Time alignment and calibration of the SPD with first collisions

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Outline

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- **Time alignment**
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  - Plans
- **Calibration**
  - Requirements
  - Status
  - Plans

When the SPD is needed?

- At the very beginning, only interaction trigger at L0

LHC scenario	Low	Low	Low	Low	Mid	High	High	High
Bunches: LHCb/Total	1/ 2	19/ 43	19/ 43	68/ 156	68/ 156	468/ 468	468/ 468	468/ 468
$\nu(\sigma^{\mathrm{Tot}}$ =93.90 mb)	0.20	0.20	1.00	0.20	1.00	0.50	1.00	1.34
Rates (kHz)								
bb-xings	11.2	213.7	213.7	764.7	764.7	5263.0	5263.0	5263.0
eb,be-xings	11.2	269.9	269.9	989.6	989.6	0.0	0.0	0.0
ee-xings	40057.5	39596.4	39596.4	38325.7	38325.7	34817.0	34817.0	34817.0
xings MC-Mbias	2.0	38.7	135.1	138.6	483.4	2070.8	3326.9	3884.9
Maximum L (10^{31})	0.002	0.046	0.228	0.163	0.814	2.802	5.605	7.511
Visible xings (kHz)	1.2	22.1	89.9	79.2	321.9	1258.0	2215.3	2732.0
% single pp-vis	94.6	94.6	75.2	94.6	75.2	87.0	75.2	67.8
μ/vis (σ^{μ} =51.30 mb)	1.06	1.06	1.30	1.06	1.30	1.14	1.30	1.41
L0-rate (kHz)								
L0-μ (0.8 GeV)	0.028	0.539	2.688	1.930	9.619	33.168	66.205	88.583
L0-hadron (2.5 GeV)	0.149	2.828	13.912	10.120	49.789	173.145	342.668	455.579
L0-e (1.5 GeV)	0.063	1.197	5.943	4.283	21.269	73.514	146.382	195.508
L0-γ (1.5 GeV)	0.041	0.787	3.917	2.816	14.018	48.379	96.479	129.003

for calibration of L0
e&γ triggers

- Hans Dijkstra@ PPG http://indico.cern.ch/subContributionDisplay.py?subContId=0&contribId=6&confId=33306

Occupancies

- Vary a lot from cell to cell
- **The cell with minimum occupancy defines the number of events needed for any procedure**

	E (TeV)	B	Sample	Occ. Min. (%)	Occ. Max. (%)
2010	0.45	Off	>0 interact.	0.12	4
	5	Off	>0 interact.	0.3	10
	5	On	>0 interact.	0.14	7
No-minal	7	On	40 MHz	0.09	2.5
	7	On	>0 interact. (14 MHz)	0.24	6.8
	7	On	L0 (1 MHz)	0.3	17

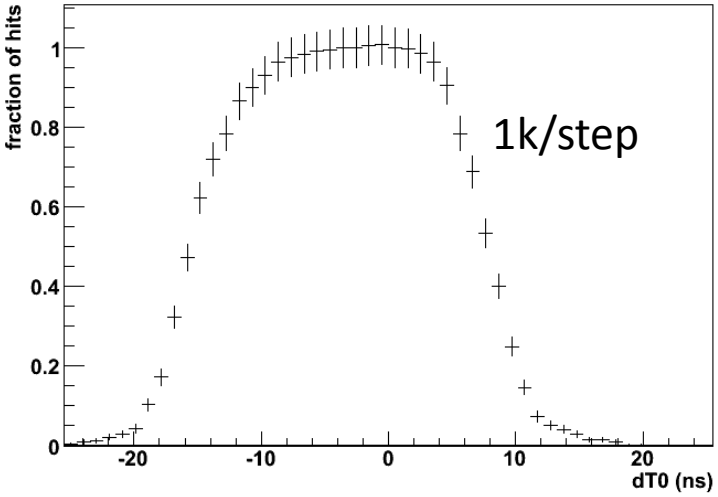
x 40

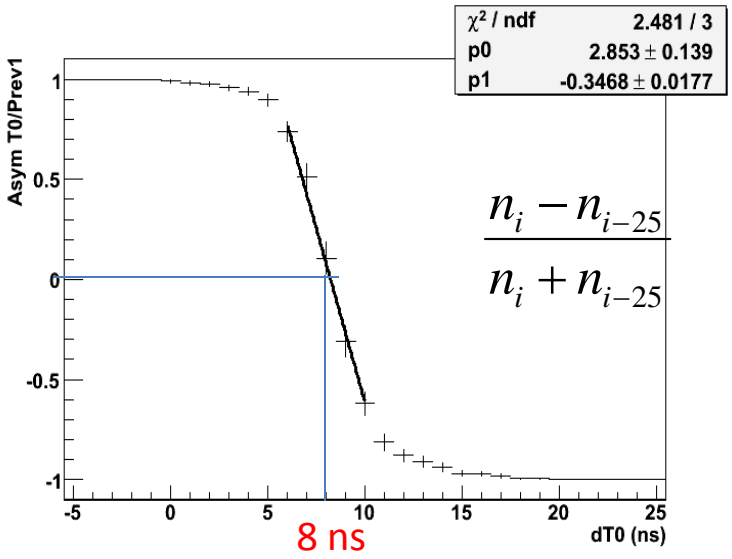
Time alignment: **objective**

- **Objective: time-align the detector to the intrinsic precision of the asymmetry method (1-2 ns)**
  - Time-align. not an issue in 2010, > 50 ns bunch spacing
  - **Physics:** only requirement is no signal in previous or next
  - **But** we want to adjust it finely first, because:
    - Avoids having a 2D time alignment – calibration problem later
    - Phases does not change with time
      - Changes in some hardware may affect it: cables, CB 1-2 ns
    - It requires small amounts of data
- Need to time-align **100 VFE boards (groups of 64 channels)**

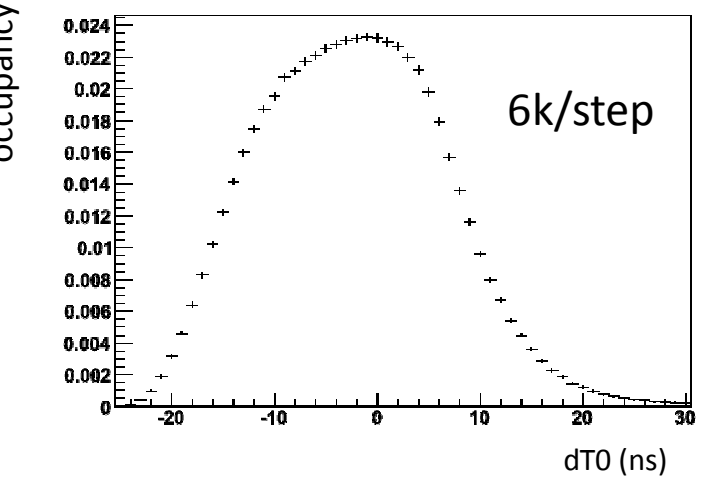
SPD time alignment – **asymmetry method**

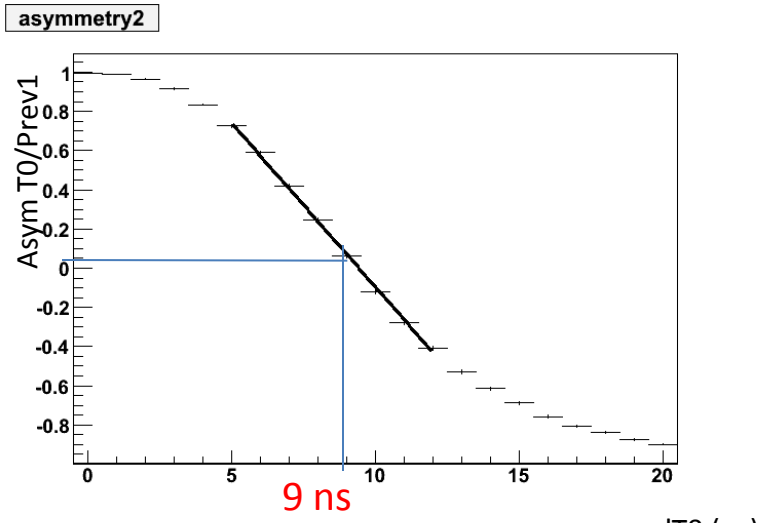
Threshold at 0.5 MIP





Threshold at 0.7 MIP

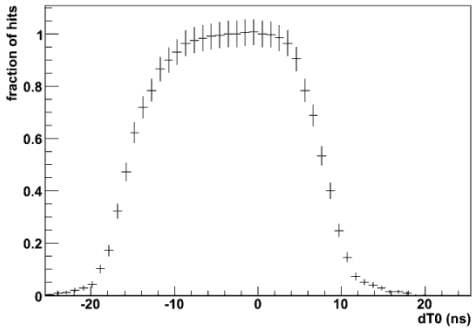




- **We need +-1 TAE** (this remove need for step-to-step normalization)
- We will see a convolution of curves for 64 channels in a VFE
- Working in automatic fitting for 100 VFEs...

Time alignment: procedure **without TAE?**

- It could be possible to time-align SPD without TAE: scan on phases, fit to MC prediction
- Problem: need to normalize each step
  - Different duration of runs
  - Changes of lumi
  - Beam backgrounds

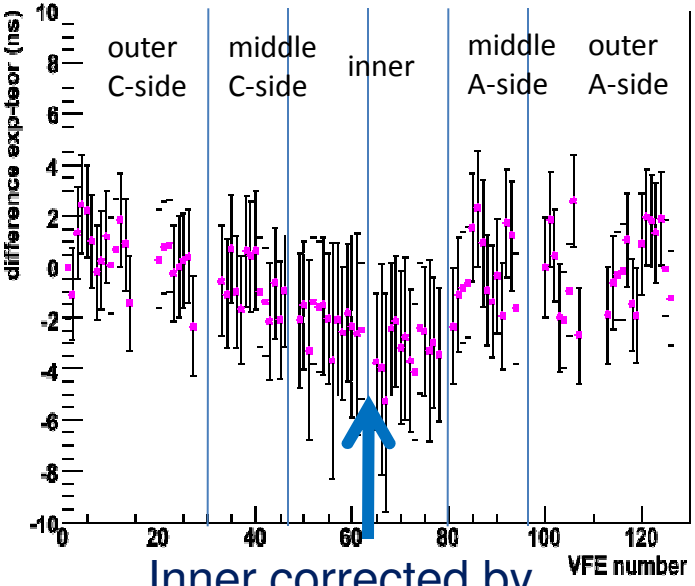


- Solution: split detector in two halves
  - Split into even/odd VFE/crates, not A and C sides, to be safer under local changes in conditions
- **But: much easier and faster with TAE**

Time alignment: **status**

- **Cosmics:** synchr. SPD-ECAL to ~ 3 ns.
  - From TED, cell-to-cell ECAL ~ 2 ns

    according to http://indico.cern.ch/conferenceDisplay.py?confId=62291
  - Cosmics in an SPD VFE come from large area of ECAL ⇒ VFEs synchronized to the average of wide regions in ECAL
- **Can we improve by phase scan on next TED run?** (Keeping half SPD stable for trigger)
  - **Problems:**
    - Non uniform intensity: difficult to interpret
    - Non-nominal HV
  - **BUT:** this will allow rehearsing many of the procedures



Inner corrected by this effect in latest recipe.

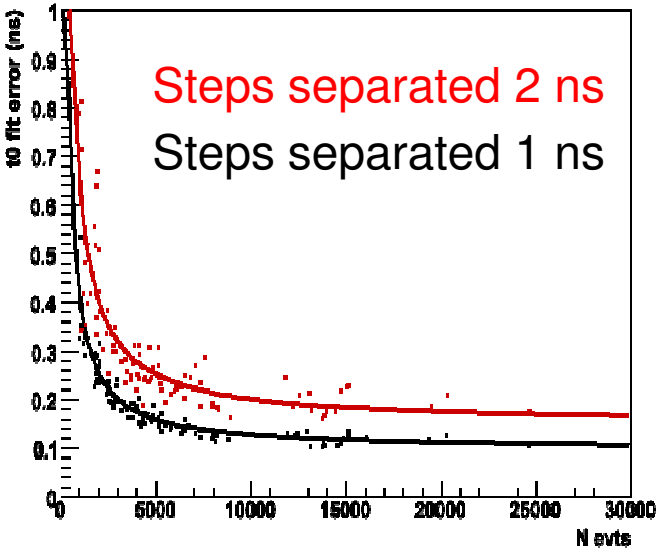
Time alignment: **plan**

1) **First rough scan to find global SPD-LHC clock synchronization**
   - Set current cosmic delays + cosθ correction
   - Expect that it will be done for the whole CALO/LHCb?
   - Precision of ~3ns?

2) **Then perform the real scan around this point to time align VFE by VFE**

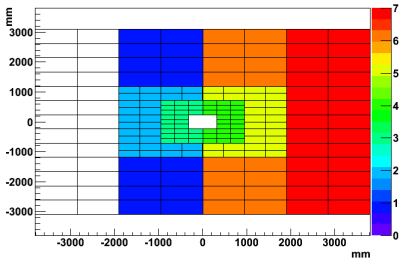
Time alignment: **data required**

- With TAE:
  - 10 steps of >1K events separated by 2 ns enough to get target precision
  - A few seconds per step at 600Hz
- Without TAE
  - Increase in the number of events/step
  - x2 for control and scan sides



Assumes min occ = 0.24%

Time alig.: **implementation options**



1) With the CROC (by crate):
   - ✓Easy
   - ✗ Need to correlate with PS
     - ✗ Need to convert observed delay on CROCs into VFE phases
     - ✗ Very bad granularity to separate reference and scan halves, only a problem if not using TAE

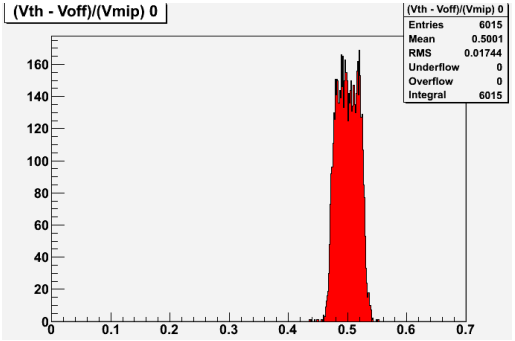
2) With the internal VFE phase:
   - ✓Independent from PS
     - ✓High granularity for normalization (only relevant without TAE)
   - ✗ Need a procedure to automatically
     - Configure VFE **and FE**
     - Invert the MIERDA line
   - ✗ Configuration of a new step takes time (10'?)

Time alignment: **to do**

- **Ned to find technical solutions and rehearse**:
  - **The scanning procedure itself (including at TED)**
  - **Obtaining the phases**
    - **Fitting procedure**
  - **(If the scan is done with the CROC) Converting the results into phases to be setup in the VFE**
    - **And in some cases inversions of MIERDA signal**

Calibration: **objective**

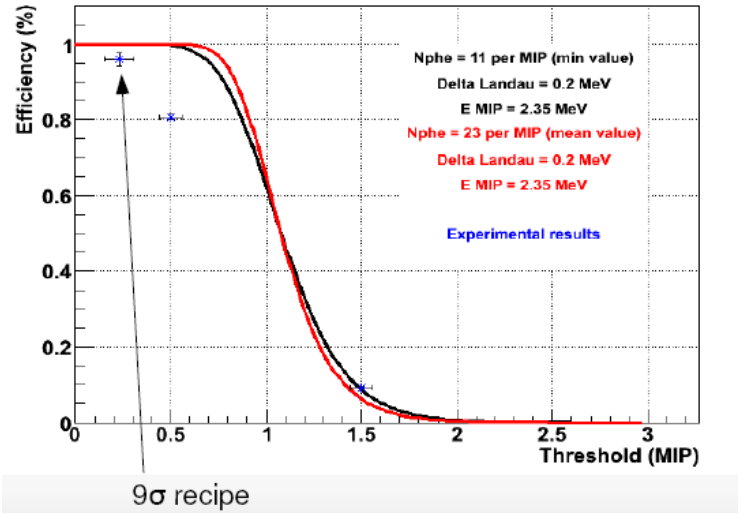
- **Objective:** resolution on the MIP position < resolution threshold setting in electronics = 5% MIP
  Say 2% of the MIP (or 4% of the threshold).

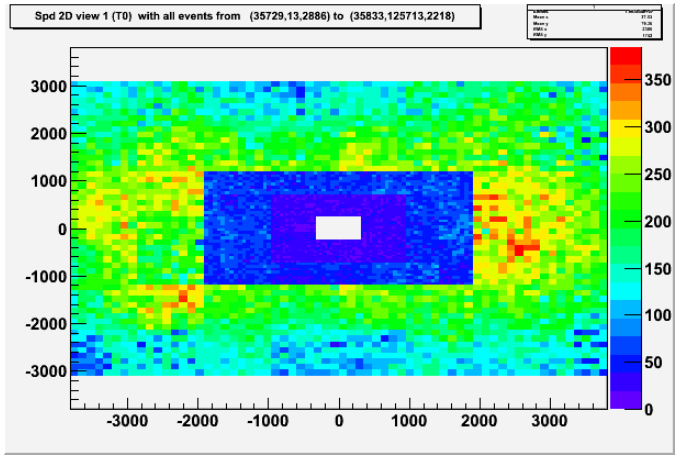


  - BTW: need a strategy: what do we need to equalize per SPD cell? Electron efficiency?
- Need to calibrate **6016 channels**

Calibration: **status**

- Gain computed theoretically, then checked with cosmics by:
  - Setting the thresholds at 0.25, 0.5, 1.5 MIPs, taking ~ 1 M events at each point
  - Comparing efficiency from expectation of a Landau x Poisson
- Lots of filtering needed (arrival time, angle) ⇒ statistics only enough to perform comparison for whole SPD
- But things look uniform in 2D plot ⇒ **calibration should be ~ reasonable for all VFEs**





(Calibration on nominal conditions)

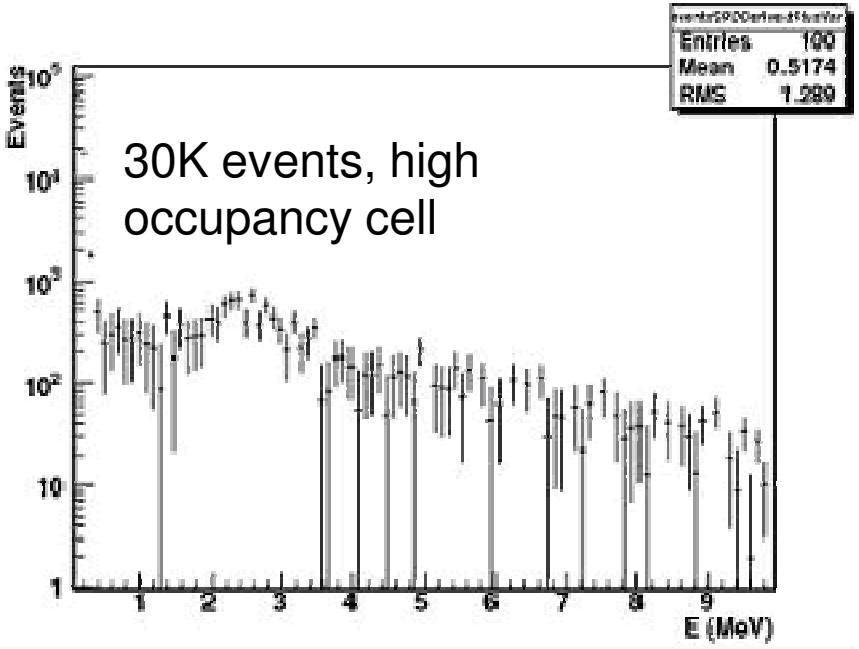
- You may remember the SPD can be calibrated within a few minutes of dedicated calibration run
- But: that is for
  - Nominal luminosity
  - Running a dedicated task at EFF at 1 MHz
- So we are not talking about that today

Calibration: **plan**

- Procedure:
  - **A) Without tracks:**
    - Apply different thresholds at different fills/runs
    - Count occupancy in each step, normalized to reference half of SPD
    - Look for the MIP peak
  - **B) With tracks:**
    - Perform an efficiency vs threshold scan similar to that done with cosmics
    - Compare it with theoretical expectation
    - Recompute MIP

A) Calibration **without tracks**

- MIP peak is quite humble above background
- **Large amounts of data required**
  - **Long time**
  - **Hard to analyse**



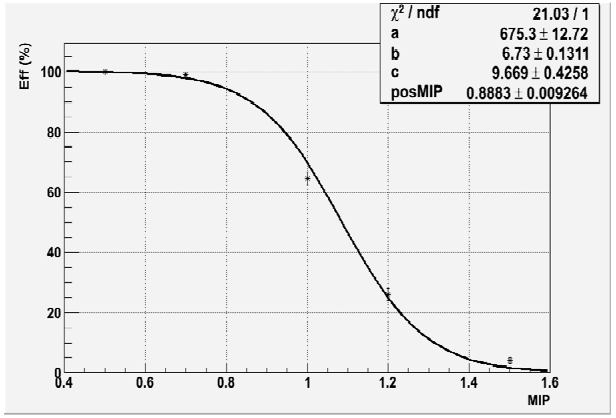
Steps	Evts / subchan for a 2% MIP calib in lowest occupancy cell			Time/step @ 600Hz
	Outer	Middle	Inner	
14	33M	22M	12M	38h
8	37M	25M	14M	43h

Assumes min occ = 0.24%

Remember:
need to do it twice
factor 40 less for some cells

B) Calibration **with tracks**

- **Preliminary: 250 tracks** pointing to a cell at each step, allow σ(MIP) ~ 2% (5 steps)
- **SPD "efficiency"** is:
  - 98% from theoretical computation
  - 95% using cleaned long tracks
  - 82% using cleaned T tracks (purity? bad extrapolation?)
    - Using M1: no gain in purity, but maybe in quality of extrapolation?



lowest occup. Cell

Assumes min occ = 0.24%

Type of track	# per min bias	# after cleaning	Evts needed / subchannel	Time/step @ 600 Hz
Long	12	0.2	10 M	4.7 h
T	22	8	0.2 M	6 min *

*** For T tracks need to understand effect of impurity on fit**

Calibration: **technicalities**

- **Avoid changing HV**, only thresholds when possible
- W/o tracks need half SPD to normalize
- The change of thresholds in all the VFEs takes 30 seconds
- Probably will not know if we will have tracks or not beforehand:
  - Change thresholds often rather than take many million events at one threshold
  - If no tracks for a while, maybe worth calibrating VFE by VFE (common components of gain: HV, PMT).

Calibration: **to do**

- **Ned to find technical solutions and rehearse:**
  - **Best choice of number of steps and events per step for scan (w/o tracks, w tracks)**
  - **Transform comparison of observed and theoretical curves into a measurement of the gain**
  - **Transform measurement of the gain into a new threshold to be set**

Two last steps

- 1) **Recheck time-alignment** at the end
  - **A single run with TAE is enough**

- 2) **The SPD electronics subtracts a tuneable fraction of signal in previous BX** to correct from spill-over, now set at 20%
  - Check if there is too much signal in next in some cell, **a run with TAE is required**
  - If so, change the subtraction factor

Conclusions

- **At LHC start-up, SPD not needed at trigger for a while**
  - **Take this opportunity to time-align it for good**
    - **Need TAE**
  - **Provide a ~2% calibration based on early data**
    - **Much much easier if we can use tracks**
    - If needed can be improved in dedicated runs at higher luminosity

- **Not so long time left for designing and prototyping all procedures...**