Hit-Reconstruction and Calibration for eToF

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Hit Reconstruction

Basic data format out of daq-file unpacking:

StETofDigi: time
time over threshold
electronic channel address

Information needed for track matching:

StETofHit: time
position

➡ Task: reconstruct precise hit information from digis

Two step strategy (adapted from CBM test-beam experiences):

1. Match digis from different sides of the same detector strip into single strip hits

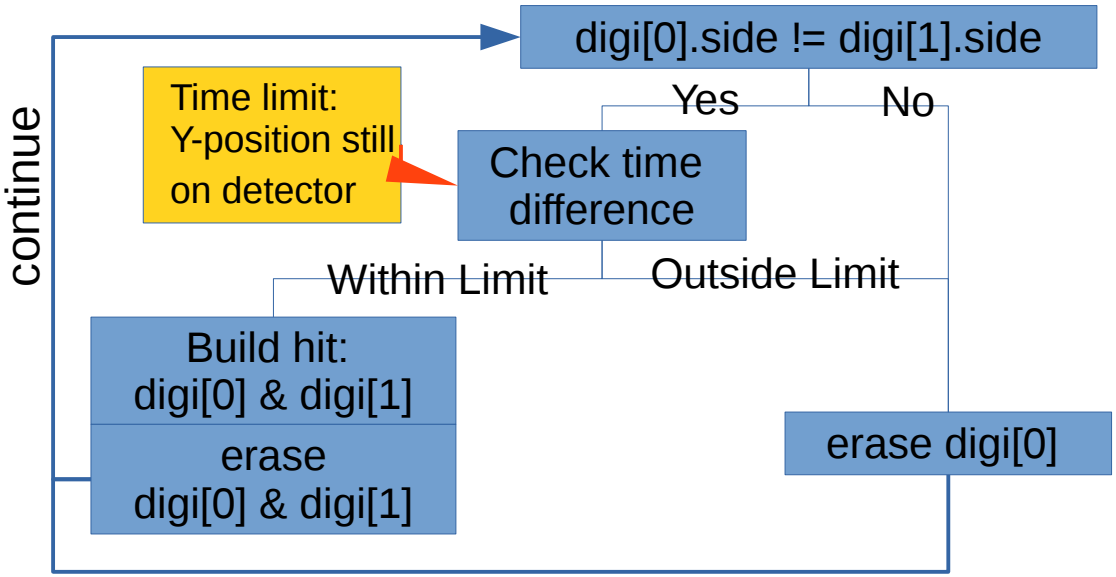
2. Cluster single strip hits into multi-strip hits based on time and position correlation

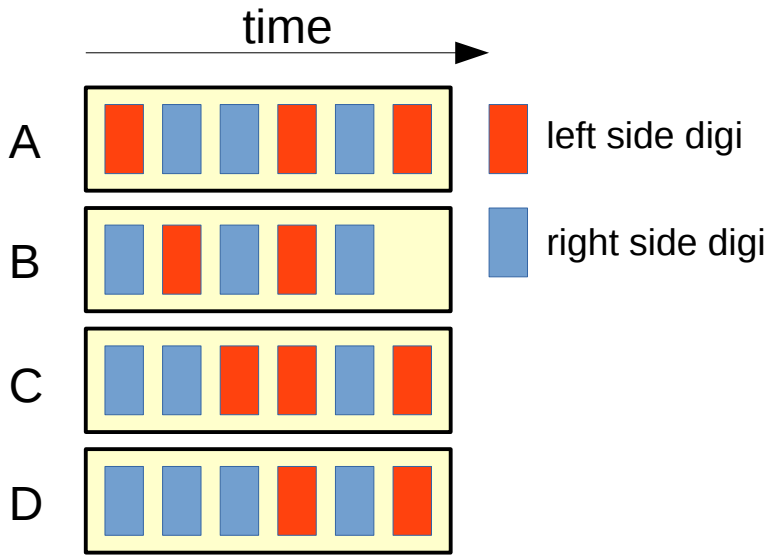
Hit Reconstruction

Digi matching

Strategy:

1. Sort Digis from both sides of a detector strip into a common vector
2. Sort digi in the vector by time
3. Start checking digis at beginning following the strategy below





Once matched, reconstruct hit time and position:

t = (t [0] + t [1])/ 2
x = x (strip)
y = ((t [0] - t [1])/ 2)* signal velocity
z = z (module)

Hit Reconstruction
Cluster merging

WHY:

- Physical avalanches induce signals on more than one strip => Correlated signals

- Multiple measurements of the same avalance => improved resolution in x,y,t

- Reduction in combinations for track matching

Strategy:

1. Sort single strip hits on the same MRPC into common vector

2. Sort hits in the vector by time

3. Check 4D-distance between hits

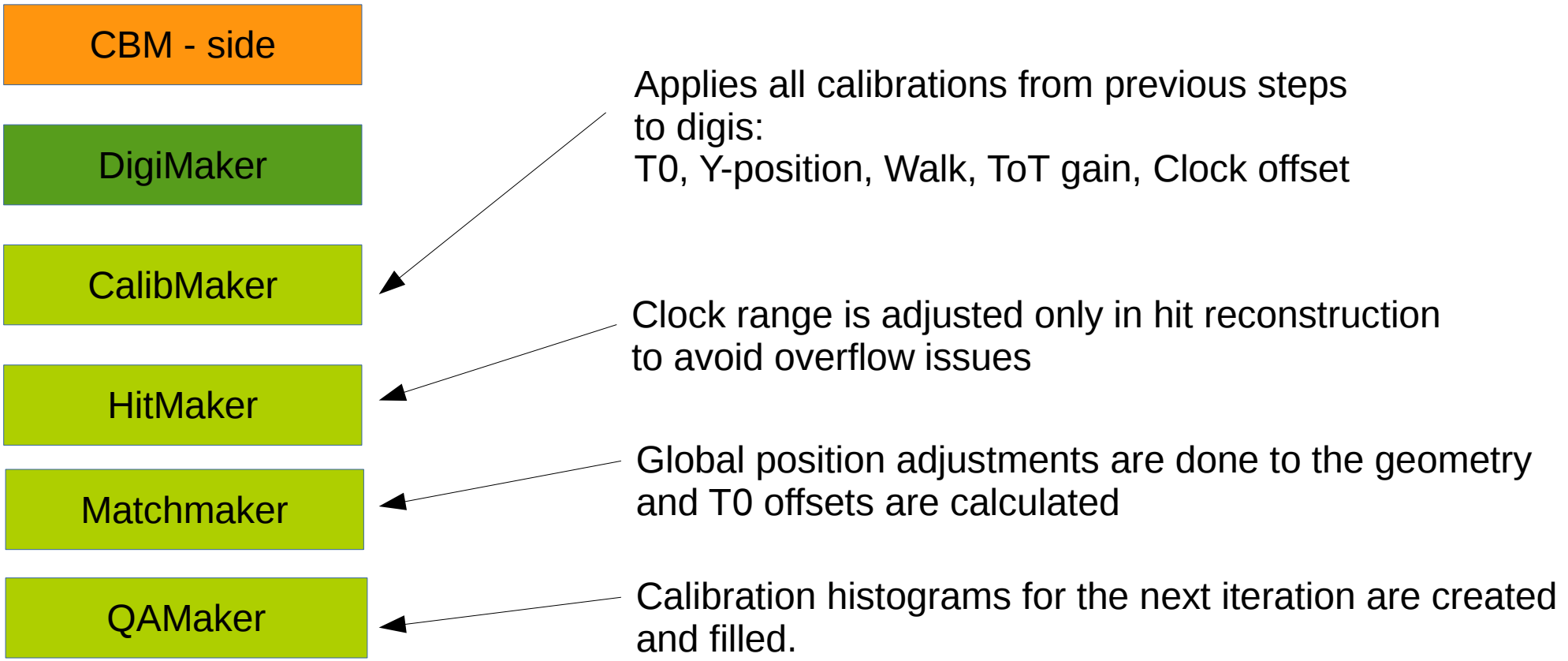
4. Merge hits on adjacent strips if $(\Delta y / v\_sig)^2 + \Delta t^2) > r\_merge$

5. Recalculate x,y,t based on ToT-weighted average

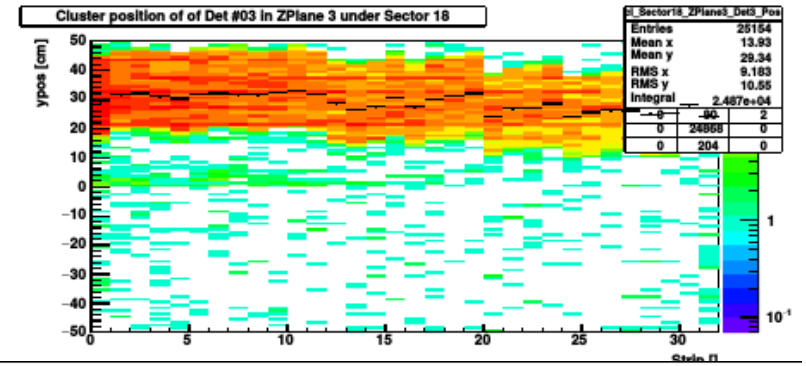
Effects to consider for calibration:

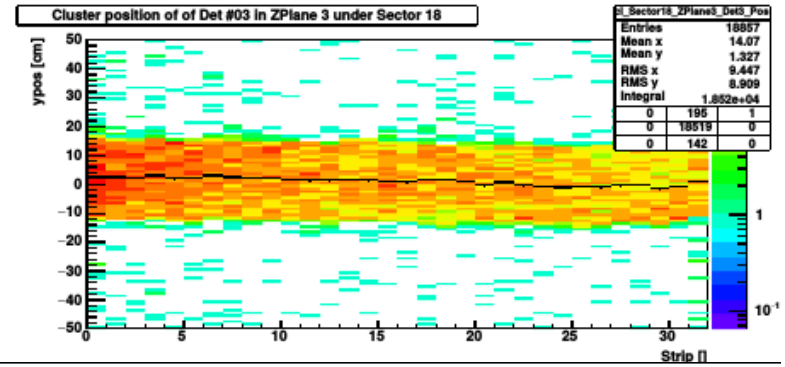
- 1. Clock reset delays between eToF and bToF (constant)
- 2. Clock range differences between eToF and bToF (constant)
- 3. Cable delays between eToF electronic channel
  - 3a: local y-position offsets (iterative)
  - 3b: T0 offsets (iterative)
- 4. Gain differences between eToF preamplifier channel (iterative)
- 5. Signal height dependence of signal times: Walk / Slewing (iterative)
- 6. Global position offsets (hopefully constant)
- 7. Signal velocity differences between MRPCs (constant)

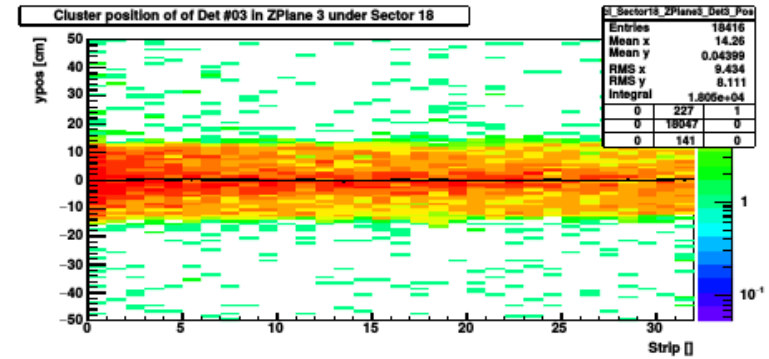
Software
What happens where?



Local position calibration

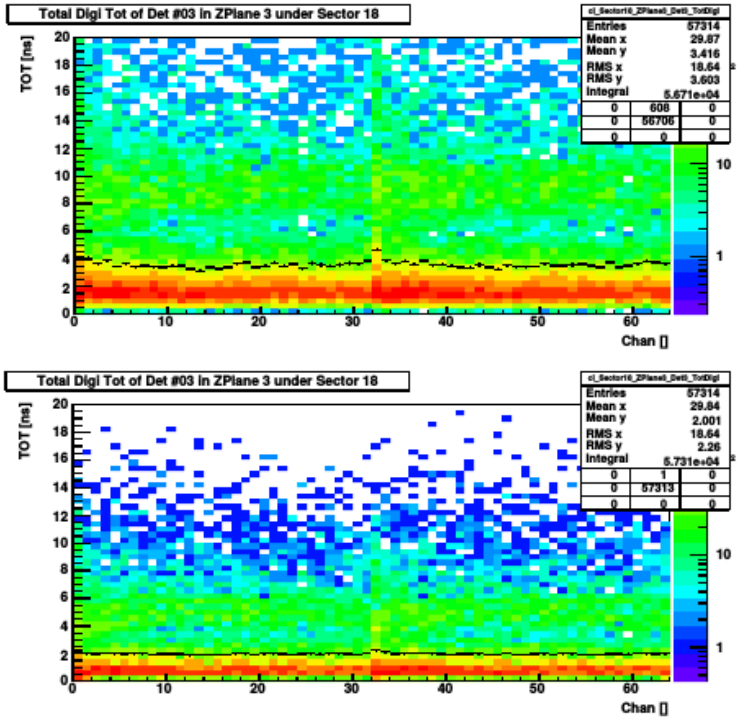






- Initial hit positions are significantly shifted in the local coordinate frame of the counter due to delays between sides.
- calculate mean position of hits on each strip
- calibrate digi times such that the mean y-position is shifted to 0. Apply half of the correction to each side to keep T0 offset constant.
- Procedure has to be iterative due to rebuilding of hits in between iterations and cross-correlation with walk correction
- Careful: Hotspots can skew the mean position on a strip. No problem in triggered data. Otherwise, fit box function instead of just taking mean.

Time over threshold calibration



- Amplification gain between pre-amp channels varies slightly => ToT spectra are slightly different
- Comparable ToTs are needed for averaged walk calibrations and ToT-weighting in hit reconstruction
- No cross-correlations to other calibrations. Should converge immediately.
- Iterations for some reason improve things a bit.

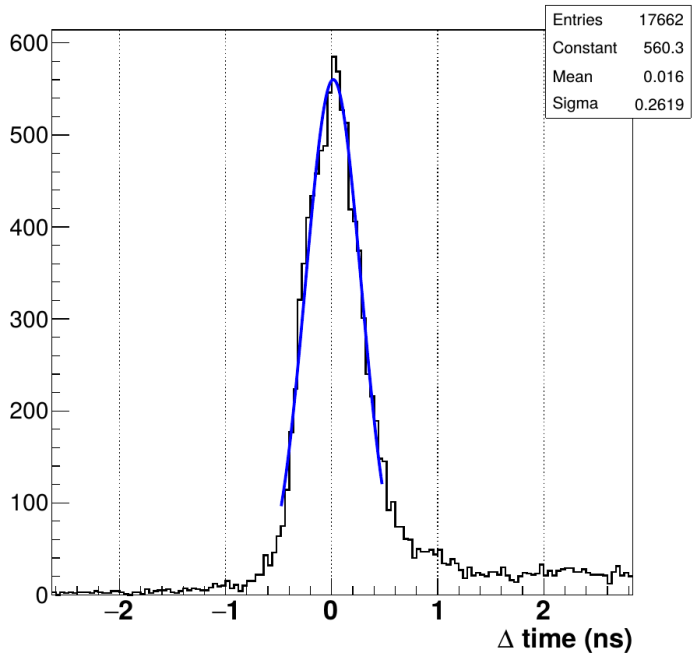
T0 determination

- Reset signal is routed from bToF/VPD to eToF Daq and recorded on eToF Clock
  => Can be subtracted directly from raw time.
  T0 offsets should be constant afterwards!

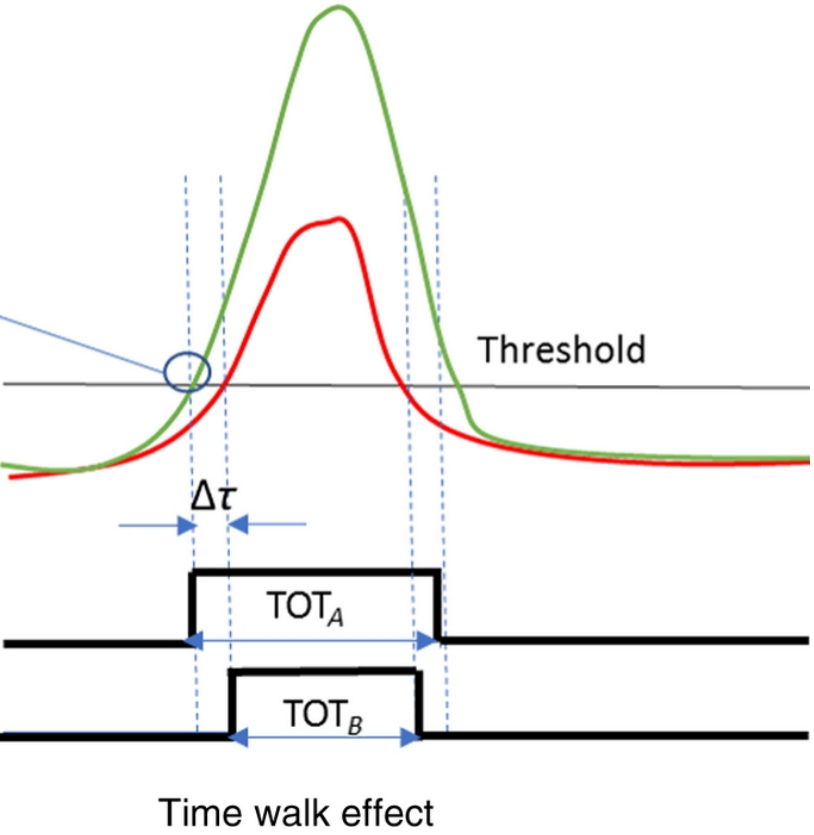
  Problem: Reset signal reached only one AFCK in 2018 runs

- eToF-clock is reduced to match 11bit bToF-Clock after hit-building to reduce losses due to overflow.
  => now times are comparable between eToF and bToF/VPD

- T0 offset is determined by the peak position in (measured – expected) time of flight histogram and subtracted from all digis



Walk correction Introduction

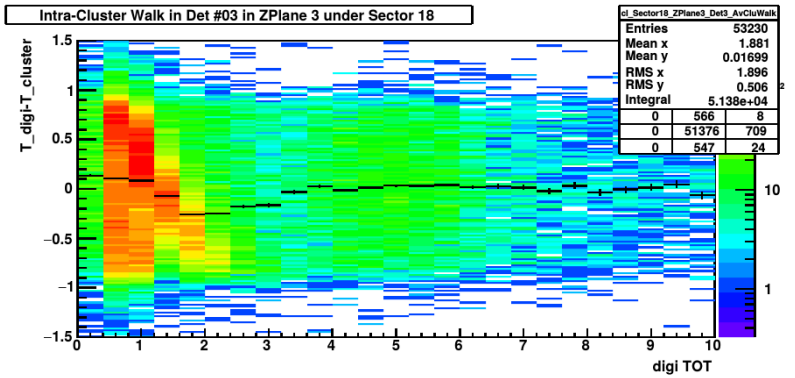


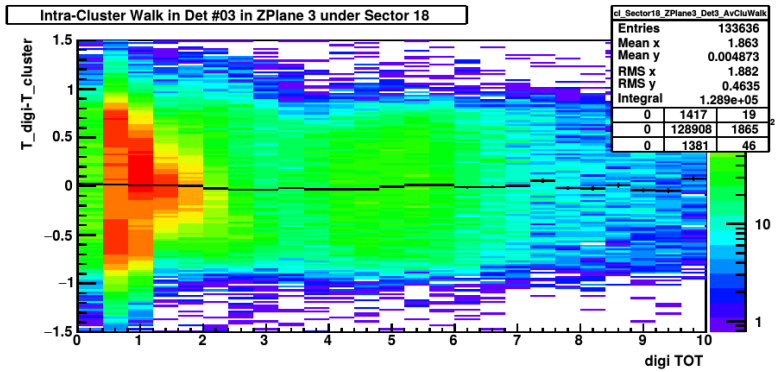
Time walk effect

taken from https://doi.org/10.1117/1.OE.56.3.031224

- Walk is a general correlation between signal detection time and signal amplitude. This effect is on single digi level.
- Tot can be used as a substitute for signal amplitude
- Time has to be taken with respect to some reference
  Usual choice: Time of hit - expected time of flight
- Alternate choice: Time of digi – time of hit
- Idea: all signals in a hit are produced at the same time. Signals are registered at different times due to propagation time and walk. Propagation time should average out with sufficient statistics

Walk correction Status





- Walk effect ~ 300ps can be seen before calibration. Gone afterwards.
- Advantages:
  - Only ETof information required
  - Works with any avalanche. No track match required. High statistics.
- Disadvantages:
  - Need to be very careful not to mess with position information => have to average over el. channels on both sides
  - Self-correlation between digi time and hit time => slow convergence
- Influence on y-position is apparently not completely averaged out => Problem for track matching
- Channel averaged walk calibration limits detector resolution O(100 ps). Good enough to spot problems with eToF, need to get better for data analysis!

Walk correction
Further steps

- Need to go to a calibration mode with respect to expected time of flight.
- Has to be done after track matching. Almost done.
- Workload of changing this mode: Change ~5 lines of code

BUT:

- High statistics in every channel and ToT bin needed. ~ 10^6 Events per iteration & O(10) iterations!
- Currently: 2-3s / Event! (maybe improved now ?)
  => Need massive speed up in the runtime of the EToF change or/and parallelization!

Optimization: Memcheck: no major memory leaks
Event-by-Event print-outs disabled
=> I'm out of ideas!

Parallelization: Work in Progress!

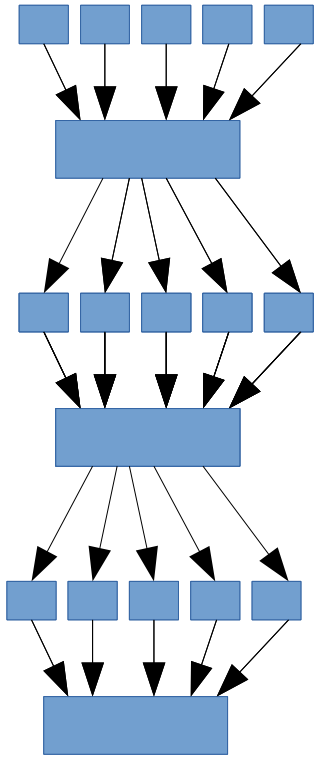
µDST integration: Work in Progress!

Strategy:

Run iteration in parallel jobs

Merge into high statistics calib file for next iteration

Apply calib file in each parallel process and run next iteration



Outlook: What is still needed for next year?

1. Improved walk calibration
   => see last slide

2. StarDB integration of calibration files
   => DB content to be finalized in this meeting

3. Automatize procedure to create calibration files for next year

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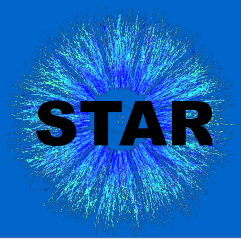
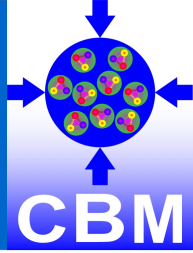
Experiences with the eToF calibration will be applied in CBM!





THANK YOU FOR YOUR ATTENTION!

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