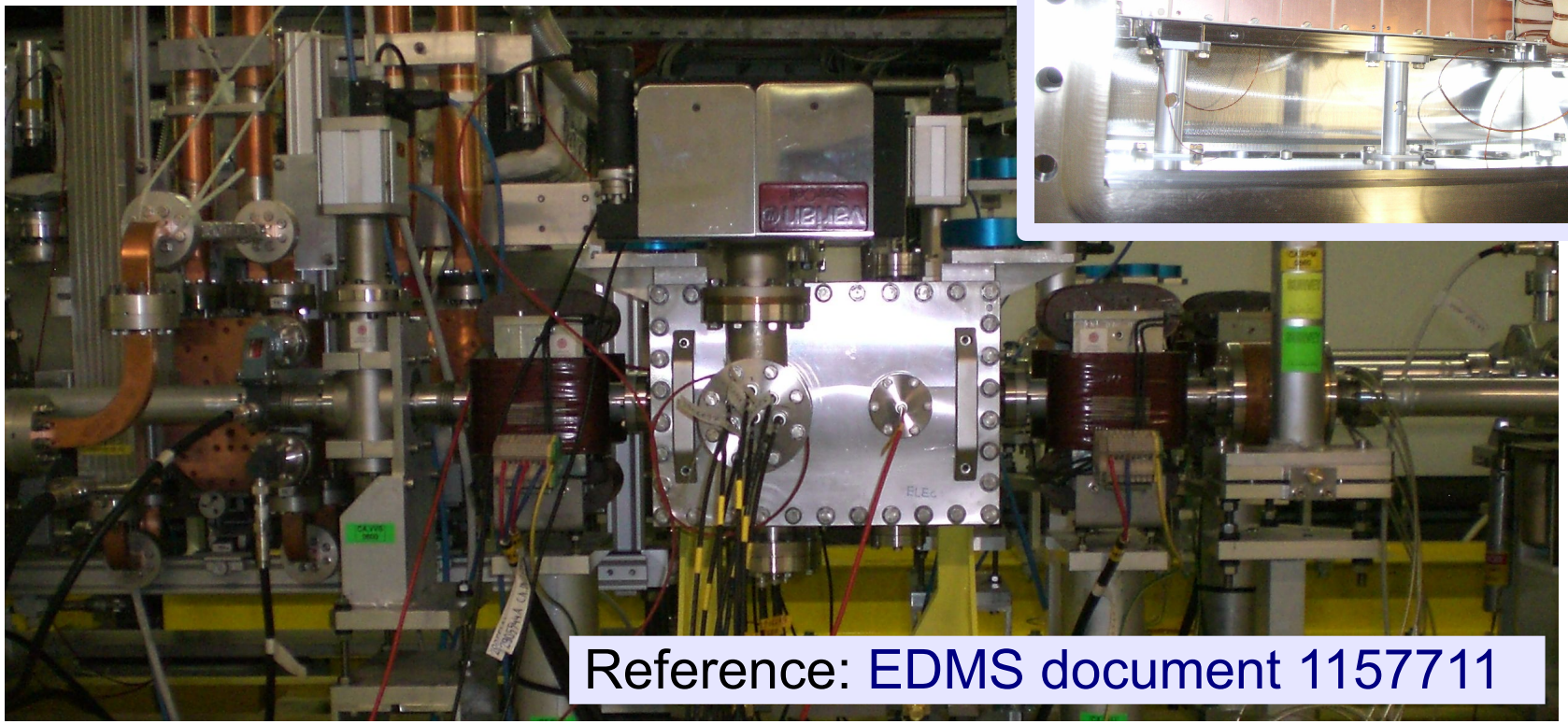
These BPMs are likely to be immune to the low-freq (<100 MHz) noise induced by the drive beam on the diagnostics → back-up solution for the the kick measurement

Flashbox

Installed in the probe beam on 28-29 July 2011, upstream of the ACS

ICT followed by two parallel 8-electrodes plates on the horizontal plane





Reference: EDMS document 1157711

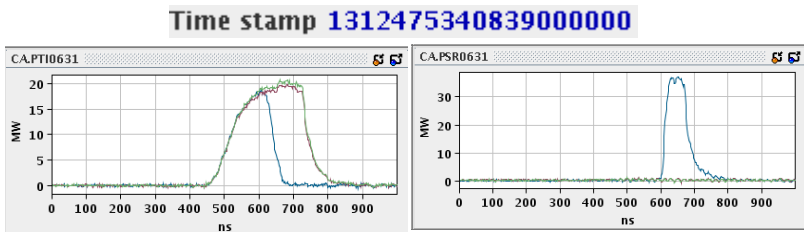
Flashbox

All channels operational

Able to detect signals in correspondence of RF-breakdown in the ACS

Read-out:

- test phase with (2011) ADCs kindly borrowed from AB/CO (Anastasiya Radeva)
- 2x Acqiris ADC + 1x Spectrum ADC ordered



FLASHBOX SIGNALS (example)

Reference: CTF3 e-log on 4 Aug 2011