Alternative Readout ASIC Test Beam Results

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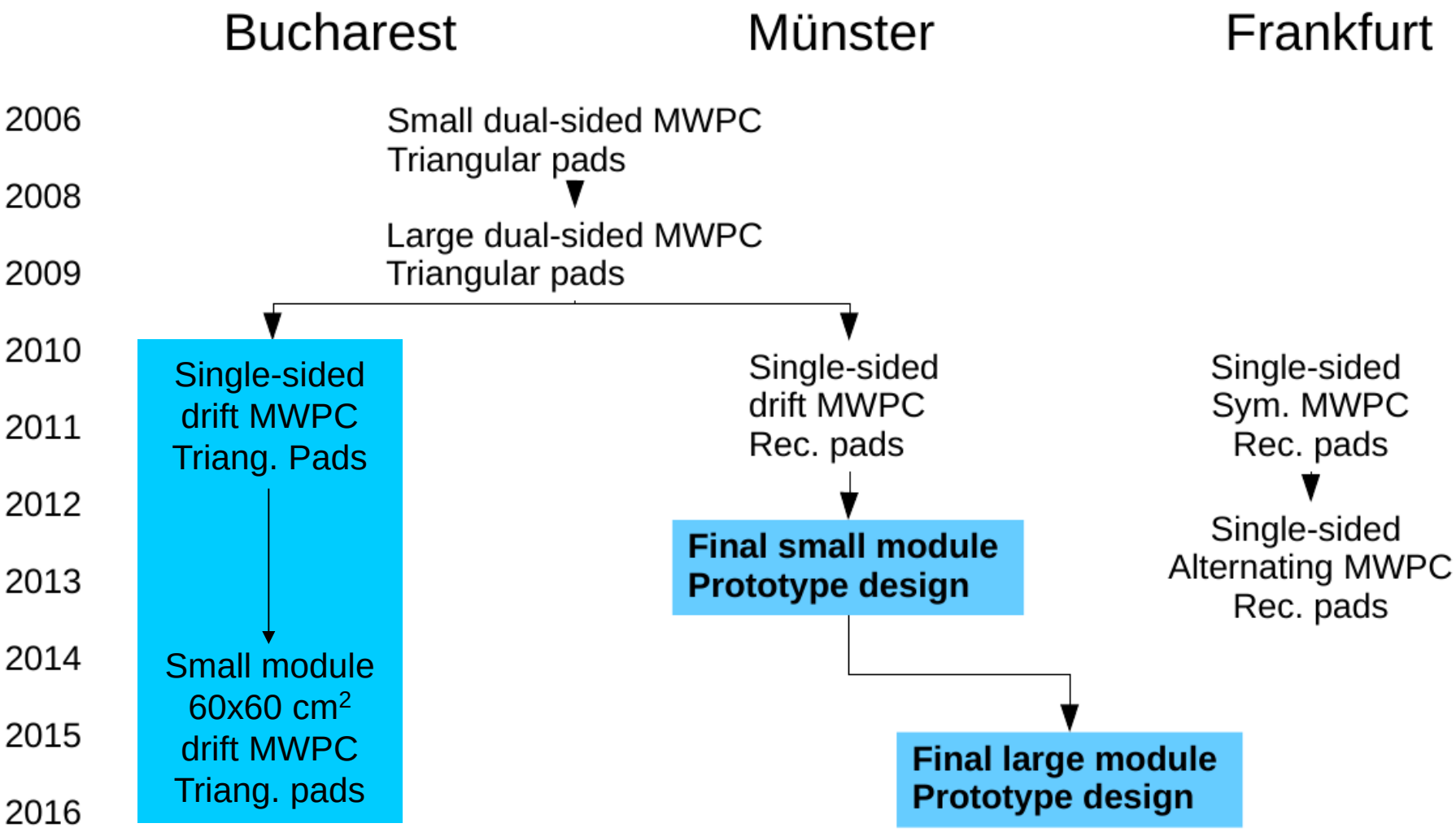
CBM TRD TDR Review
14th – 15th March 2017

A Short History of CBM TRD

Westfälische Wilhelms-Universität Münster

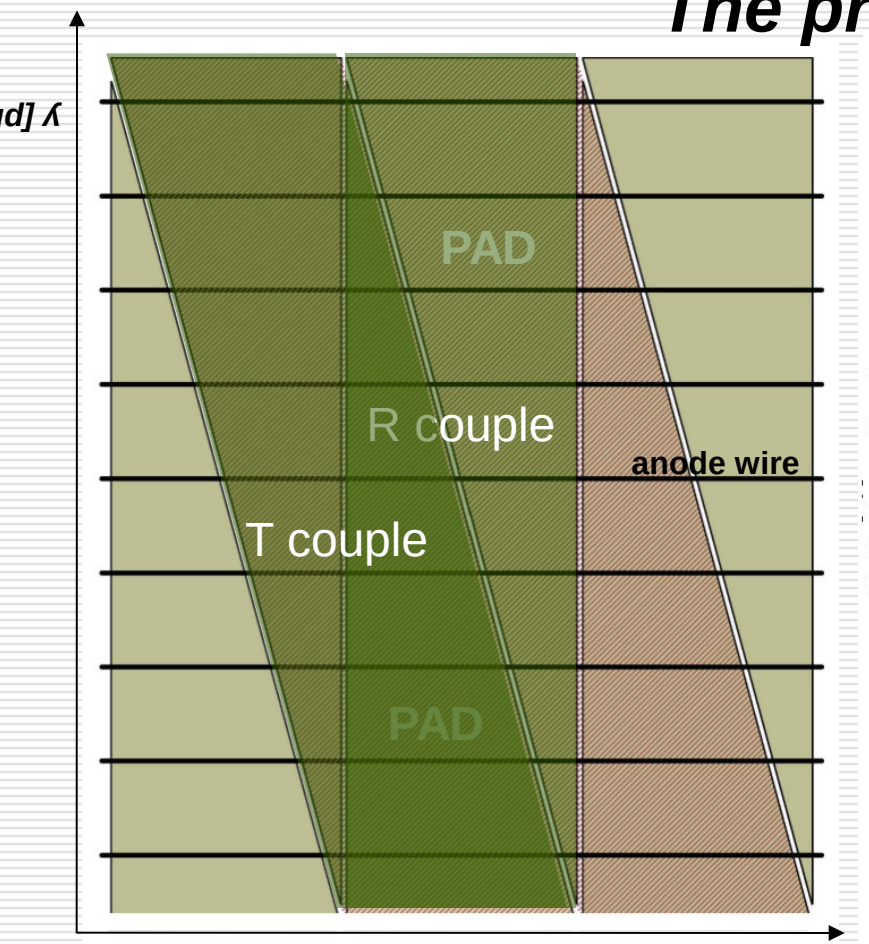


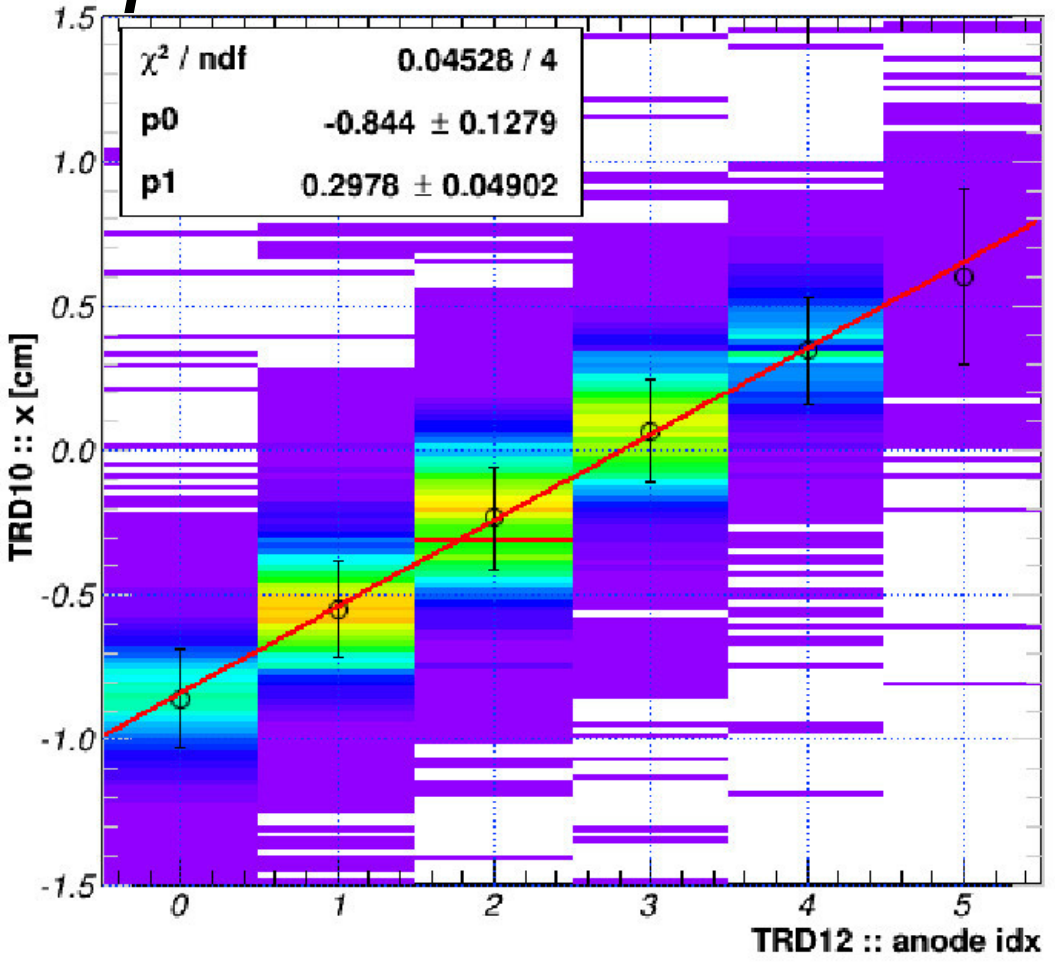
Features of the Bucharest TRD prototype

- Target application : **central CBM regions**
  - *PID*
  - *Tracking < 300 μm (x 3000 μm) position resolution*
  - *Rate 100 kHz/cm²*
- Chamber design : **equilibrated 4mm drift + 2x4mm amplification**
  - *Reasonable S/N for dE/dx (PID) and cluster size (position resolution)*
  - *Fast charge collection (130/240 ns for $ArCO_2$/$XeCO_2$)*
- Signal collection : **original 1cm² triangular shaped pads**
  - *Full-surface, single-layer 2D position information*
  - *Static & independent position calibration capabilities*
- Read-out : **robust self-triggered**
  - *100 ns shaping @ 40 MHz sampling read-out*
  - *Radiation hardness : minimalistic digital circuitry & GBTx readiness*
- Operation : **built-in continuous monitoring**
  - *Channel wise signal / time calibration*

Signal collection : Δ pads

The principle





Features of triangular pad design

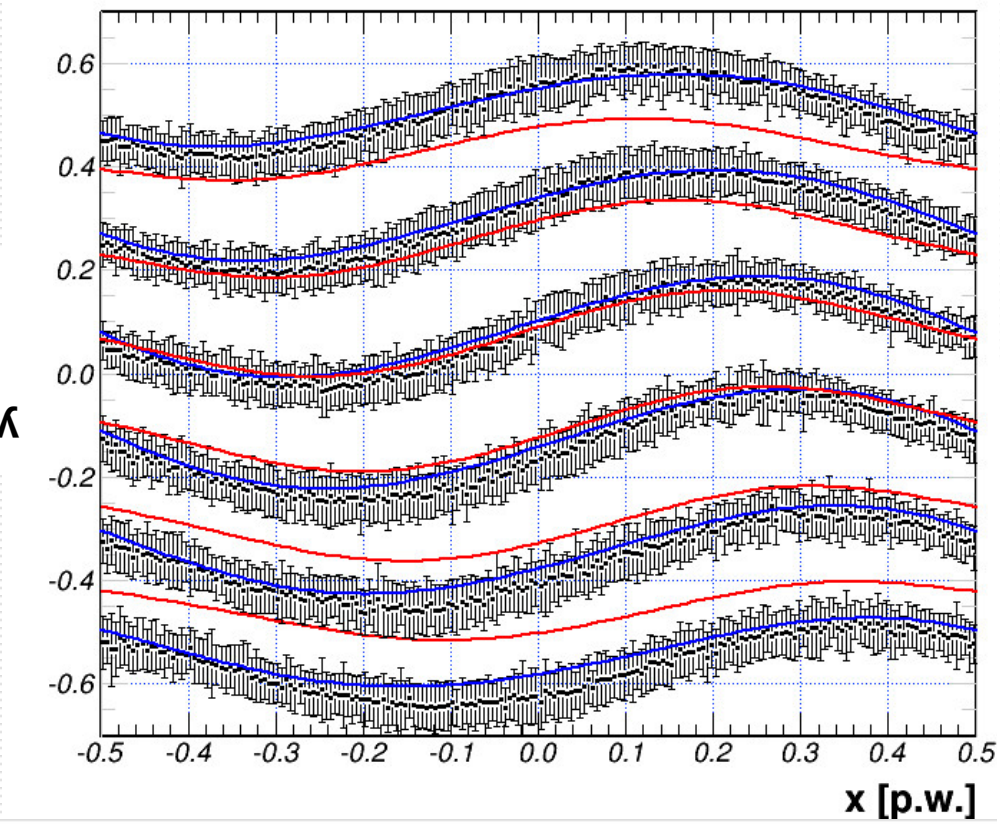
- Pad size/position coupled with anode wire pitch
- Our best match 27 mm height for 9 x 3mm anodes
- Individual pad read-out version on FASP-01
- R/T coupled pad read-out version on FASP-02 for better S/N and uniform charge response

Test of the principle

- Uniform ^{55}Fe illumination
- Anode wires identified through maxima in the reconstruction yield
- Anode pitch reconstructed with an independent TRD @ CERN-PS

Signal collection : Δ pads

Simulations and Calibration



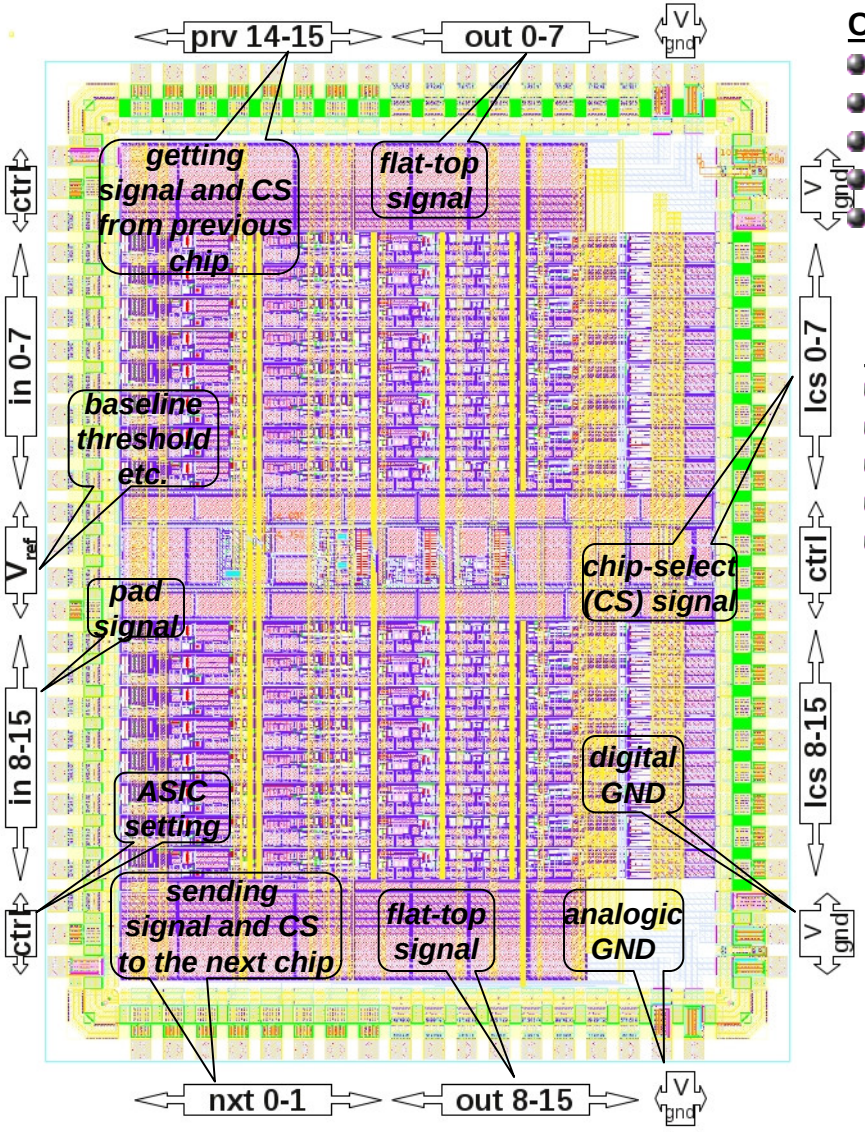
- Data from CERN-SPS 2015 campaign
- Gaussian image on the pad-plane
- Gaussian + XT

Position calibration

- Static : based on comparing a printed out 2D image with its reconstruction obtained with an uniform irradiation.
- Independent : in a large detector set-up (e.g. CBM) does not depend on other sub-systems.
- Cheap and absolute
- E.g. using letters printed out on a copper foil can reveal systematic effects on the x-y reconstruction over the full detector surface

Read-out

FASP-02 ASIC



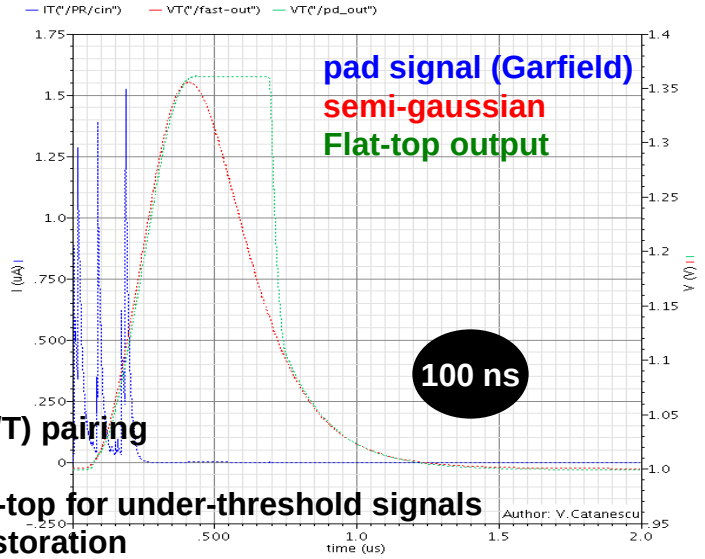
Channel components

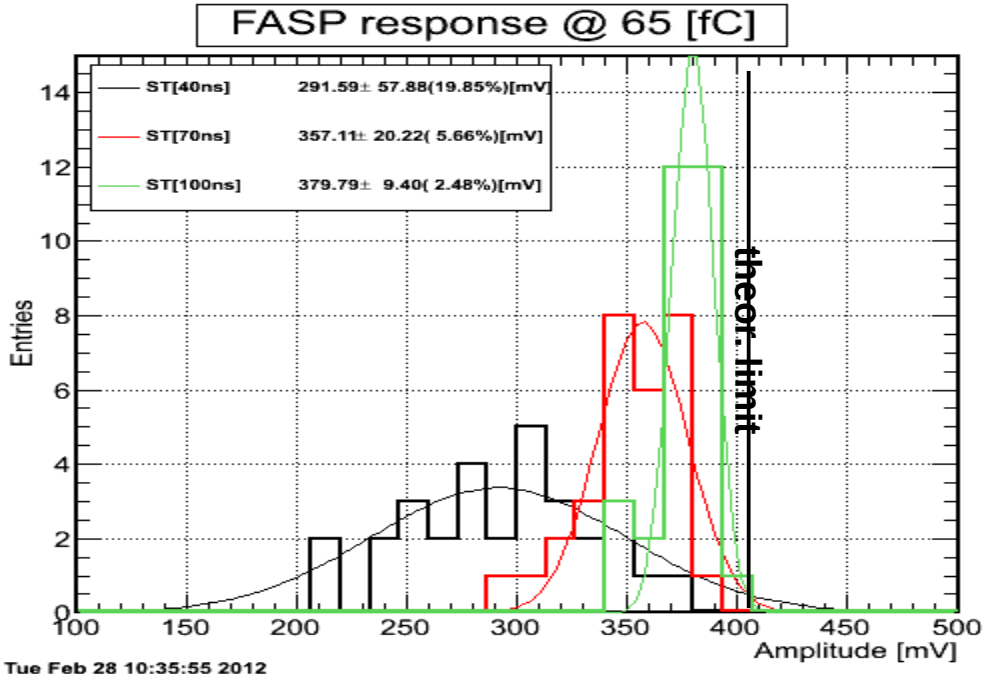
- Pre-amplifier
- Shapper
- Flat-top generator
- 160mW/16ch
- 28.8W for 2880 chs

Features of FASP-02

- Rectangular / Tilt (R/T) pairing
- Shaping time 100 ns
- Enable neighbor flat-top for under-threshold signals
- Analytic baseline restoration
- Fa

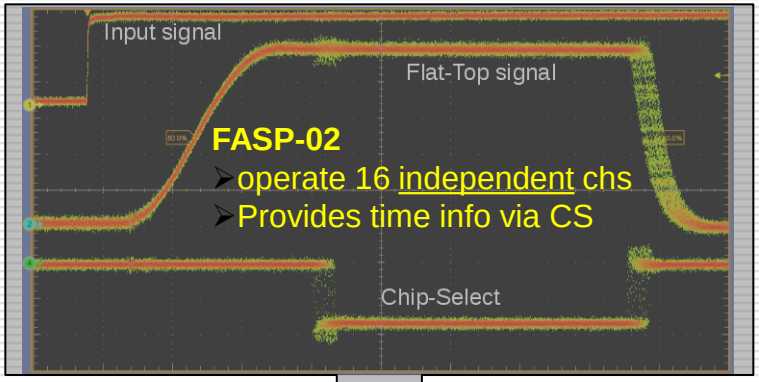
CADENCE SIMULATION ON GARFIELD SIMULATION



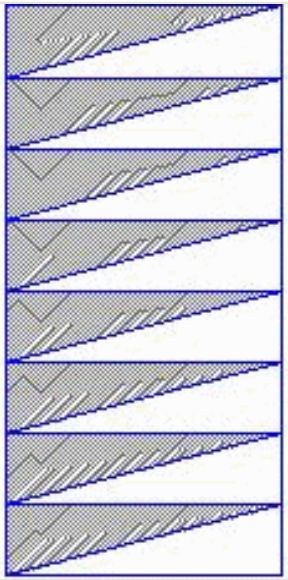


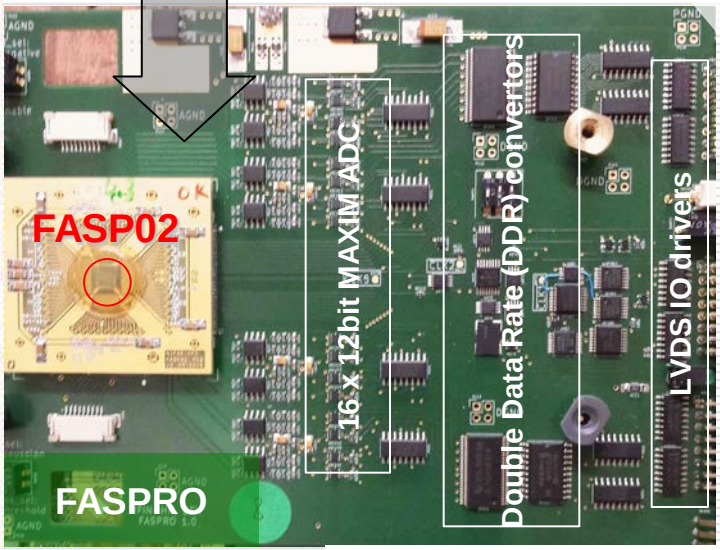
Read-out

Free-running operation



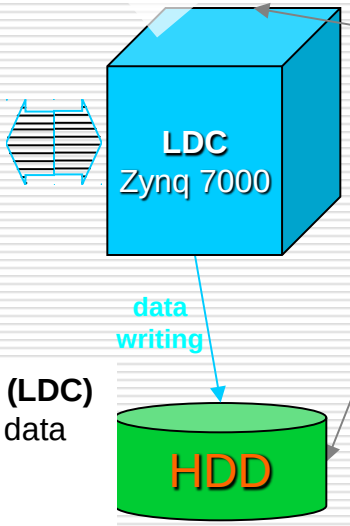
FASPRO
- ➢FASP Read-Out
- ➢Digitize (12bits) FT during CS
- ➢Pack DDR GBTx ready
- ➢Sends data to LDC

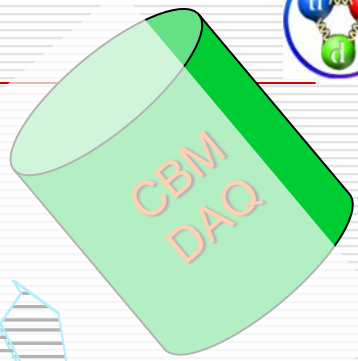


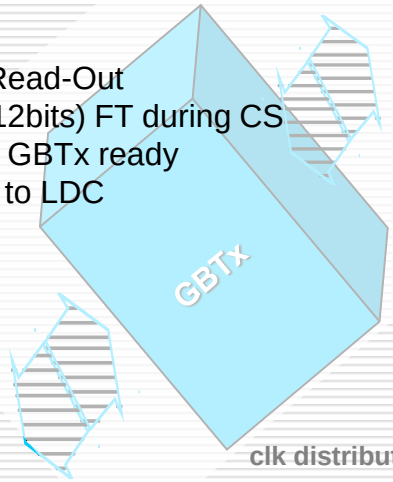


16 R/T coupled pad signals and detector GND are fed to the FASP-02 entry

Local Data Concentrator (LDC)
- ➢Receive 32 independent data pairs (CS+ADC)
- ➢Adds Time Label (TL)
- ➢Write data (CH, TL, ADC) to storage (HDD)



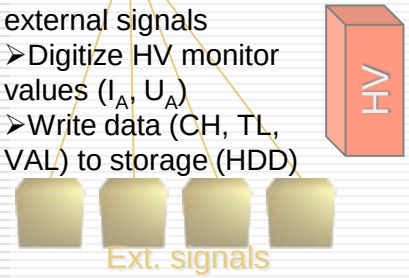




MASTER
- ➢Synchronize LDCs at start-up

ext data writing

- ➢Adds Time Label (TL) to external signals
- ➢Digitize HV monitor values (I_A, U_A)
- ➢Write data (CH, TL, VAL) to storage (HDD)

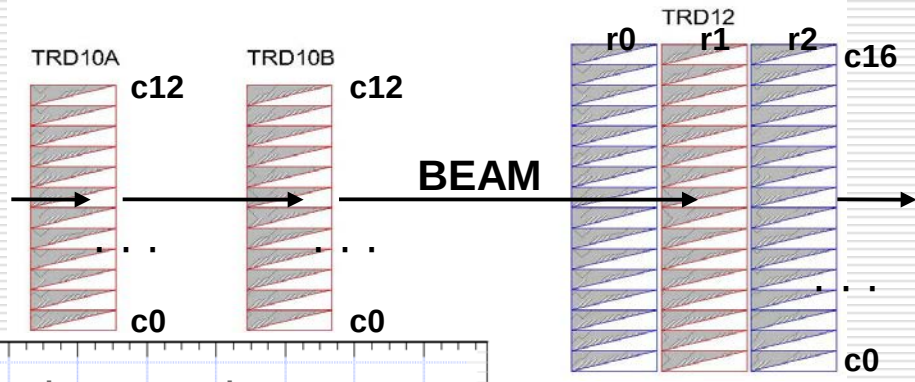


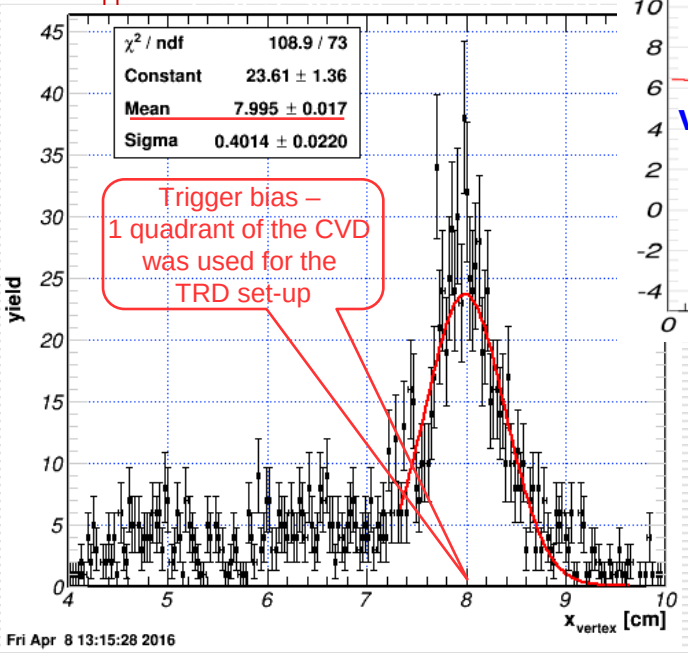
Applications

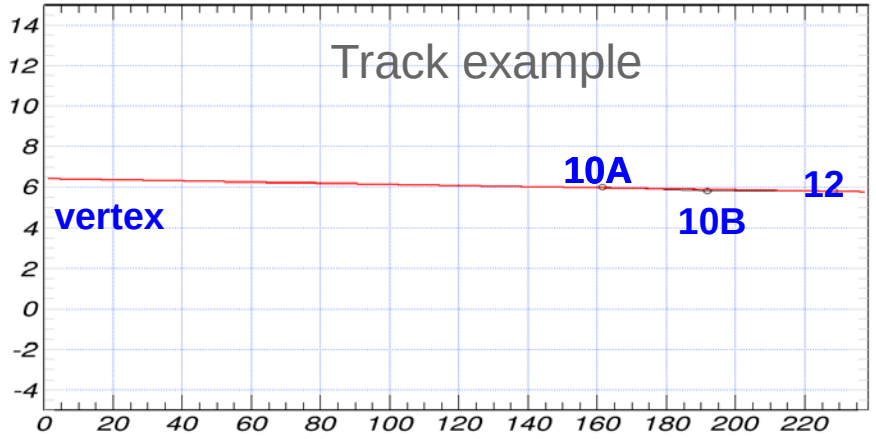
Tracking

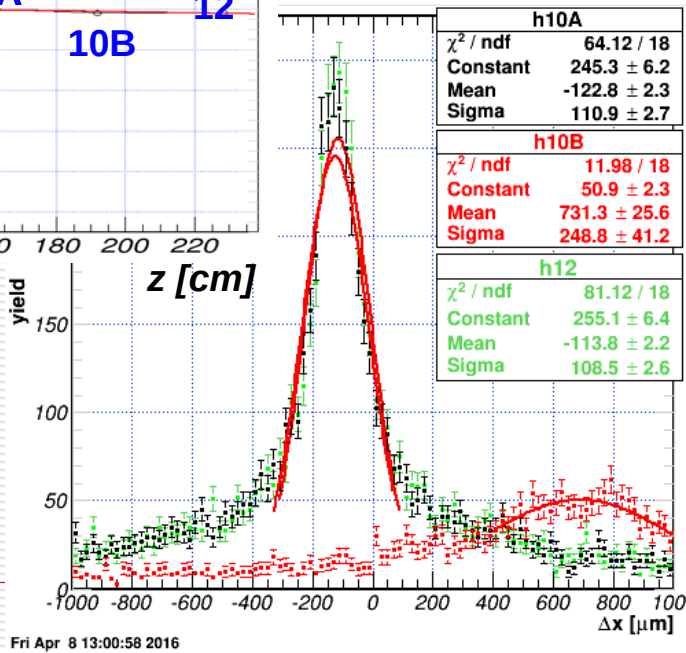
CERN-SPS 2015 campaign

- FASP-01/FEE on 2 FEB versions
- MBS triggered DAQ
  - *2 x TRD10 & TRD12 (2 x 24+32 read-out channels)*
  - *Trigger Plastic & CVD & RPC*
- Event statistics
  - *9.7e6 triggered events*







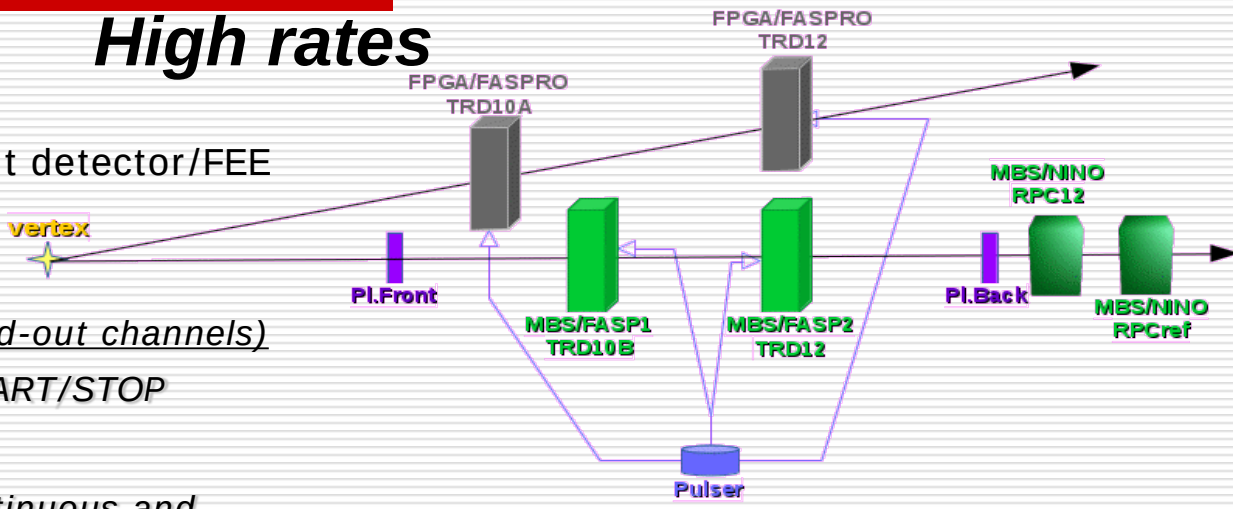


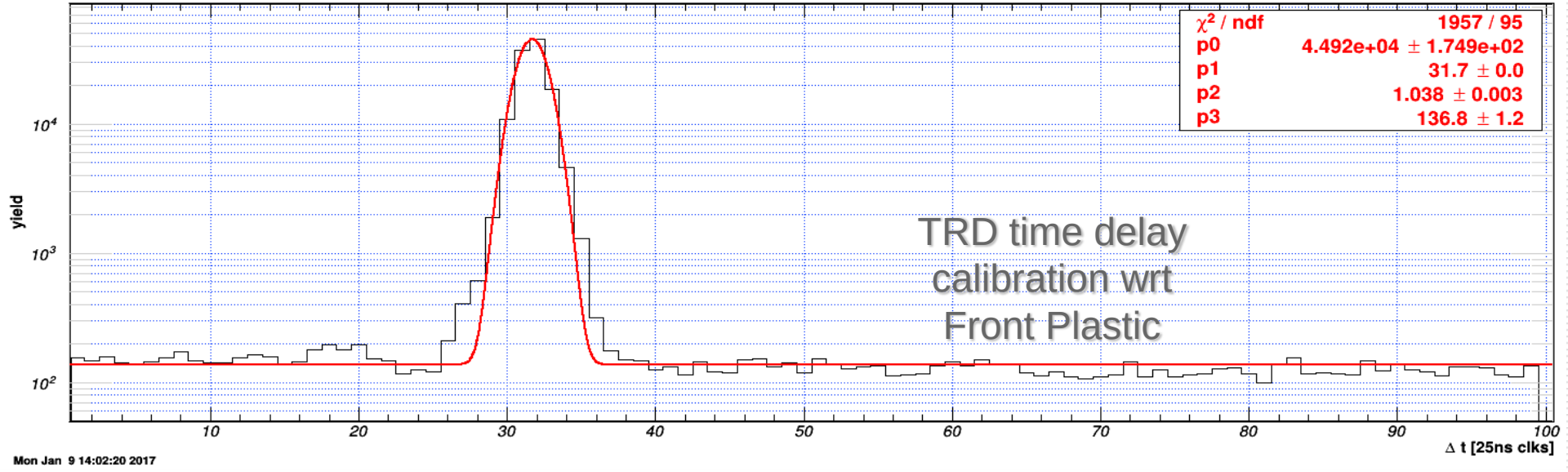
Applications

High rates

CERN-SPS 2016 campaign

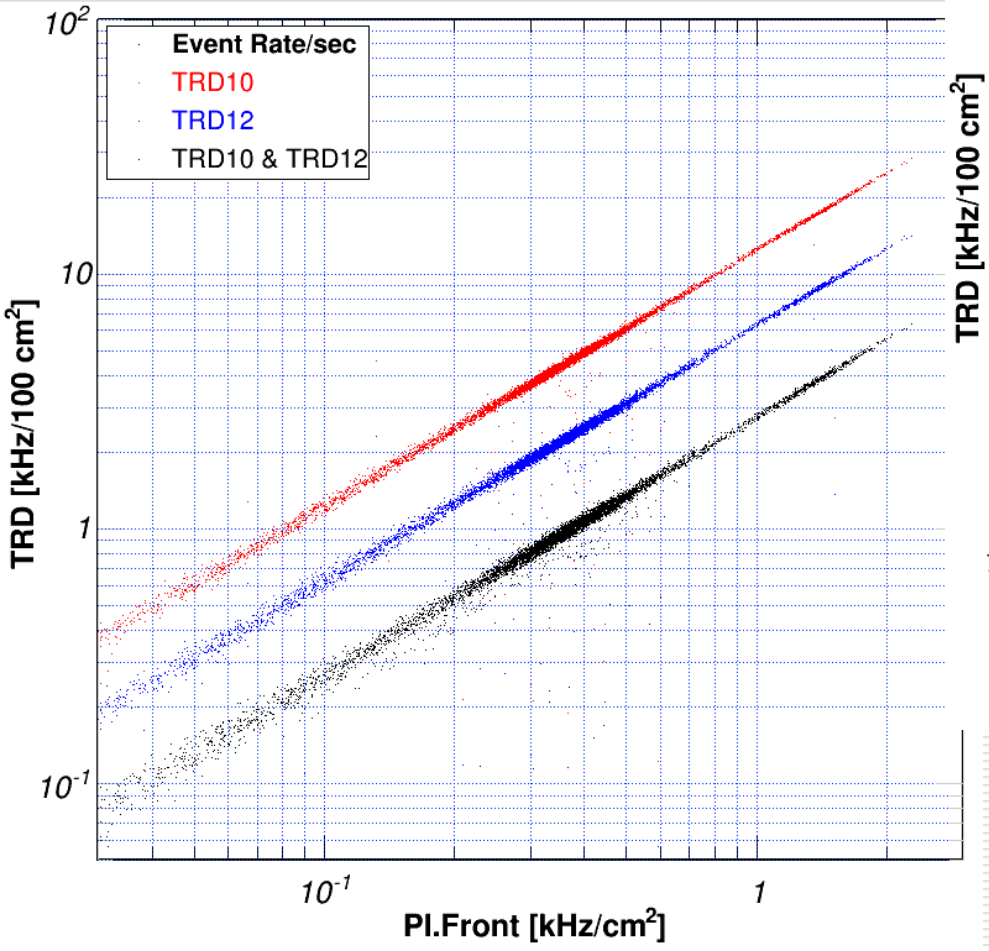
- 3 running periods with different detector/FEE configurations
- FASPRO free-running DAQ
  - *TRD10 & TRD12 (2 x 96 read-out channels)*
  - *2 x Plastic & HV & beam START/STOP*
- Online calibration
  - *Pulser reference signal (continuous and synchronous on all TRDs)*
  - *^{55}Fe calibration during beam time*

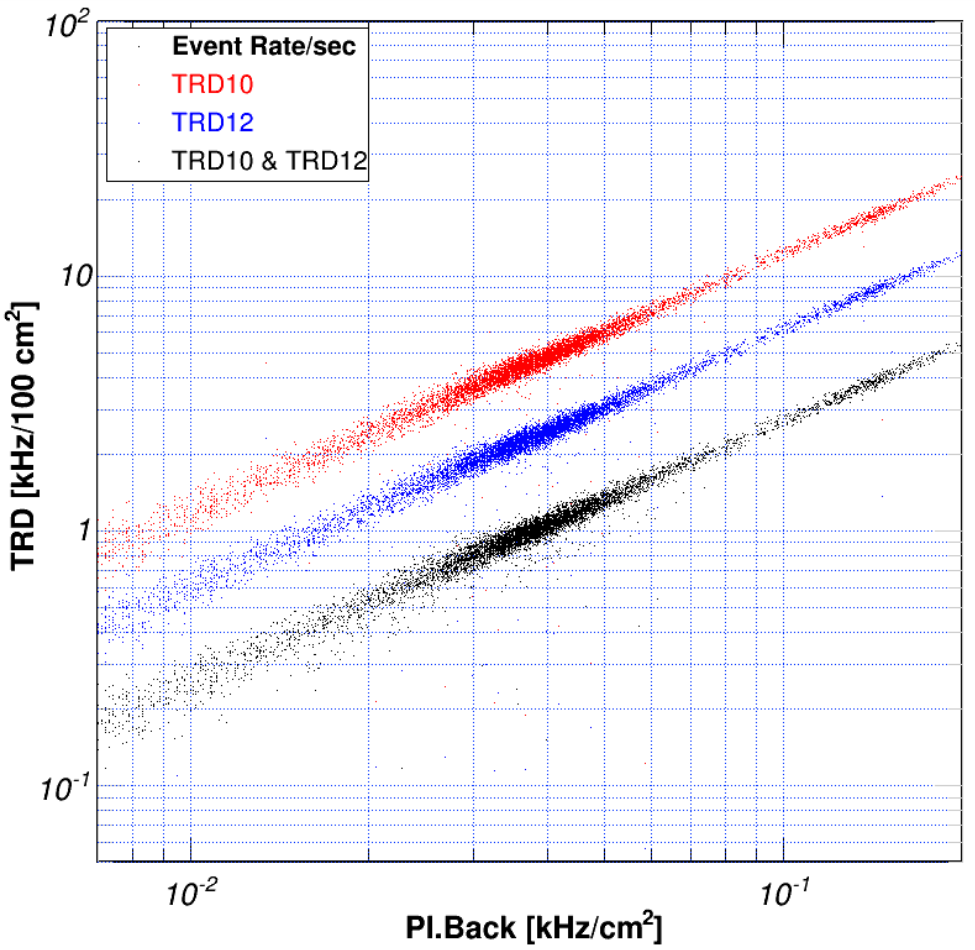




Rates @ SPS '16 :: *Events / Spill*

- Rates calculated on 1 s intervals
- Spill duration approx 10 s
- Correlation with front/back scintillators for systematic effects

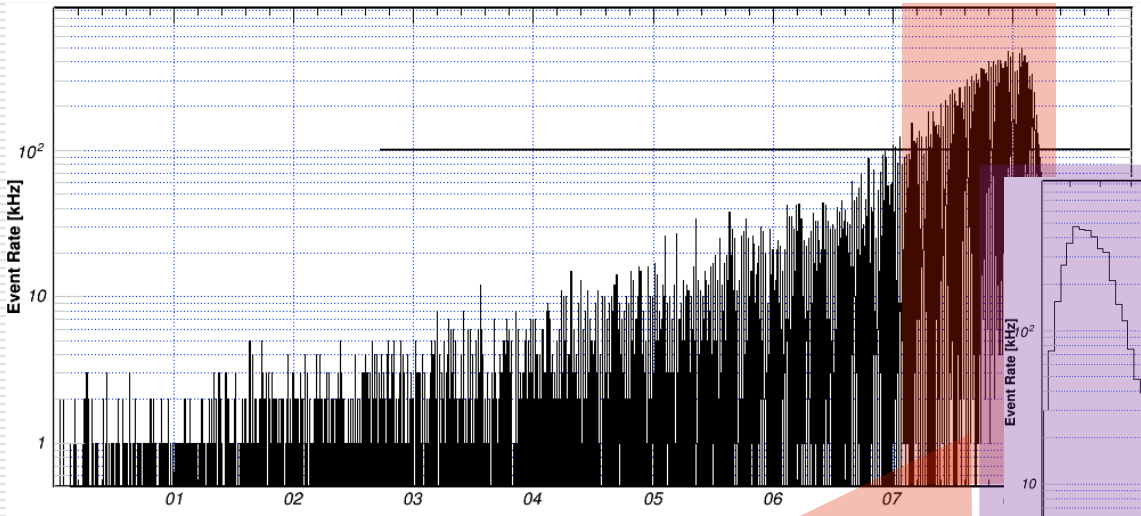




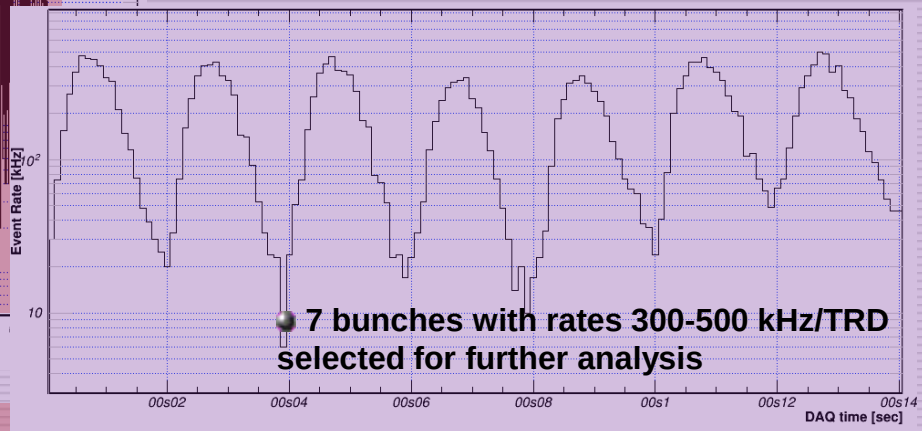
Maximum Rates measured on TRD prototypes

- TRD10 (front) → 300 Hz/cm²
- TRD12 (back) → 150 Hz/cm²
- Track candidates → 70 Hz/cm²

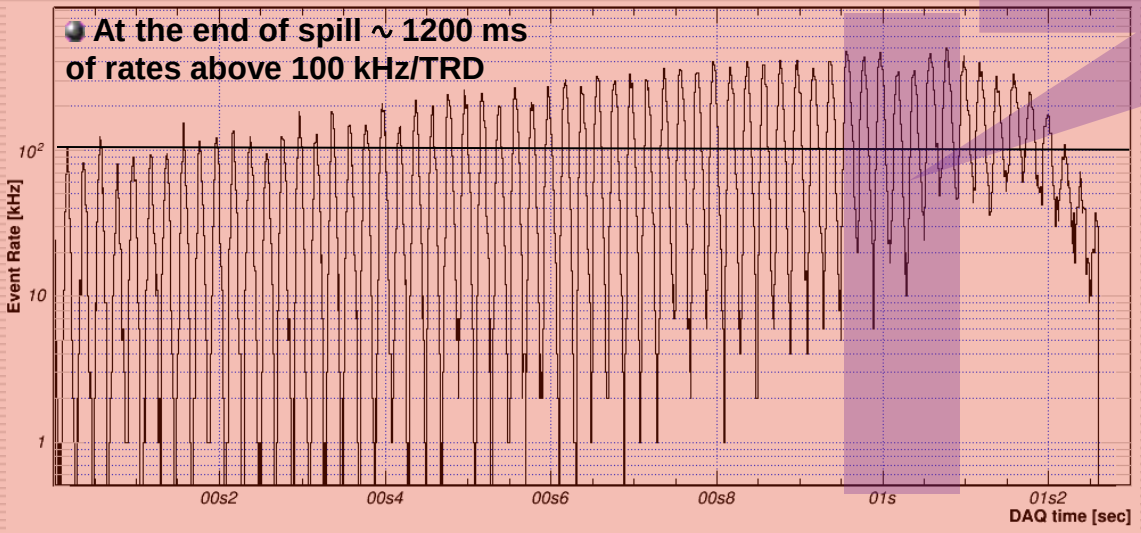
Rates @ SPS '16 :: *Events / Bunch*



- On 10th Dec 2016 @ 1:40:24 AM
- 3 consecutive “lucky” high intensity spills
- First of them presented here as seen in TRD10



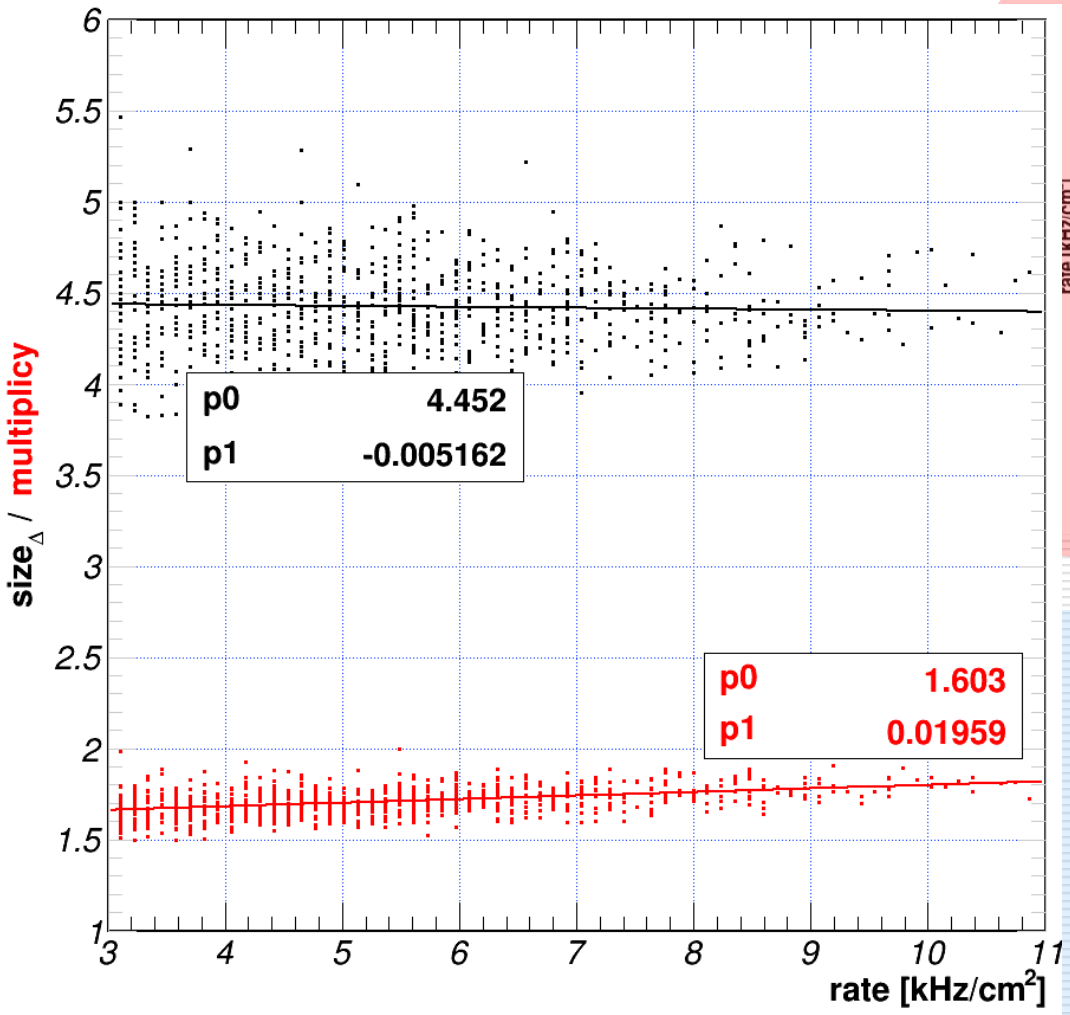
- 7 bunches with rates 300-500 kHz/TRD selected for further analysis

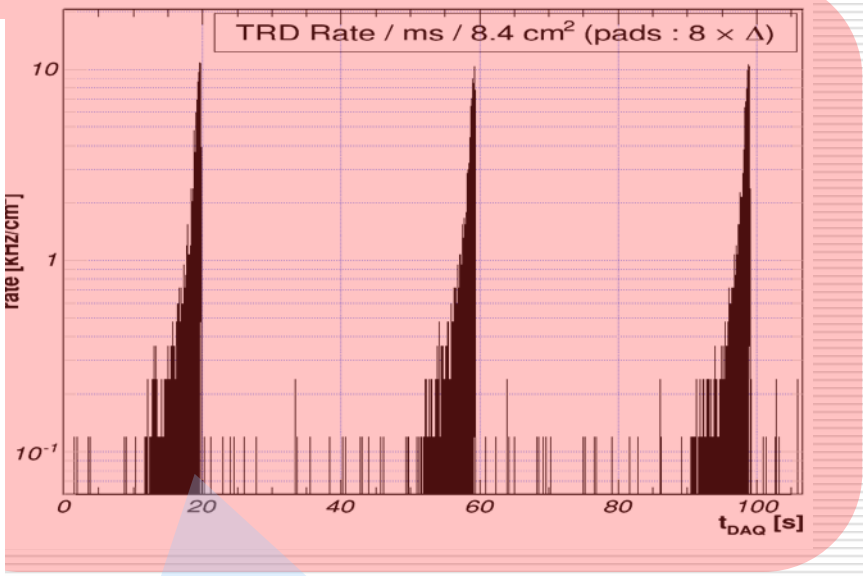


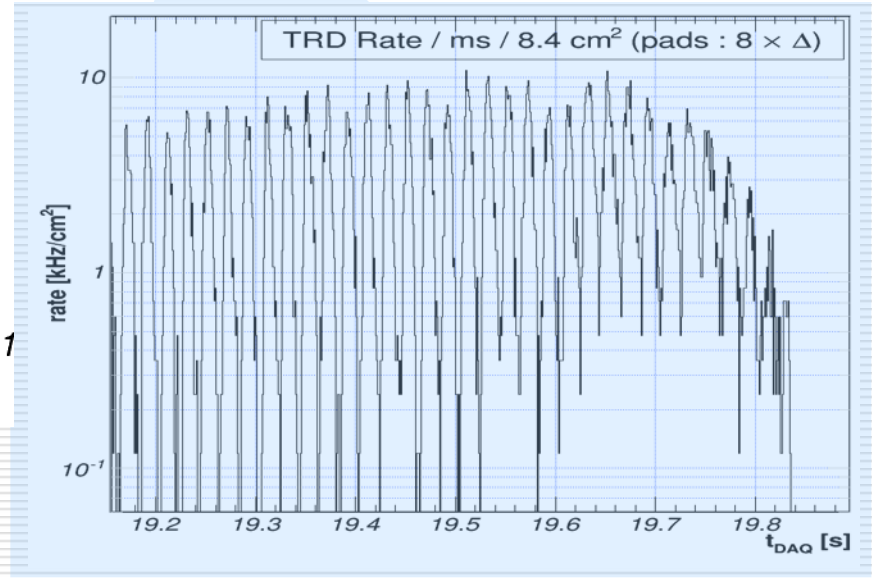
- At the end of spill ~ 1200 ms of rates above 100 kHz/TRD

- TRD rates were correlated with reference plastic scintillators to assure data quality
- The highest rates were measured continuously over 140 ms

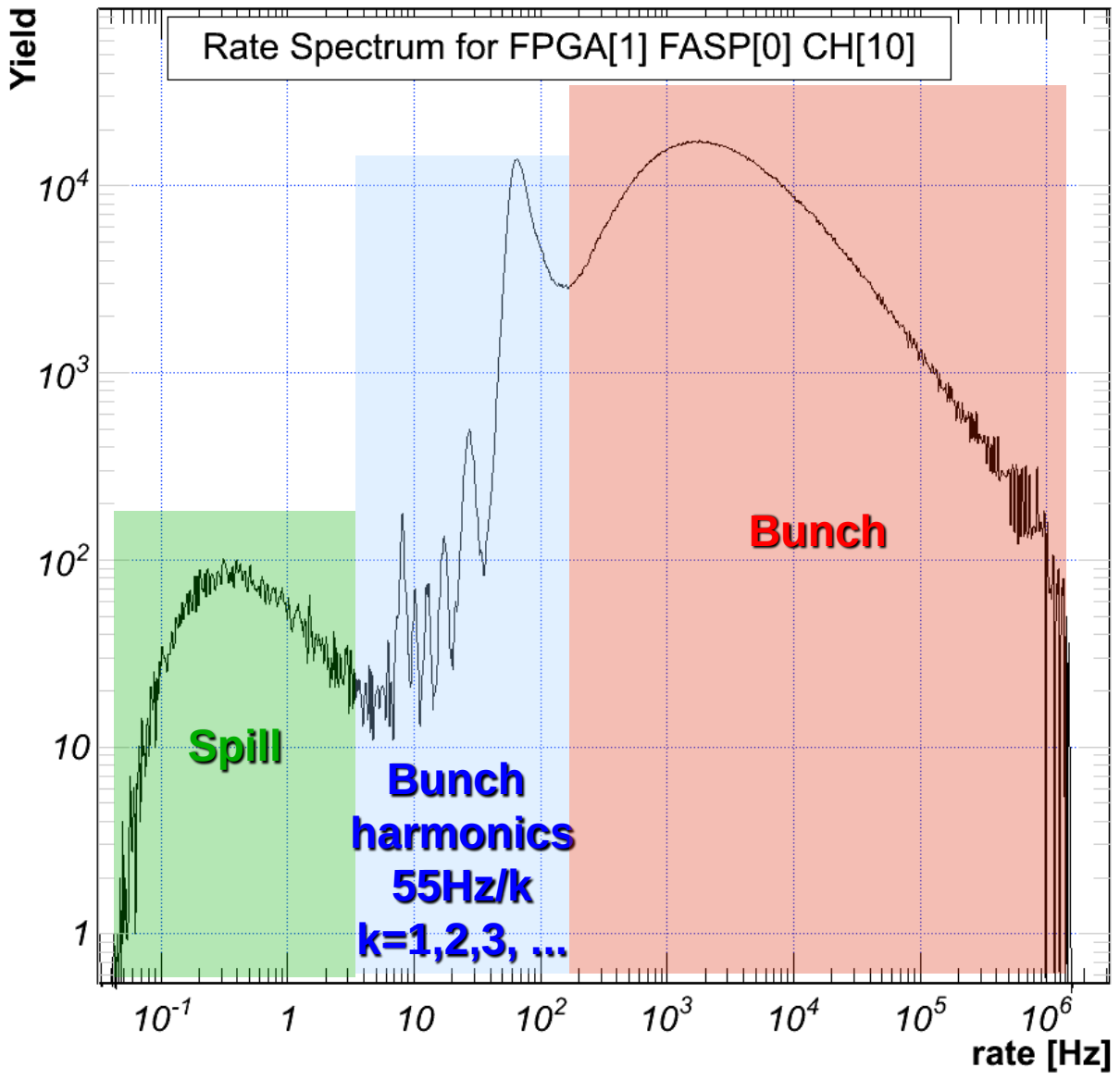
Rates @ SPS '16 :: *Clusters*







Rates @ SPS '16 :: *FASP channel*

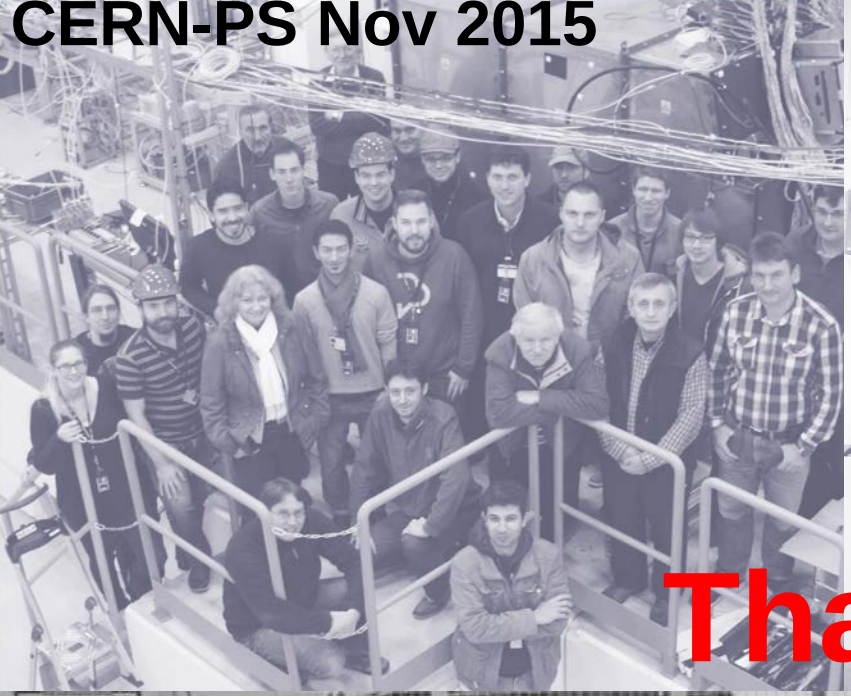


- Rate estimation as inverse of time between consecutive hits/channel
- Structures of SPS beam are indicated on the figure
- Theoretical limit of FASP (>1.5 MHz) reached

Bucharest TRD prototype checklist

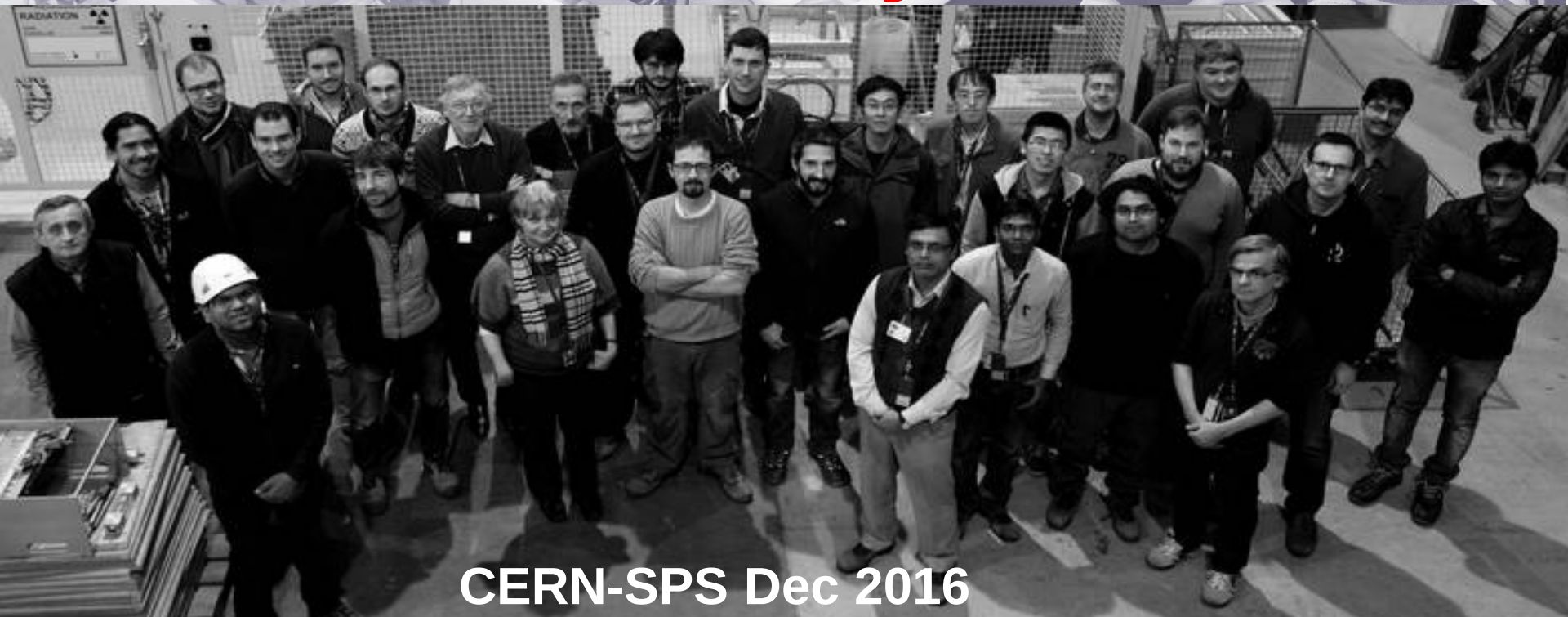
ITEM	TARGET	STATUS
Chamber design		
*Optimized for PID and tracking. Charge collection **[ns]***	***300***	***<130/240 for $ArCO_2$/$XeCO_2$***
Read-out unit (pad)	***1 cm^2***	**done**
Full 2D position information	***yes***	***triangular***
Signal simulation	***CbmRoot***	***standalone***
FEE		
FASP ASIC running @	**> 100kHz**	***1.5 MHz[i]***
Free running	***yes***	***self triggered @ 40MHz***
Radiation hardness / Technology [***μm***]	***0.18***	**0.35**
PID		
1% π suppression @ 90% e efficiency	***10 layers***	**6 layers**
Tracking		
*Position resolution **[μm]***	***300***	**<150 [ii]**
Pile up capabilities	***???***	**in progress**
High rate capabilities		
*High Multiplicity/ High rates **[kHz/cm^2] CERN-SPS***	***100***	**11**
Sustained rate	***10 s***	**ms**

i. For constant pulser rate injected on anode wires. 1 MHz with particle irradiation.
ii. Single track events @ kHz cluster rates background


CERN-PS Nov 2015

CERN-SPS Feb 2016

Thank you



CERN-SPS Dec 2016

BACKUP

Reconstruction of transverse position

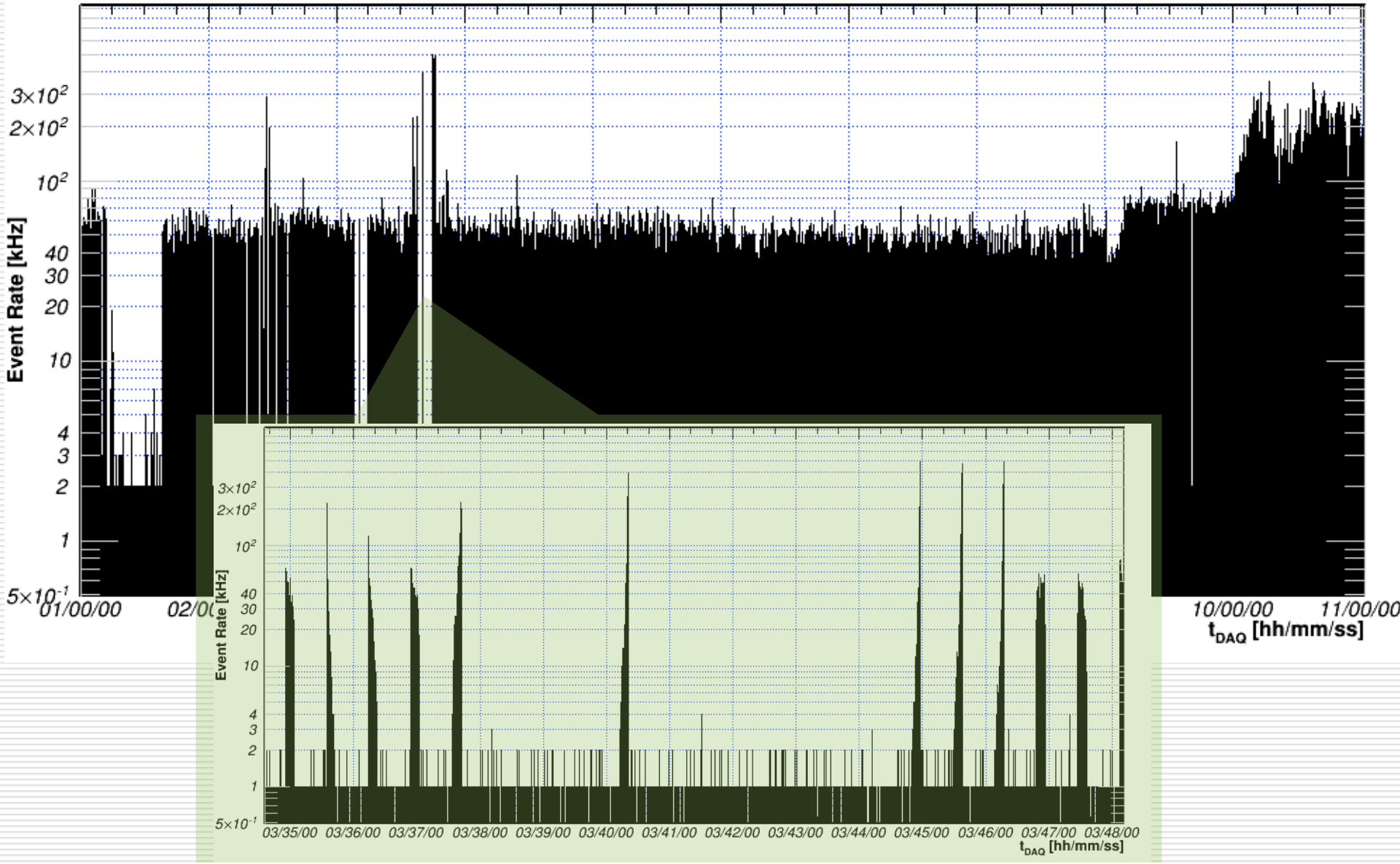
$$Q_i = q_i^{\nabla} + q_i^{\Delta},\ for\ i = \overline{1,5}$$

$$\begin{aligned} qq &= (Q^{\nabla} - Q^{\Delta})/(Q^{\nabla} + Q^{\Delta})\ \ with \\ Q^k &= \sum_{i=1}^{5} q_i^k;\ \ k = \nabla,\ \Delta \end{aligned}$$

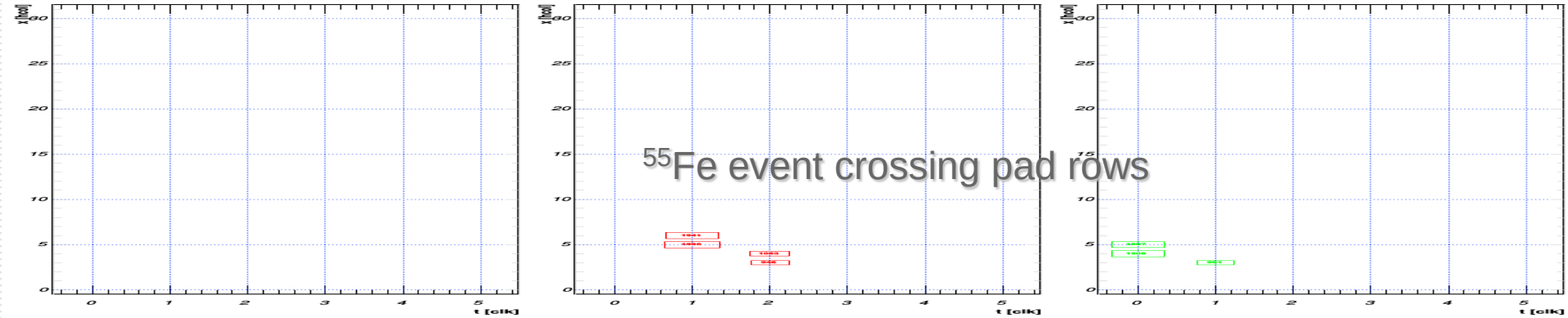
$$qq(x) = A + B \cdot sin(C \cdot (x + D))$$

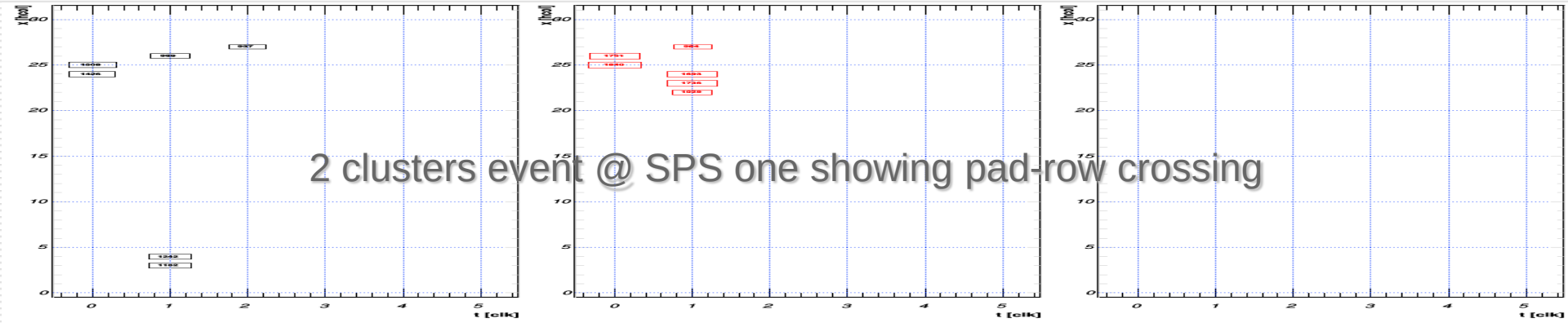
$$\begin{aligned} q^{\nabla/\Delta} &= \int_{-w/2}^{w/2} dx \int_{-kx}^{kx} dy\ \ \mathcal{G}(x|x_0, \sigma_x)\ \mathcal{G}(y|y_0, \sigma_y) \\ &\approx \sum_{i_x} \sum_{i_y} \mathcal{G}(x(i_x)|x_0, \sigma_x)\ \mathcal{G}(y(i_y)|y_0, \sigma_y)\ d\mathcal{A}(i_x,\ i_y) \end{aligned}$$

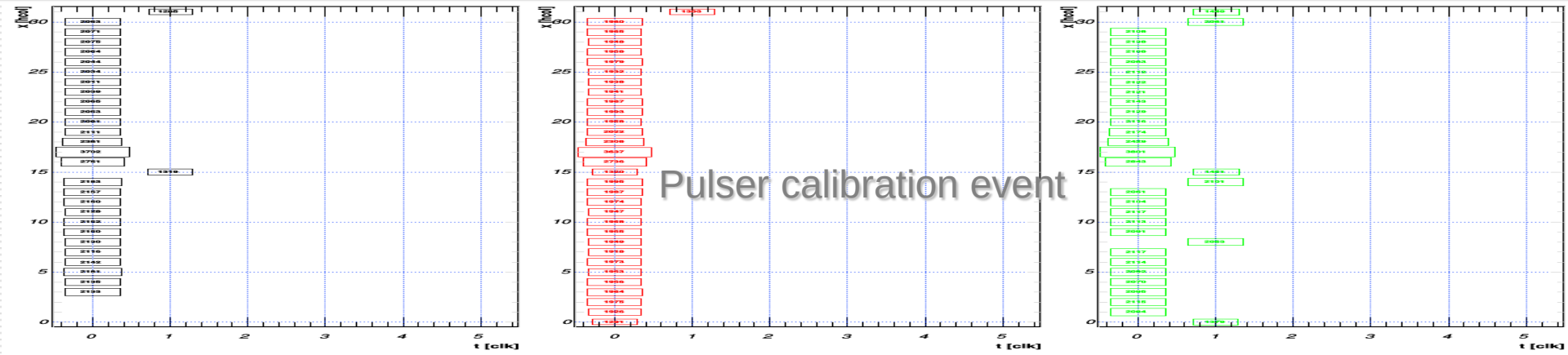
FASPRO - Run 33



TRD event types



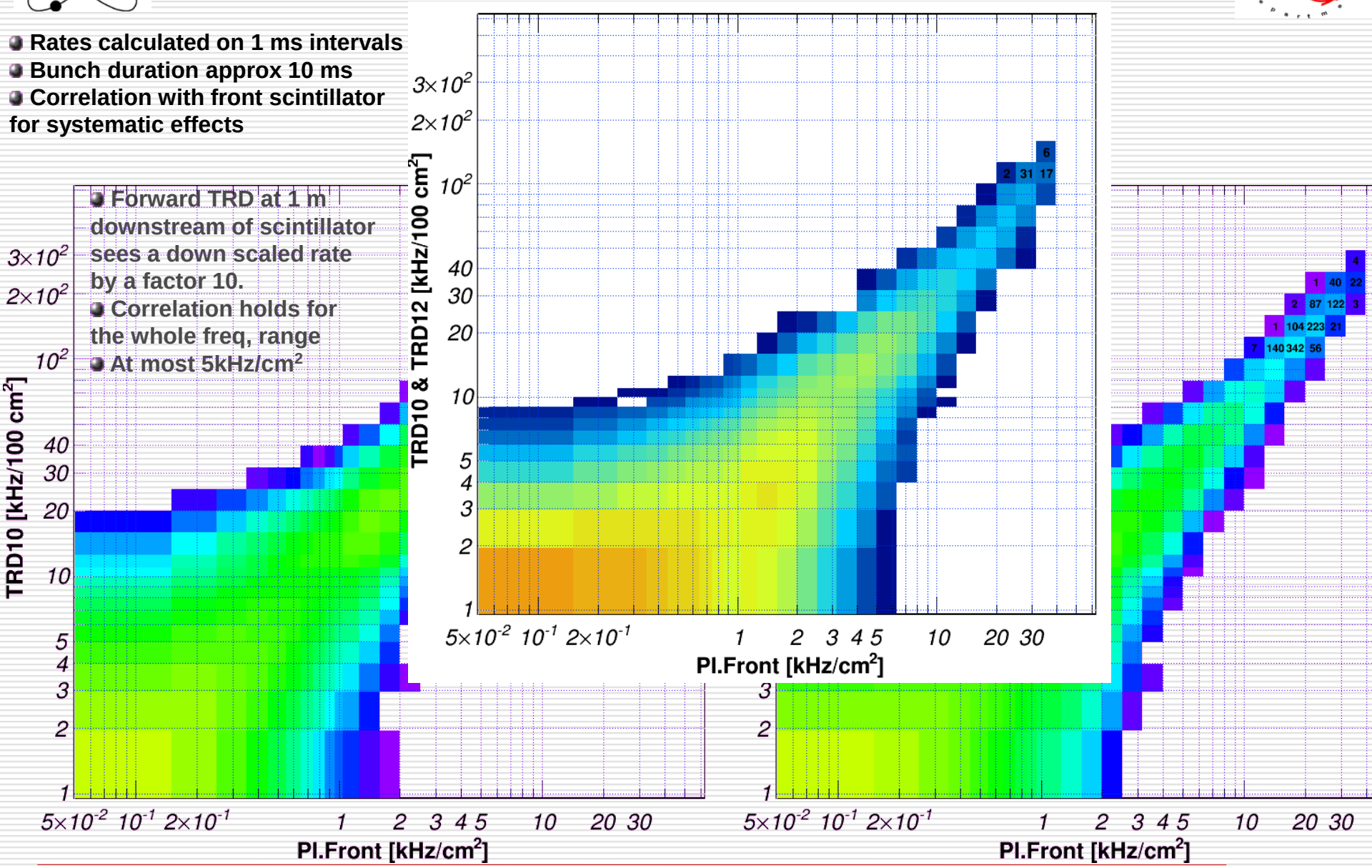




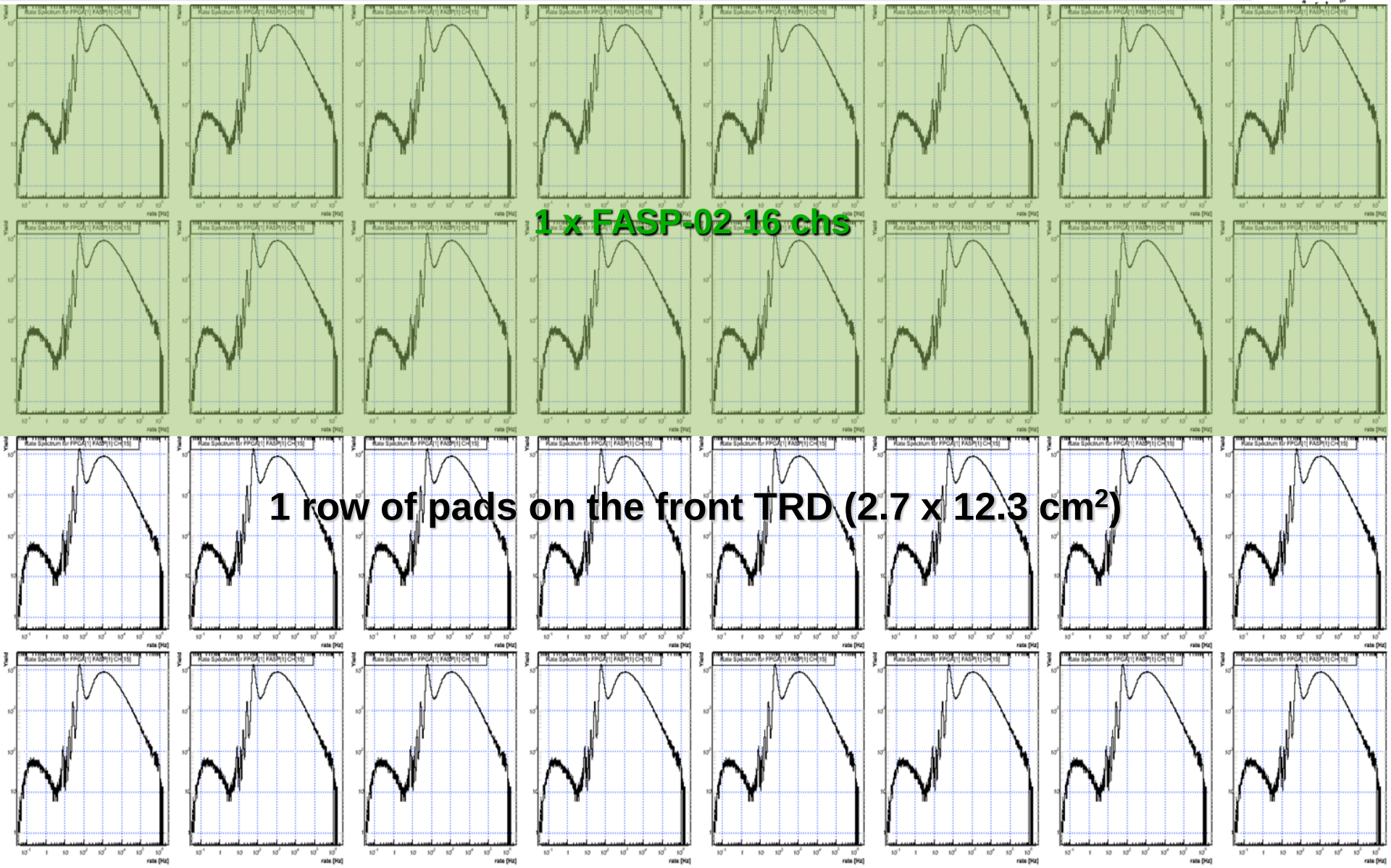
Rates @ SPS '16 :: *Events / Bunch*

- Rates calculated on 1 ms intervals
- Bunch duration approx 10 ms
- Correlation with front scintillator for systematic effects

- Forward TRD at 1 m downstream of scintillator sees a down scaled rate by a factor 10.
- Correlation holds for the whole freq, range
- At most 5kHz/cm^2

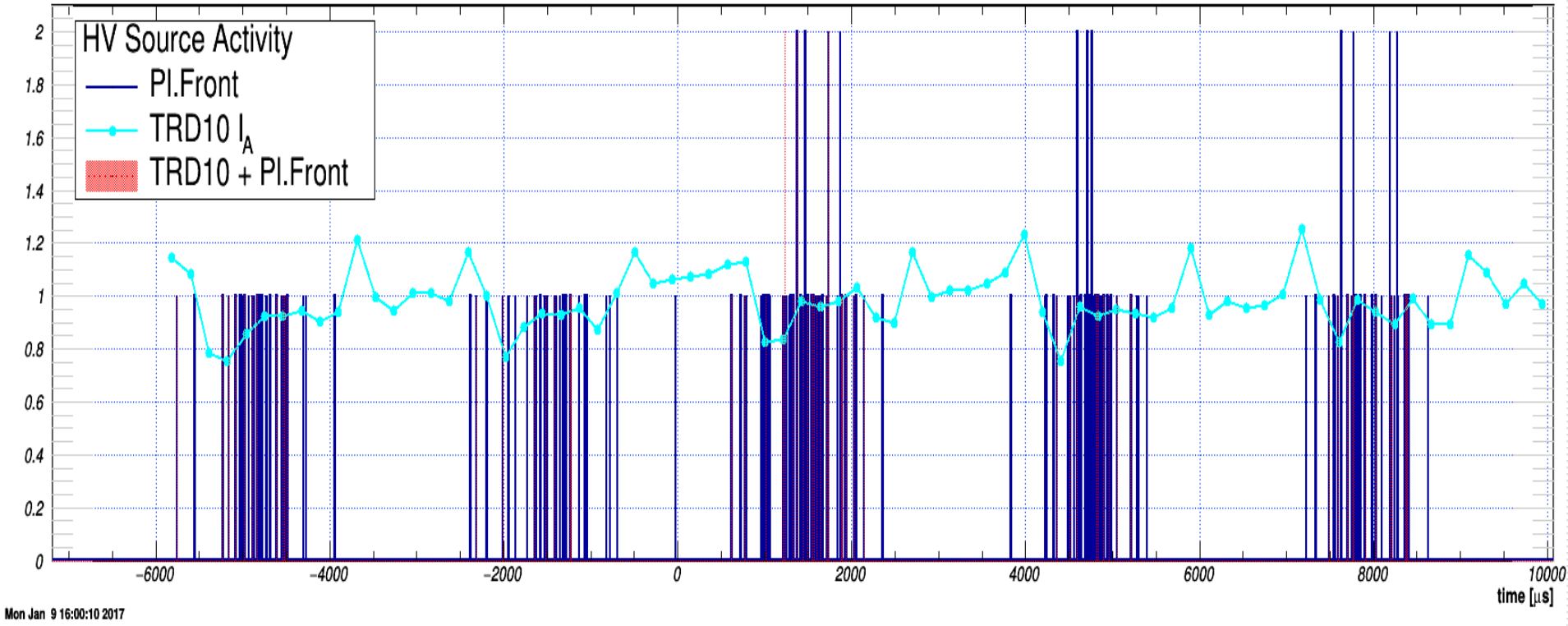


Rates @ SPS '16 :: *FASP channel*



HV – data taking correlation

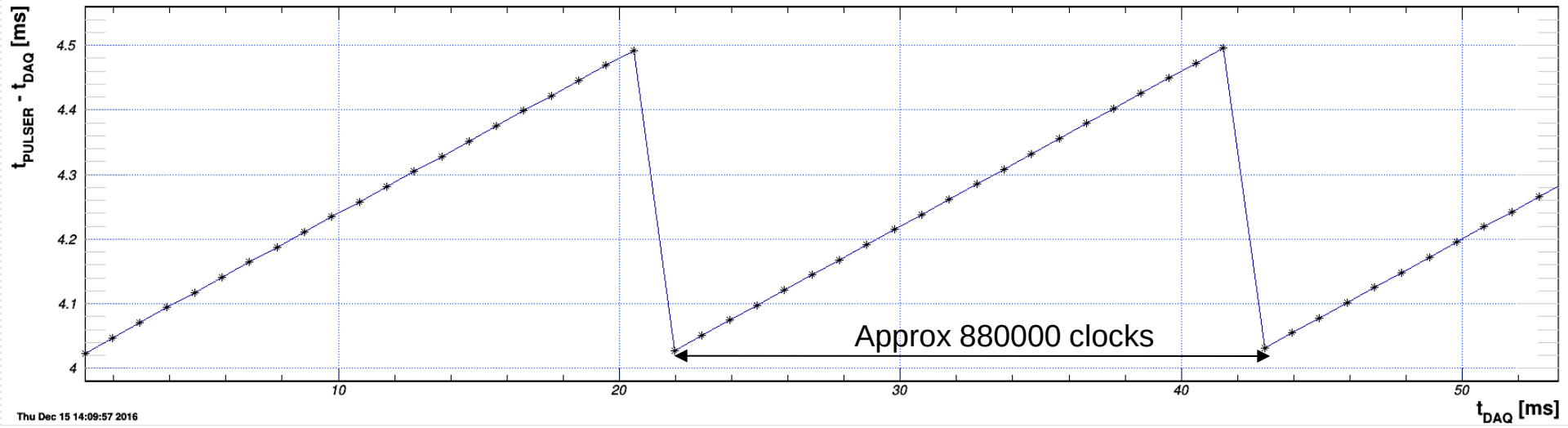
BUNCH STRUCT.



GSI/CBM reports

- Laboratory tests of the Bucharest TRD prototype performance in High Counting Rate environment.
  - Short summary of 28th CBM Collaboration Meeting report
- Tracking with the Bucharest TRDs at the CERN-SPS 2015 Testbeam
  - Selections of 27th CBM Collaboration Meeting report
- Bucharest RPC and TRD prototypes at CERN-SPS 2016 Testbeam.
  - General presentation of the Bucharest setup @ CERN-SPS '16 and first results from MBS and FreeRunning DAQs
- Tests of the Free-Running DAQ of the Bucharest TRD prototype at the CERN-SPS 2016 Testbeam.
  - Summary of current report

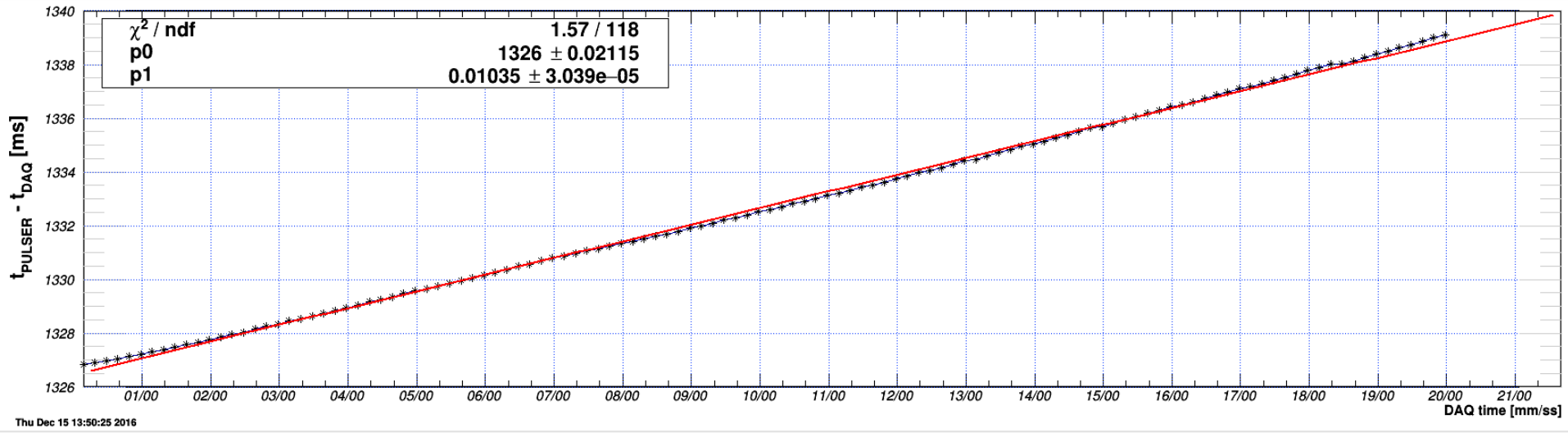
Timing the DAQ



2 clocks on the system
- Pulser @ 1kHz
- DAQ @ 40MHz

Linked by TRD events

Timing the Free Running DAQ



Time run-away
- Pulser @ 0.1Hz
- DAQ @ 40MHz

A time discrepancy of 10μs/s is observed

Pulser being faster