Mu2e Calorimeter triggers

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MUSE workshop
September 28, 2016

General requirements for Mu2e triggers

(docdb:1150-v14, 6782-v2, 7237)

AVERAGE PHISYCS BANDWIDTHS

Tracker: 18 GB/s
Calorimeter: 8 GB/s
CRV: 4 GB/s
Monitors ~1 GB/s

Total DAQ bandwidth: ~31 GB/s
Storage limit: 7 PB/y ~**0.7 GB/s**

Required trigger rej. Factor > 45

Filter	Bkg level	Rejection factor	Rate kHz	Efficiency (%)	Processing time (ms)	Doc-db
Up/downstream trk	1x	400	0.45	100	O(10)	7310-7439
Up/downstream trk	2x	400	0.45	100	O(40)	7310-7439
Up/downstream trk	3x	400	0.45	100	O(100)	7310-7439
Dual Tracker-calo.	1x	200	0.90	92	O(10)	7576
Calorimeter cluster	1x	400	0.45	60	~ 0.3	7258
Calorimeter cluster	2x	400	0.45	45	~ 0.3	7258
Calorimeter cluster	3x	400	0.45	20	~ 0.3	7258

CALORIMETER TRIGGERS

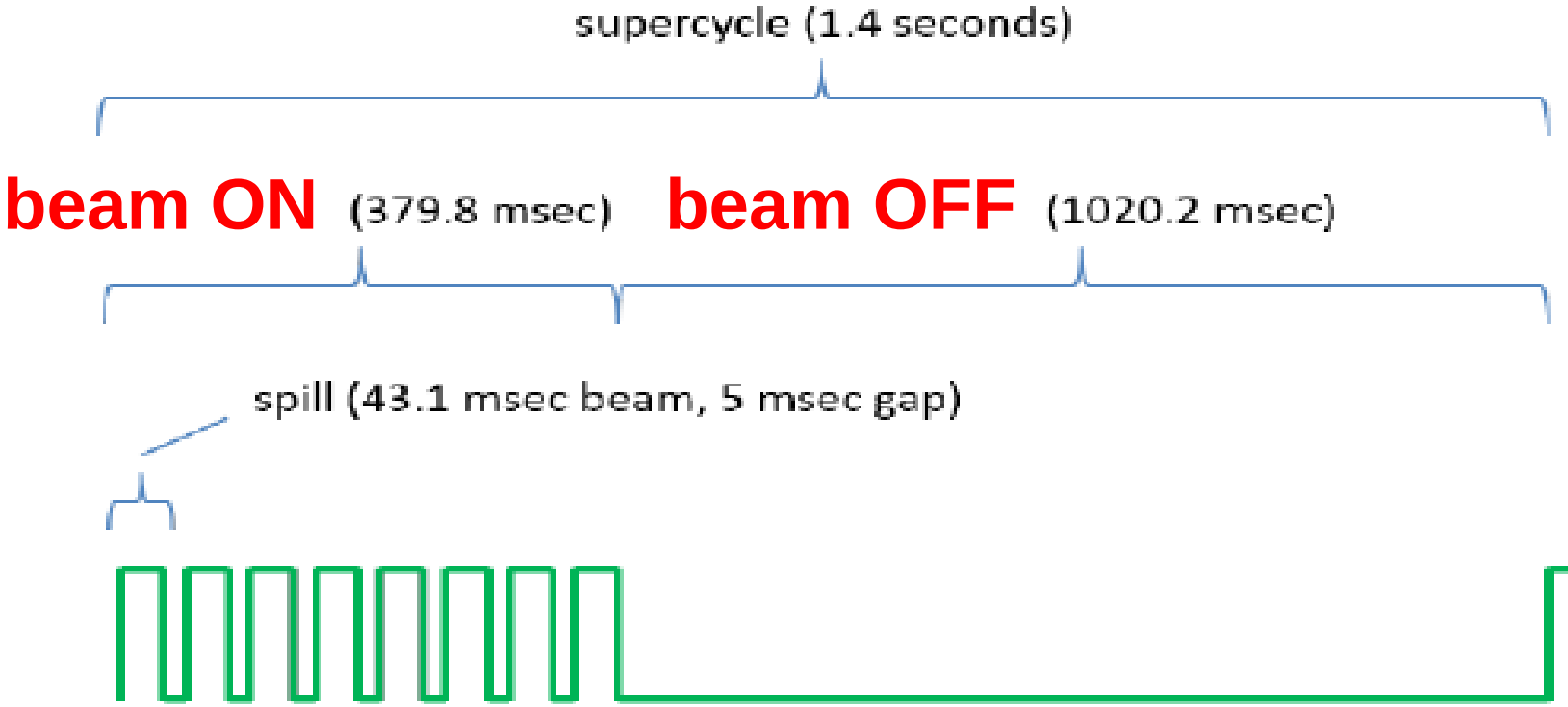
Physics triggers (beam ON)

- **Calorimeter only**
- **Dual tracker-calorimeter**
- ***special run conditions***

(low B or I, commissioning)

Calibration triggers (beam OFF)

- **Cosmic muons**
- **Radioactive source**
- **Laser pulses**
- **FEE pulses**
- **unbiased (random)**



CALORIMETER ONLY TRIGGER

Aim:

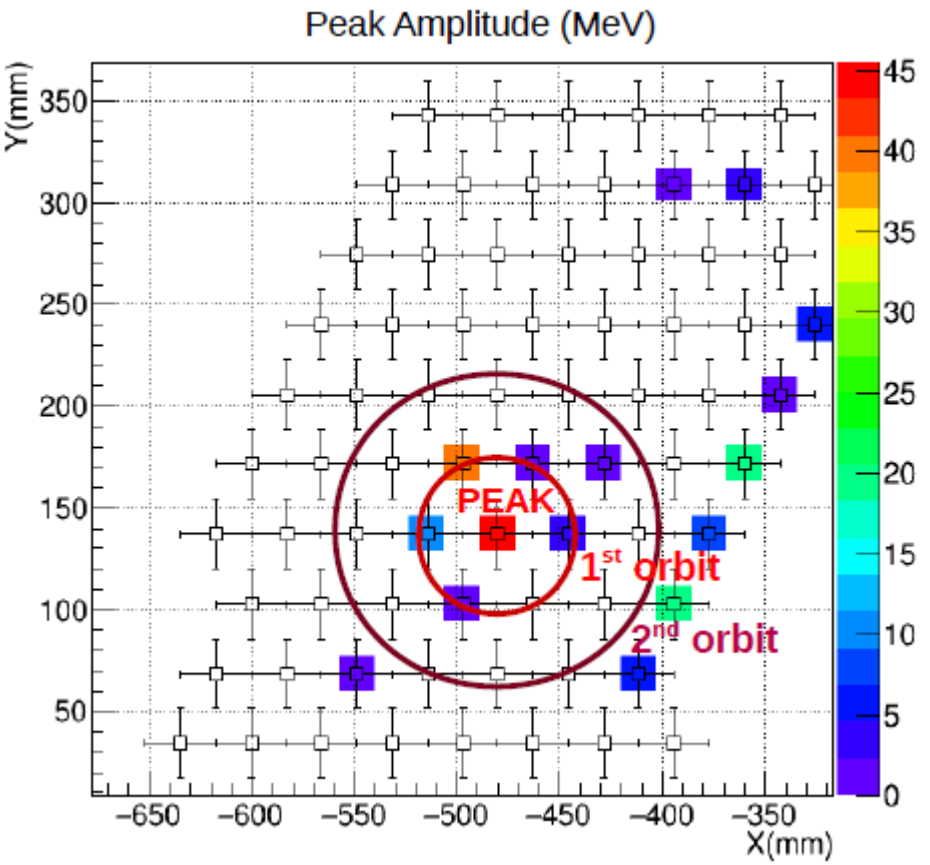
- Indepentent on tracker (measure tracker efficiency)
- Very fast decision

Calorimeter information (docdb-7258):

“Peak variables”:
- peak amplitude, time and (radial) position
“Cluster variables”:
- number of 'hits' above threshold
- sum of energy (sum of peak amplitudes)
- center of energy
- lateral and longitudinal sigma
- skewness (asymmetry)
- kurtosis (tailedness)

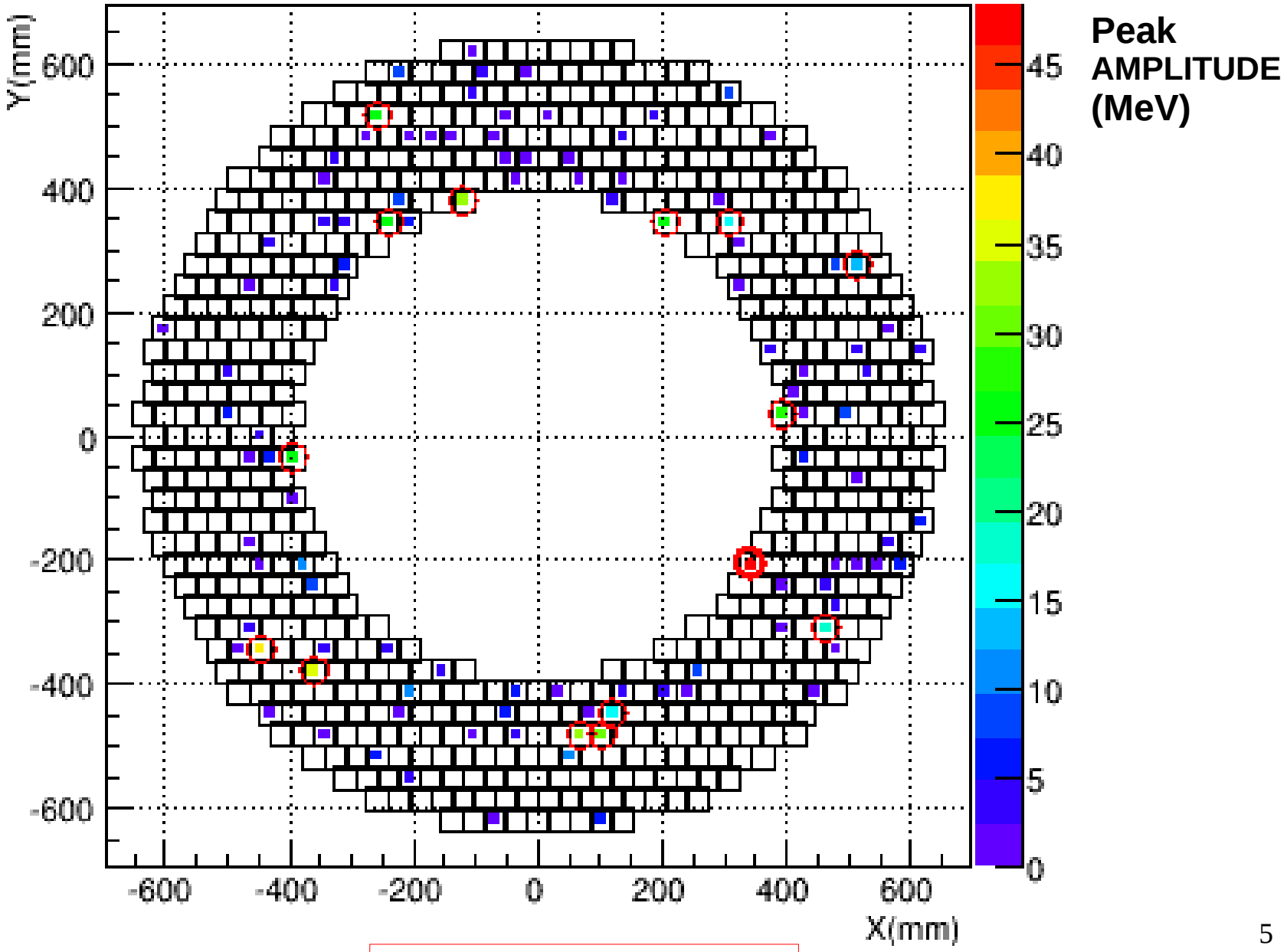
AND/OR

- energy (peak amplitude) of each hit correlated with its position



Example of peaks selected in 1 CE+bkg event

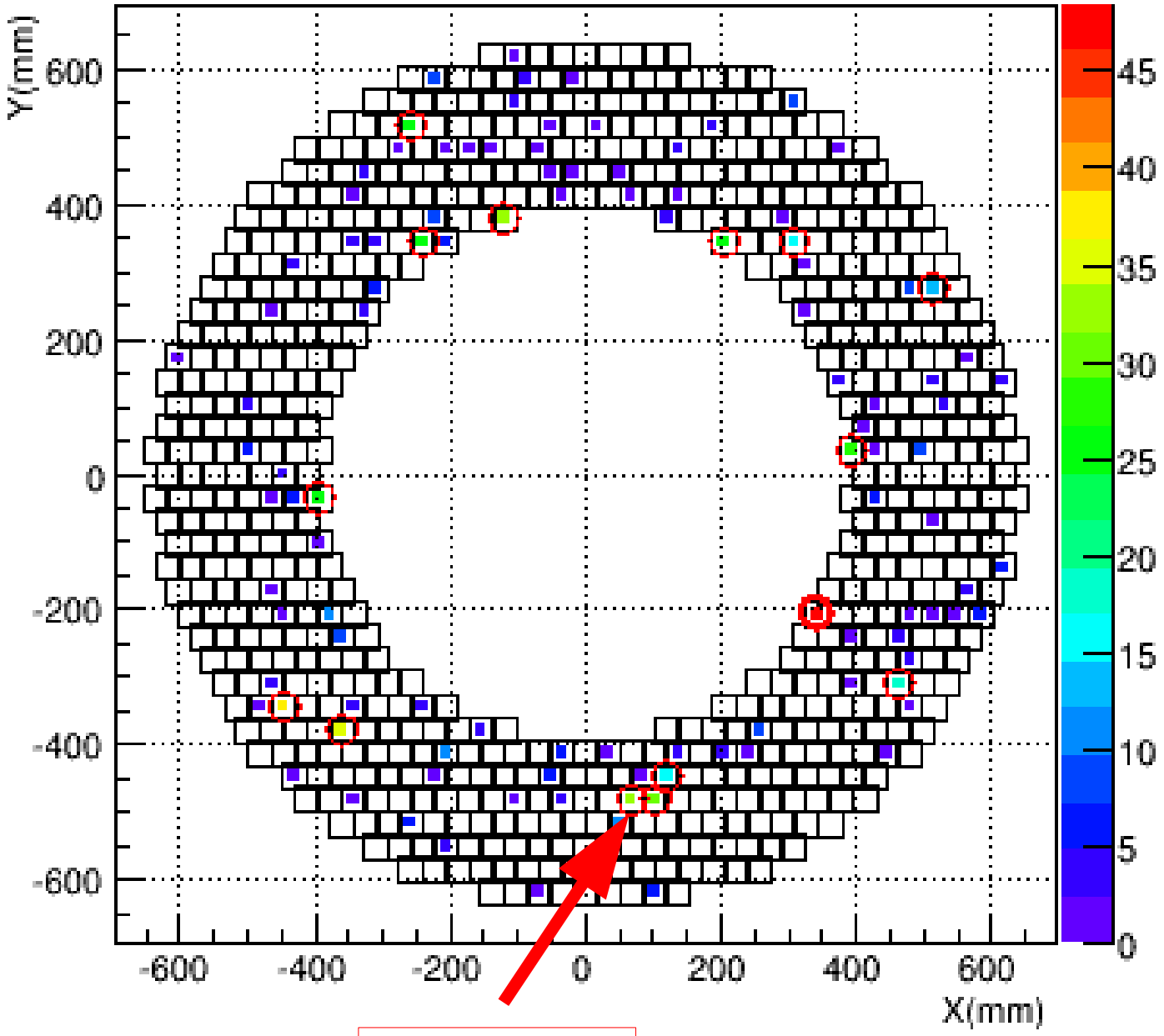
(also crystals in time with peaks are displayed)



Where is the CE?

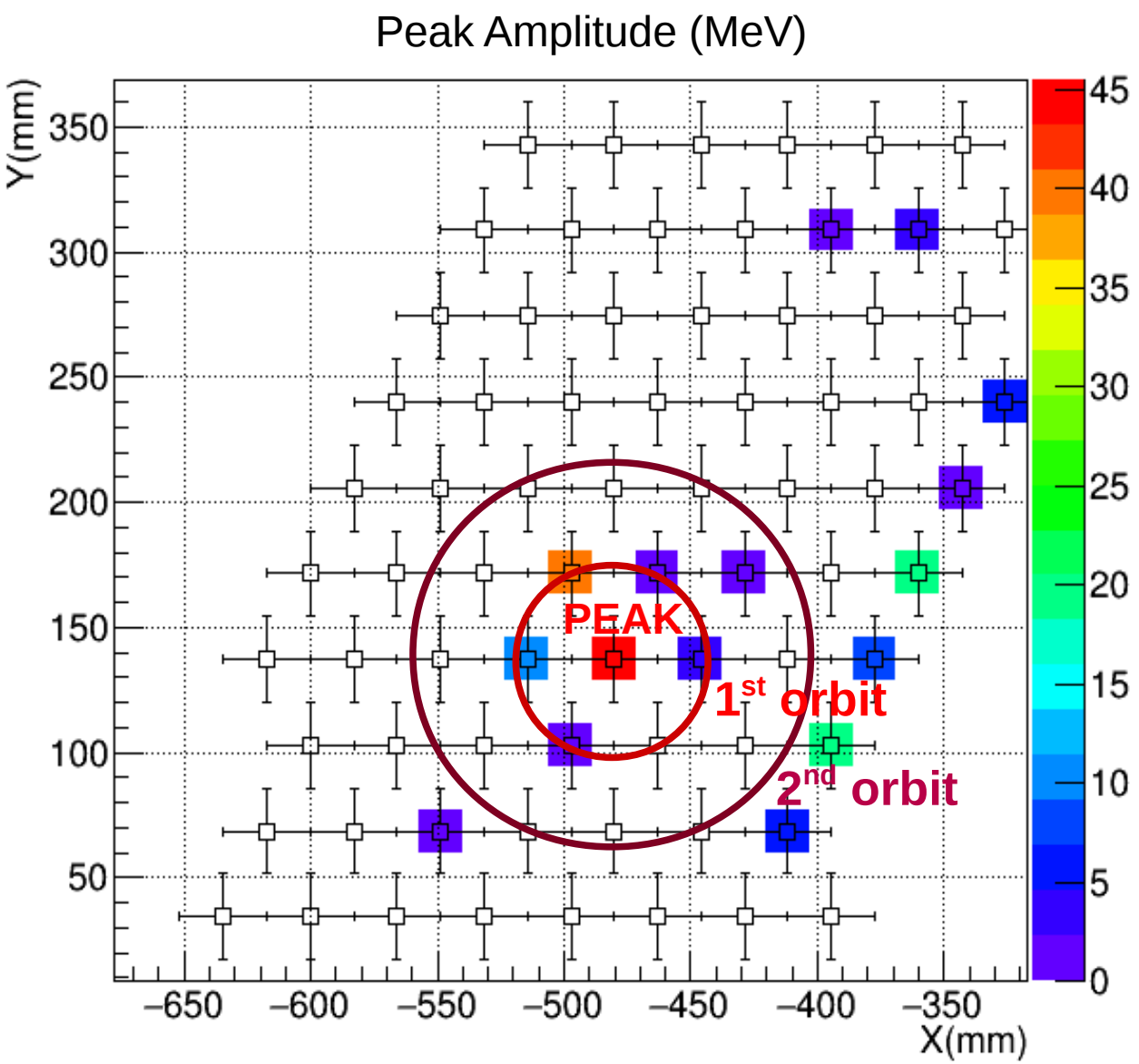
Example of peaks selected in 1 CE+bkg event

(also crystals in time with peaks are displayed)



Here it is!

Trigger algorithm variables



1st orbit: 1 crystal from the peak
2nd orbit: 2 crystals from the peak

Optimization of variable set: we used both Boosted Decision Tree (BDT) and Artificial Neutral Network (ANN) in TMVA Root package to skip variables not significantly contributing to rejection power

The optimized set is:

1) E0:
PEAK AMPLITUDE (> 20 MeV)

2) rpeak: PEAK radial position

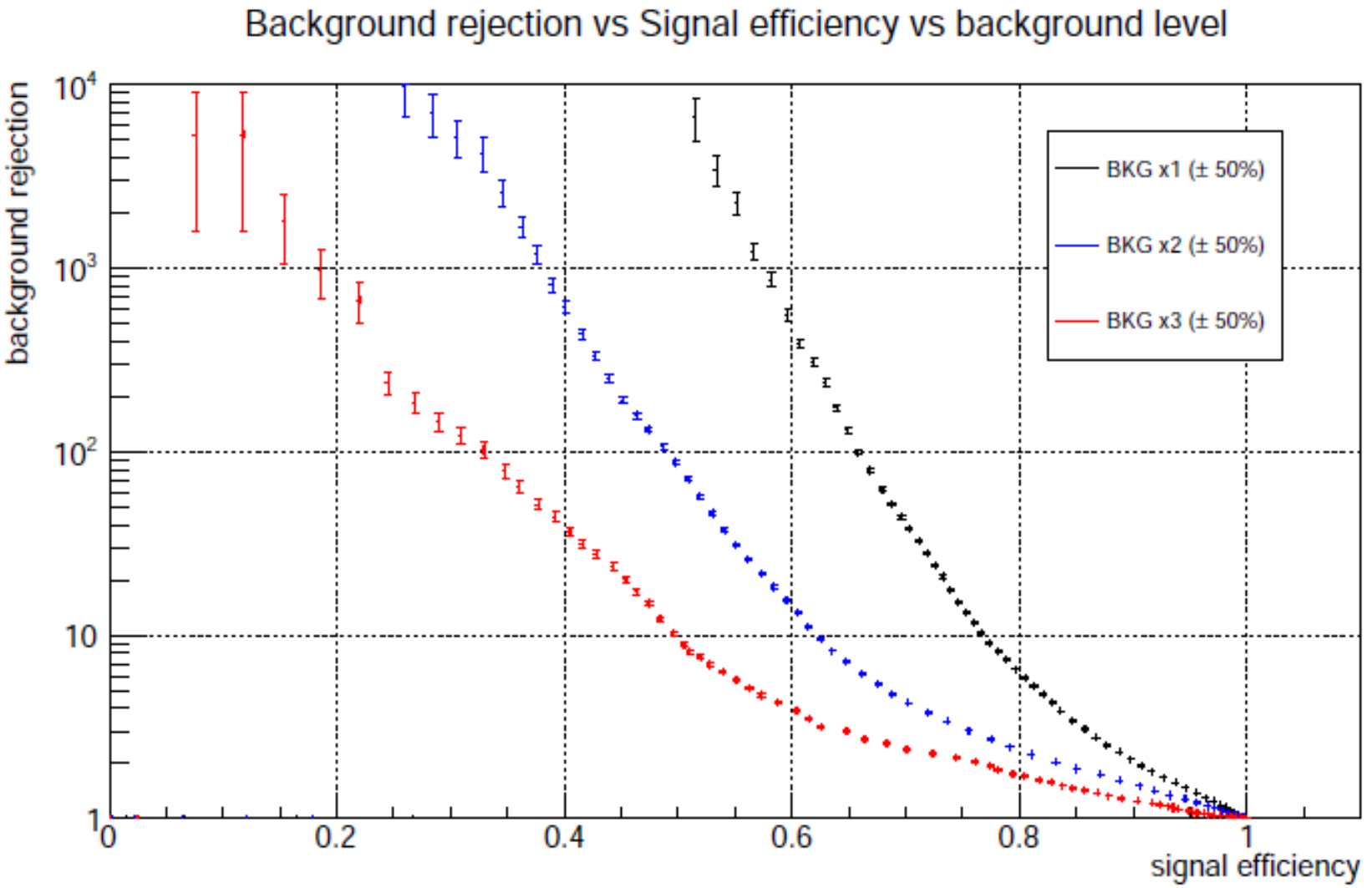
3) tpeak: PEAK time

4) E01: highest AMPLITUDE in the 'first orbit'

5) E02: 2nd highest AMPLITUDE In the 'first orbit'

6) E10: highest AMPLITUDE In the 'second orbit'

CALORIMETER ONLY TRIGGER PERFORMANCES



Pros: fast processing time (~0.3 ms), tracker independent

Cons: relatively low efficiency on CE (60% @400 rejection)

Efficiency normalization: Good Tracks hitting ECAL

DUAL TRACKER-CALORIMETER TRIGGER

Aim:

- Simplify tracker pattern recognition

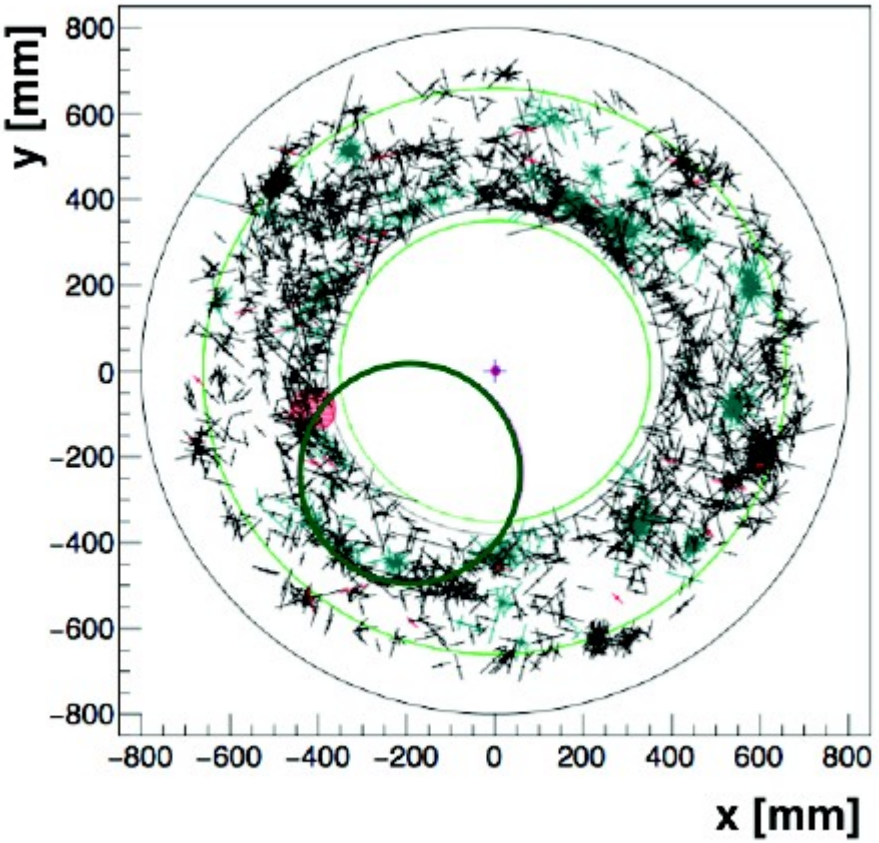
- Reduce background level dependence

Selection algorithm (docdb-7576):

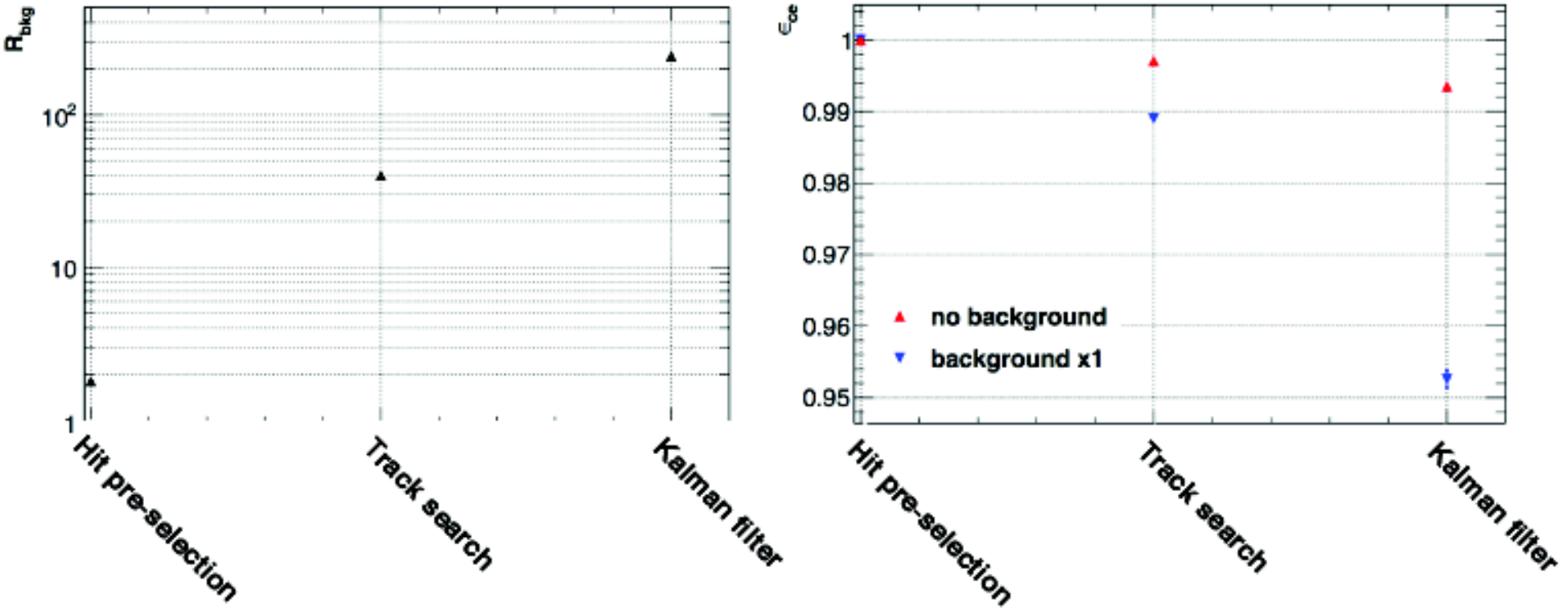
0) Calorimeter cluster with E>50 MeV. Cut on number of tracker hits matching cluster time and position

1) Pattern recognition track: cut on associated hits and χ^2

2) Kalman fit track: cut on associated hits, χ^2 and impact parameter



DUAL TRACKER-CALORIMETER TRIGGER PERFORMANCES (docdb-7776)



Pros: very high efficiency (95% @200 rejection)
Cons: processing time O(10) ms/event, tracker dependent

Efficiency normalization: good quality CalPatRec Tracks

CALORIMETER COSMIC TRIGGER

Aim:

- Energy equalization and calibration

- Time equalization and time resolution monitoring

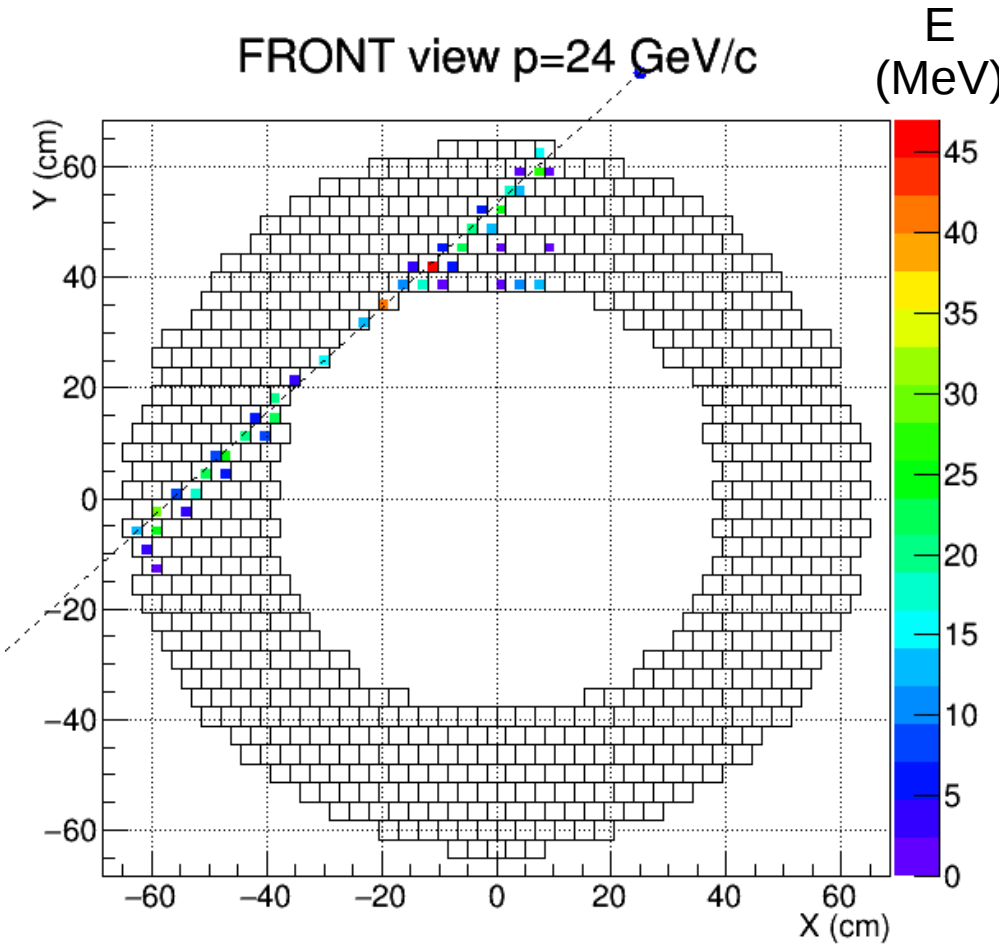
- Low additional bandwidth

A possible selection algorithm:

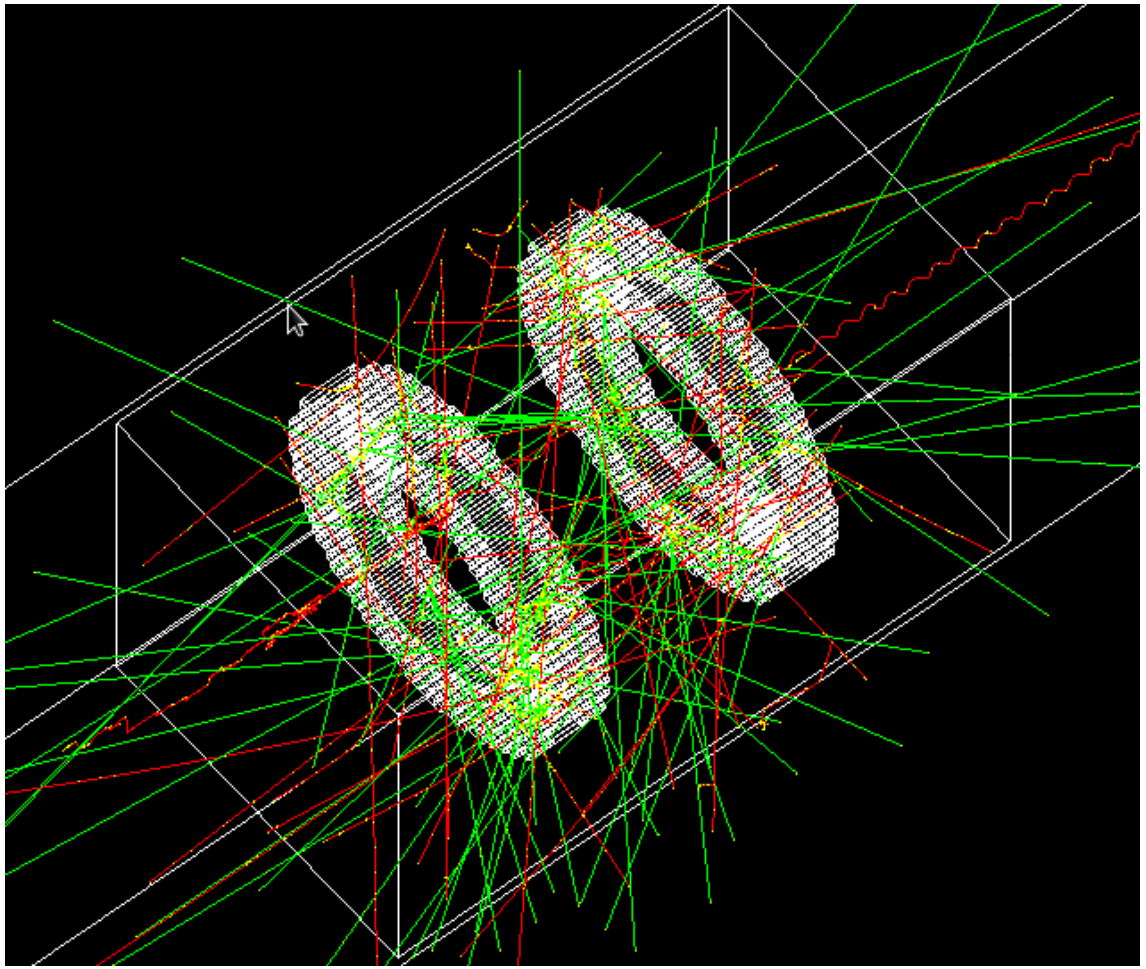
- number of crystals with energy deposit ~20 MeV

- χ^2 of fit in x-y and t-(xy)

- fit residuals



CALORIMETER COSMIC TRIGGER EXPECTED PERFORMANCES



Generation:

- Daya Bay dI/dEdΩ (docdb-1566)

- 0.5<E<2000 GeV

(effective trigger threshold:1.5GeV)

- 0<cosθ<1

- rate on ECAL: 130Hz

Trigger rate: 20 Hz

<sensors/event> ~40

<sensor event size> ~250bit/sens

Beam Off fraction ~70%

Expected bandwith: ~20 ev/s*40sens/ev*250bit/sens*0.7=17 MB/s

Calibration rate on single sensor: 0.1 Hz(*0.7)

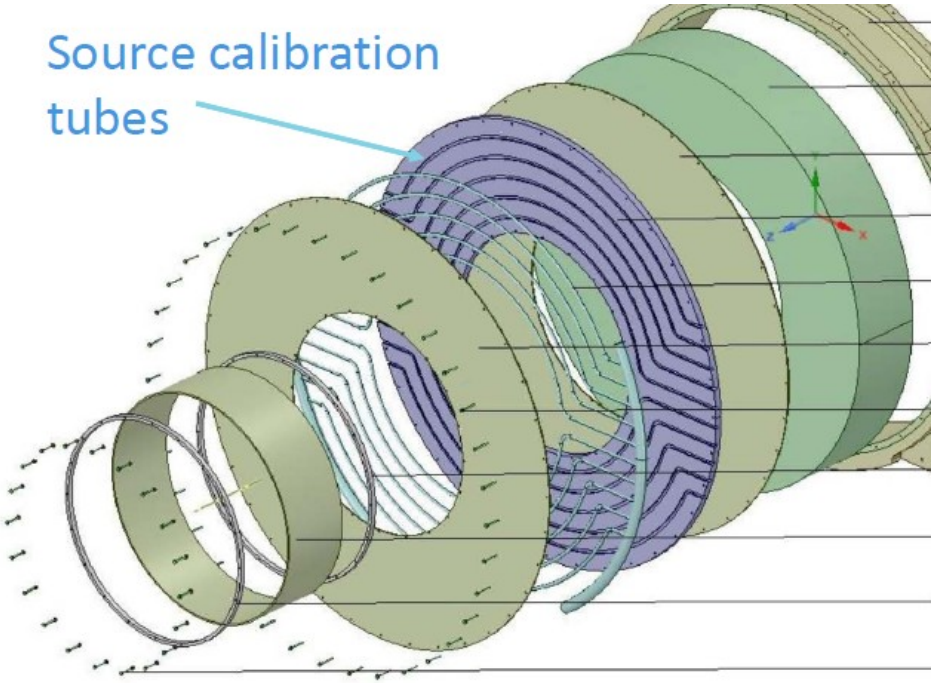
Calibration run duration (1000 ev/sensor): ~4h

6 MeV SOURCE CALORIMETER TRIGGER

Aim:

- Energy equalization and calibration

- Low additional bandwidth

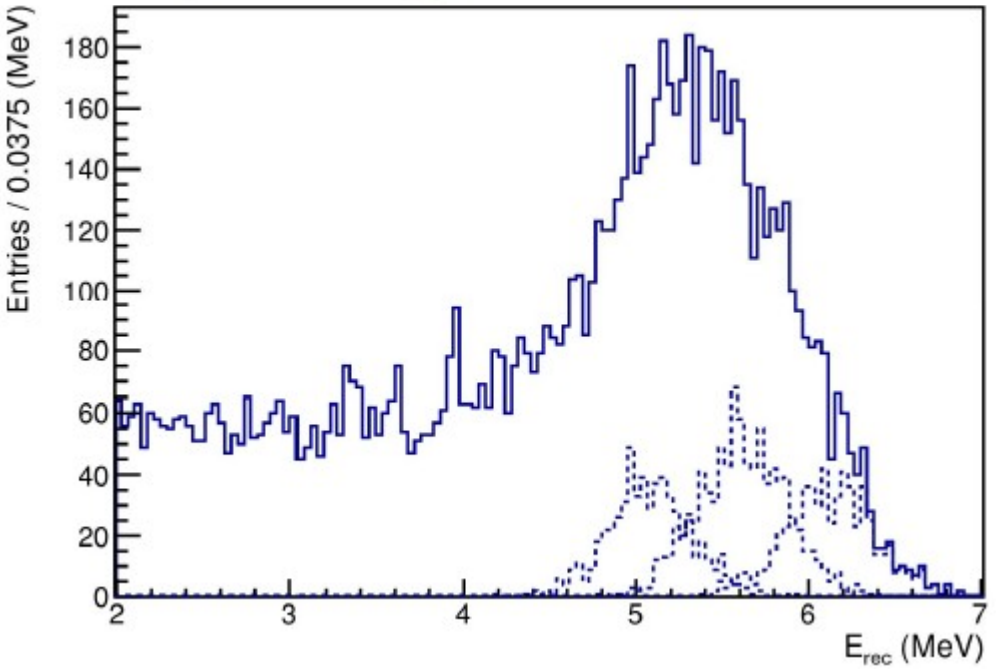


Selection algorithm:

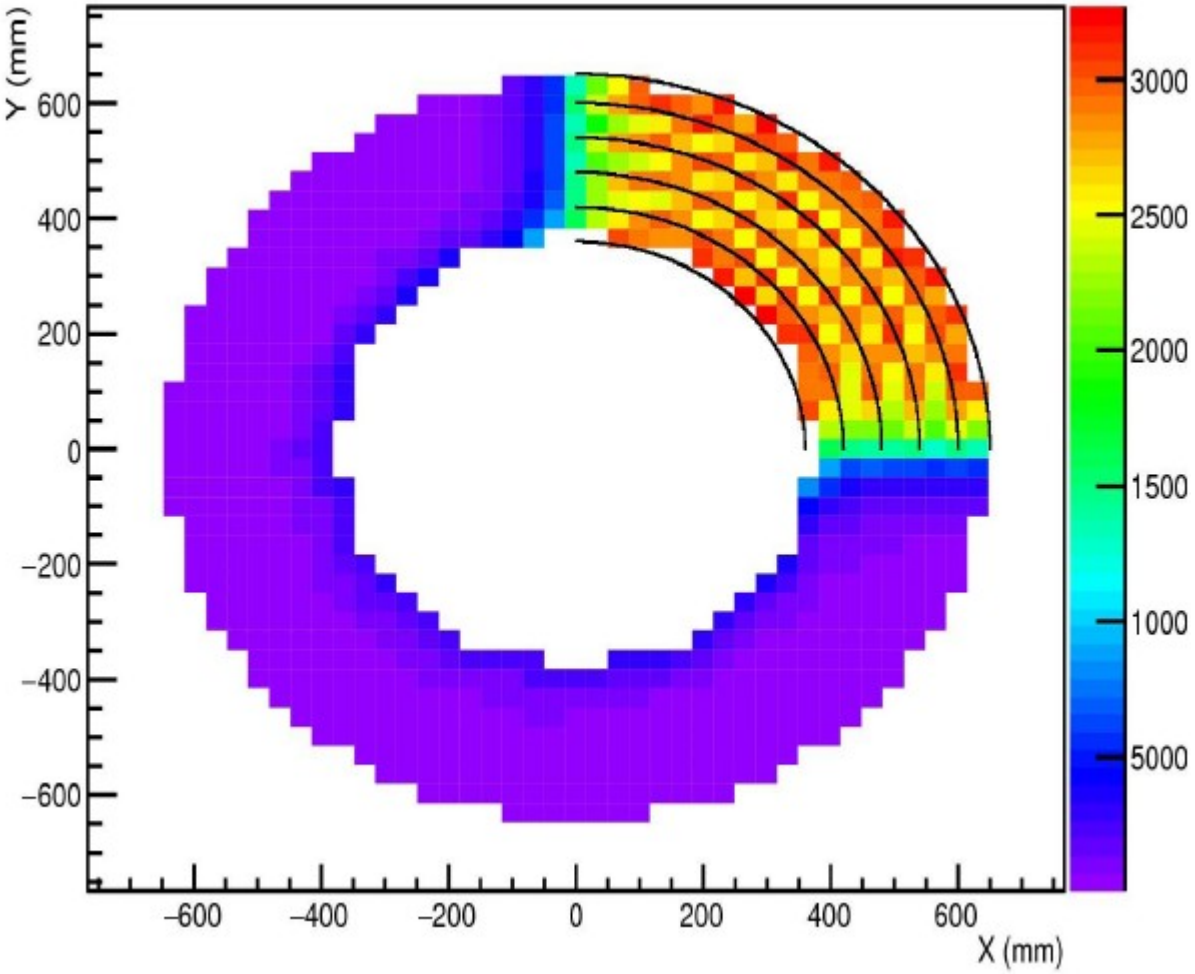
- External trigger

- Calibration flag

- sensors with E> 4 MeV



6 MeV SOURCE CALORIMETER TRIGGER EXPECTED PERFORMANCE (docdb-7517)



10000 ev/crystal/10 min

Trigger rate: 16 Hz
<sensors/event> ~1
<sensor event size> ~250bit/sens

Dedicated calibration run frequency: ~1/week
Run duration: 10-20 min
Time fraction: ~10^{-3}

Instantaneous expected bandwith: 0.5 kB/s
Average expected bandwith: 0.5 byte/s

LASER PULSE CALORIMETER TRIGGER

Aim:

- Energy equalization and Calibration

- Time equalization and time resolution monitoring

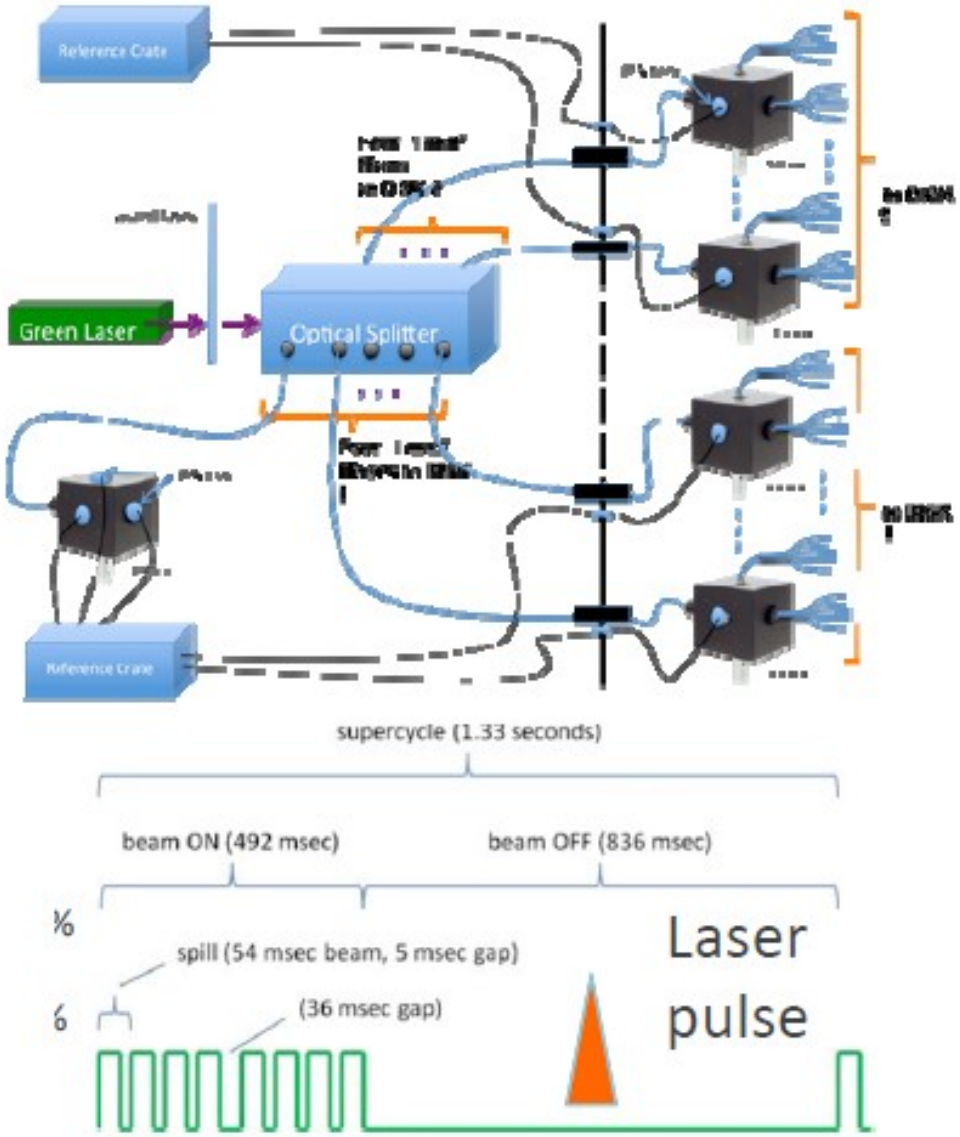
- Low additional bandwidth

Selection algorithm:

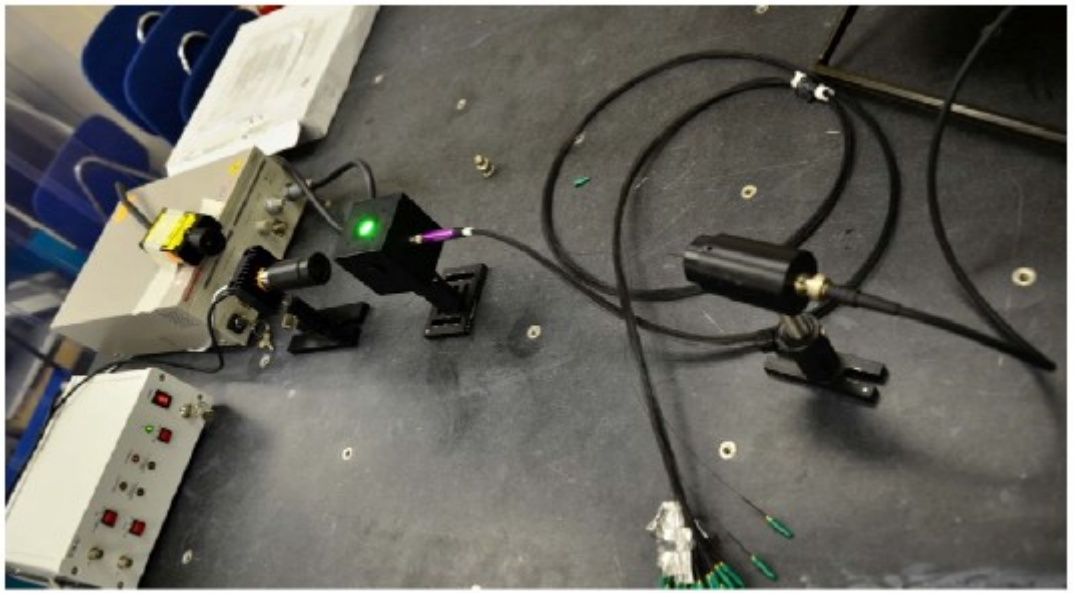
- External trigger

- Calibration flag

- sensors with E~ 20-40 MeV



LASER PULSE CALORIMETER TRIGGER EXPECTED PERFORMANCE



1 laser pulse/1.33 s (each spill off)

Trigger rate: 0.75 Hz
<sensors/event> ~2800
<sensor event size> ~250bit/sens

Time to calibrate (1000 ev/sensor): ~25 min

Expected bandwith: 0.75 ev/s*2800sens/ev*250bit/sens=525 kbit/s

ELECTRONIC CALIBRATION TRIGGERS (FEE pulses and NOISE)

Trigger rate: O(Hz)
<sensors/event> ~2800
<sensor event size> ~250bit/sens

Dedicated calibration run frequency: ~1/week
Run duration: 10 min
Time fraction: ~10^{-3}

Instantaneous expected bandwith: 700 kbit/s
Average expected bandwith: 700 bit/s

SUMMARY

Calorimeter can provide a stand alone trigger very fast, with an efficiency ~60% for a rejection factor of ~400. This can be used to monitor the tracker efficiency.

Calorimeter can also help the tracker trigger reducing the hits used as input for the tracker. The efficiency is ~92% for a rejection factor of 200.

Considering a total background rejection factor of 200, all the physics triggers produce ~150 MB/s well inside the maximum allowed data storage (700 MB/s)

Calorimeter cosmic trigger, running in continuous mode during beam off periods, requires additional ~20 MB/s (i.e. 3% of what is available)

Requests from the other calibration triggers are negligible