SBS software and tracking update

Eric Fuchey
University of Connecticut

Hall A collaboration meeting
Jefferson Lab, January 24-25, 2018

Overview

SBS Software Project:
- **Overview;**
- **Milestones.**

Tracking progress:
- **Improvements and adjustements;**
- **Summary and next steps.**

SBS Software progress:
- **Digitization and analysis;**
- **HCal digitization;**
- **Summary and next steps.**

Summary

SBS Software Project:
SBS project overview
(see Mark's slides for more details)

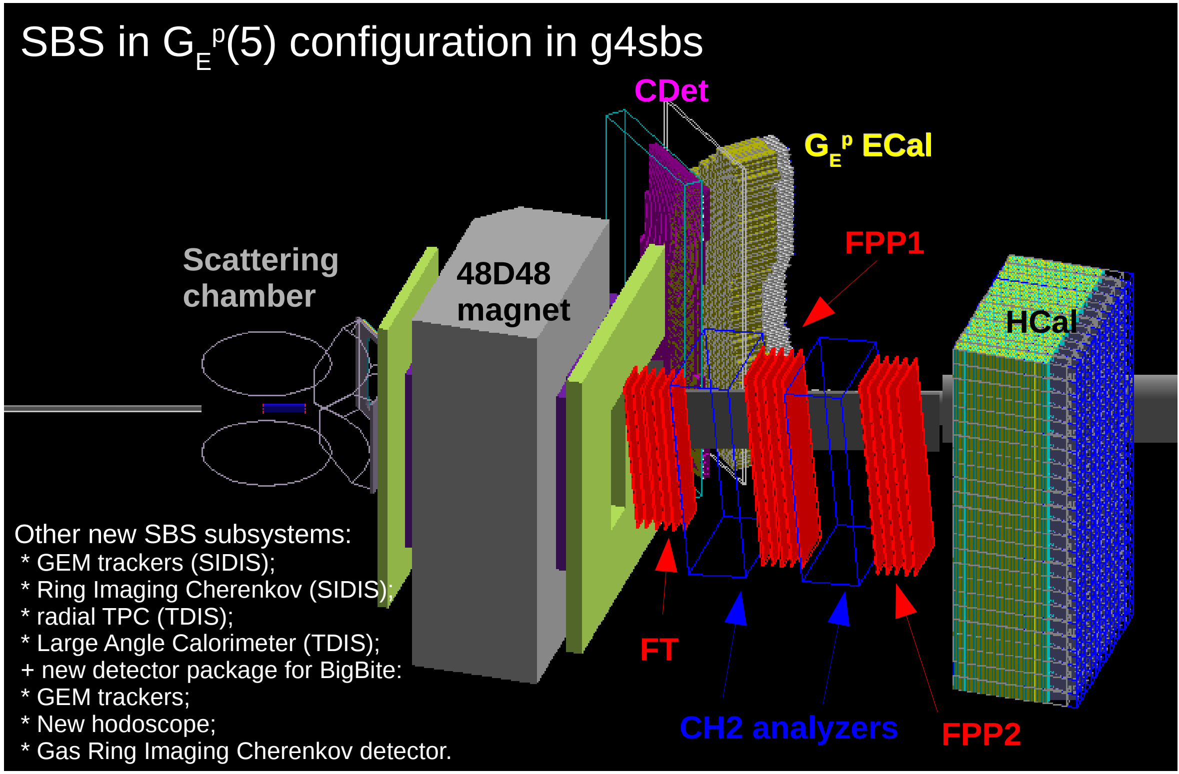
Super BigBite spectrometer:

one of the *major new projects* for Hall A @ 12 GeV (with Moller and SoLID):
Medium solid angle spectrometer with a *modular* detector package behind a dipole magnet.
=> Many new subsystems with large nb of channels / events sizes (wrt Hall A standards)
*Earliest run start: **2020**, **189** (**+27** cond.) running days approved;*
=> major occupation for Hall A collaboration for *many years*.

Physics programs:

- Form factors at *high* Q^2:
  * G_M^n (LD_2), G_E^n (pol. ^{3}He);
  * G_E^p (LH_2, recoil pol);
  * G_E^n (LD_2, recoil pol);
    (=> See John's slides);
- Semi-Inclusive DIS (^{3}He);
- Tagged π, K DIS;

=> Major physics impact;
(Good opportunity for grad students, young postdocs to join)
=> challenging measurements: high luminosities, high detectors and DAQ rates;

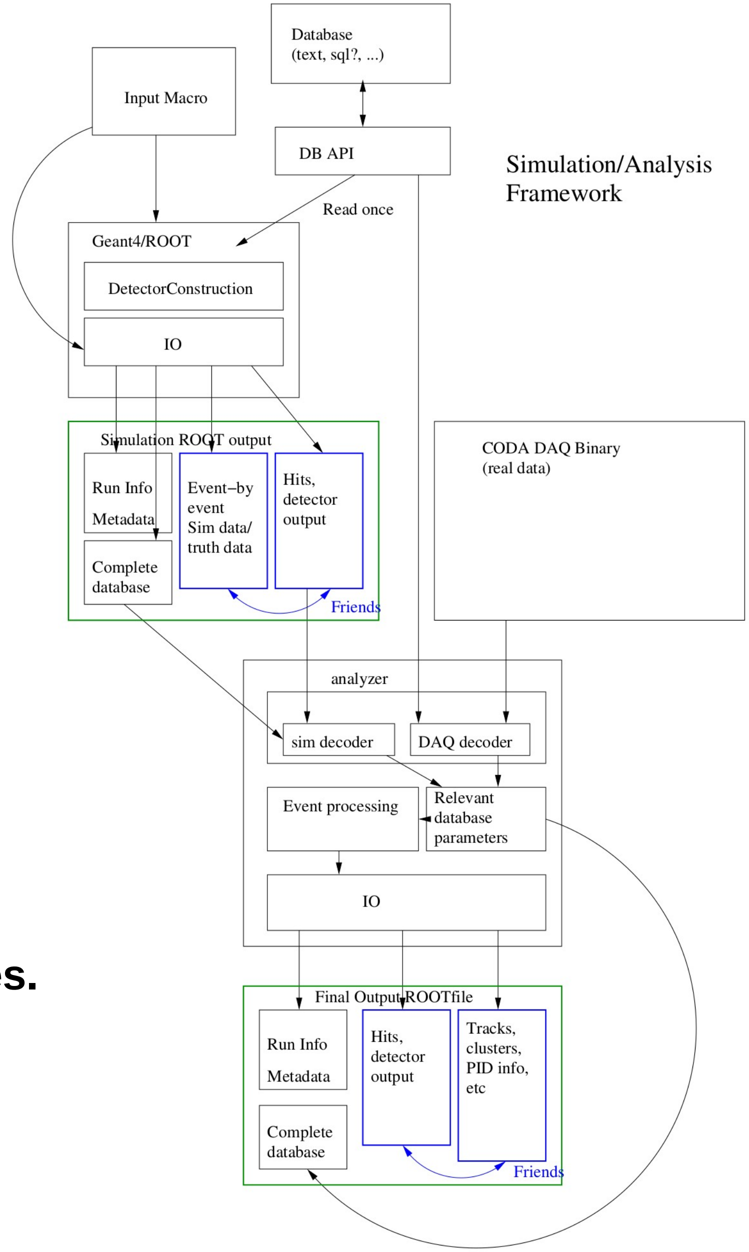


SBS Software Project:
SBS Software project overview

*** Major goal: "End-to-end" simulation:**
production of pseudodata + simulation of data sizes;
* Both simulation and analysis framework need to be:
→ *modular* (ease configuration changes);
→ *accessible* (ease handling for new people);
→ *flexible* (ease inclusion of new configurations);
* Also need:
- Well defined IO formats and standards
- Flexible database to accomodate both MC and data (SQL ?);

* Requires significant coordination between working subgroups
→ 1 dedicated software meeting every 2 weeks
(in addition to SBS weekly meeting).
\+ About to migrate to e.g. Redmine for project management

**** Well defined responsibilities and milestones*** (next slide)



Strong requirement:
Online and offline analysis both need to be ready and tested, and pseudo-data sets have to be analyzed before data taking
(likely spring/fall **2020**).
=> critical given high luminosities / high detectors and DAQ rates.

G4SBS simulation is up and running, and has already produced useful and compelling results (e.g. G_M^n ERR last summer *).
We have since then set our focus on its interface w/ analysis.

(* see my slides from Summer '17
Hall A/C collaboration Meeting)

SBS Software Project:
SBS Software milestones

Rebaselined milestones, taken into account accelerator planning change, actual progress on software and manpower:

- Nov 2016: Software review
- Jan 2017: Start digitized simulation output (first focus on GEMs)
- Apr 2017: Decoder for all DAQ modules written
- Jul 2017: Each detector system in analyzer, experiment configurations, basic reconstruction algorithms
  => can analyze channel-level raw data at this point
- **Jun-Jul 2018**: Simulation interfaced to analysis; Have detector event displays, calibration scripts
- **Jul 2018**: Start simulated analysis for detector reconstruction
- **Jan 2019**: Begin simulated experimental analysis for core Form Factors (FF) experiments
- **Jun 2019**: Ready for beam for FF experiments, start simulated expetimental analysis for SIDIS and TDIS

- Spring 2020: likely earliest start of neutron experiments
- Spring 2021: likely earliest start for Gep

SBS Software/Simulation Project:
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Summary

Tracking progress

Reminder about GEM trackers :

Gas ionizing detectors

GEM readout by 400 µm strips

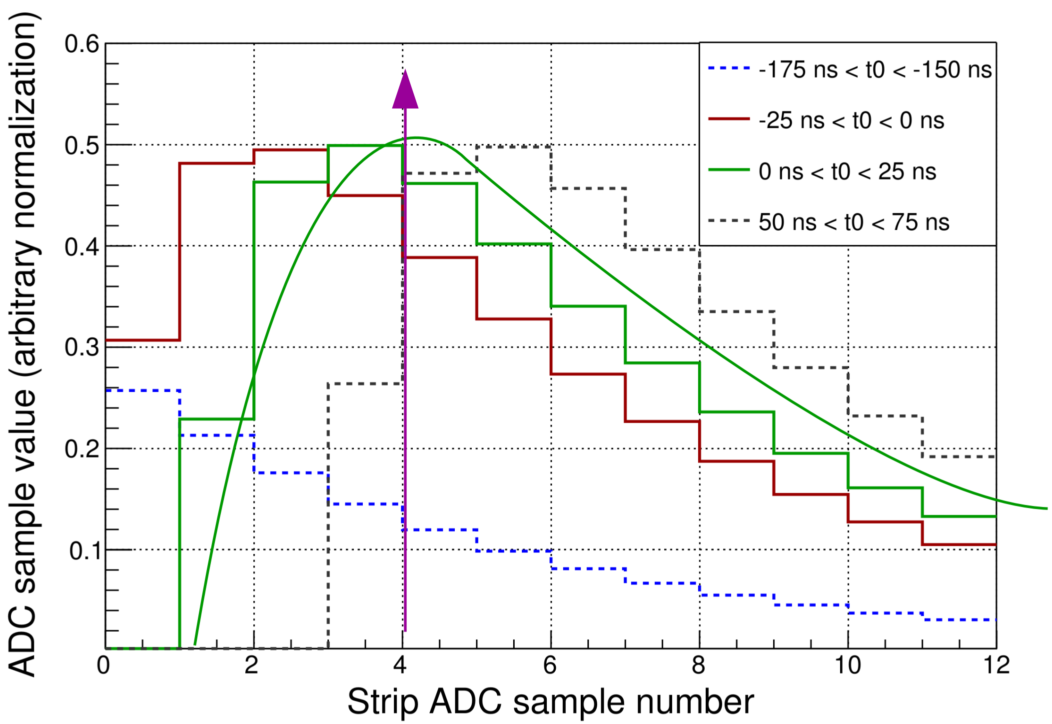
=> 40.96 x 51.20 cm2 GEMs = 1024 x 1280 strips;

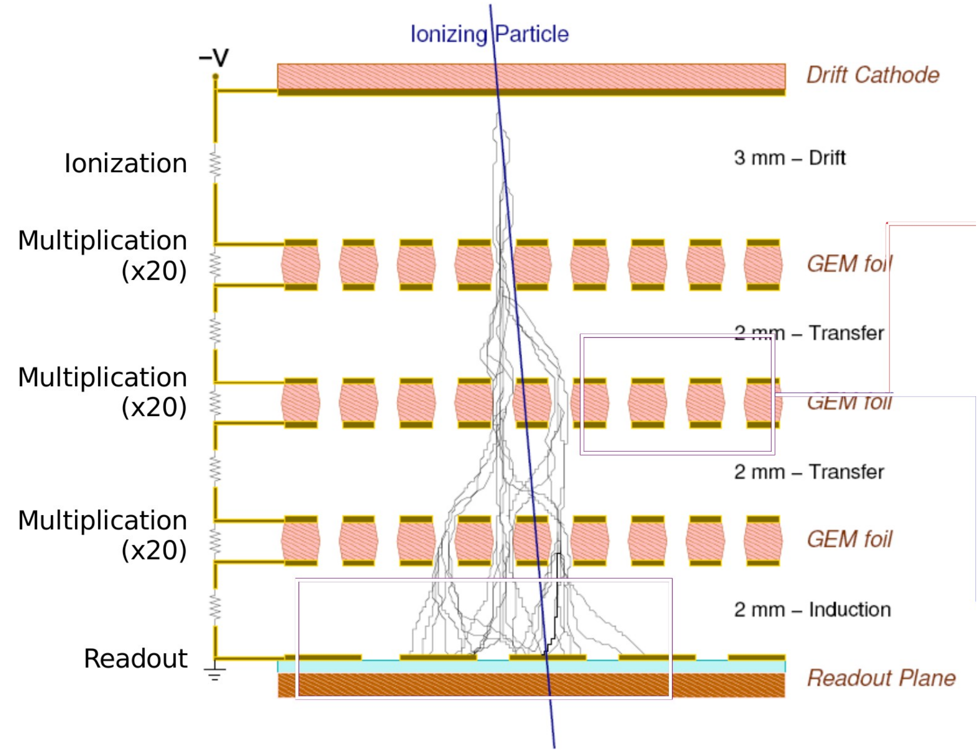
The strips will be recorded by APV25 (128 strips/chip)

6 ADC samples of 25ns each are recorded for each strip

→ pulse shape;

Of course, 1 hit spreads on many strips => clustering





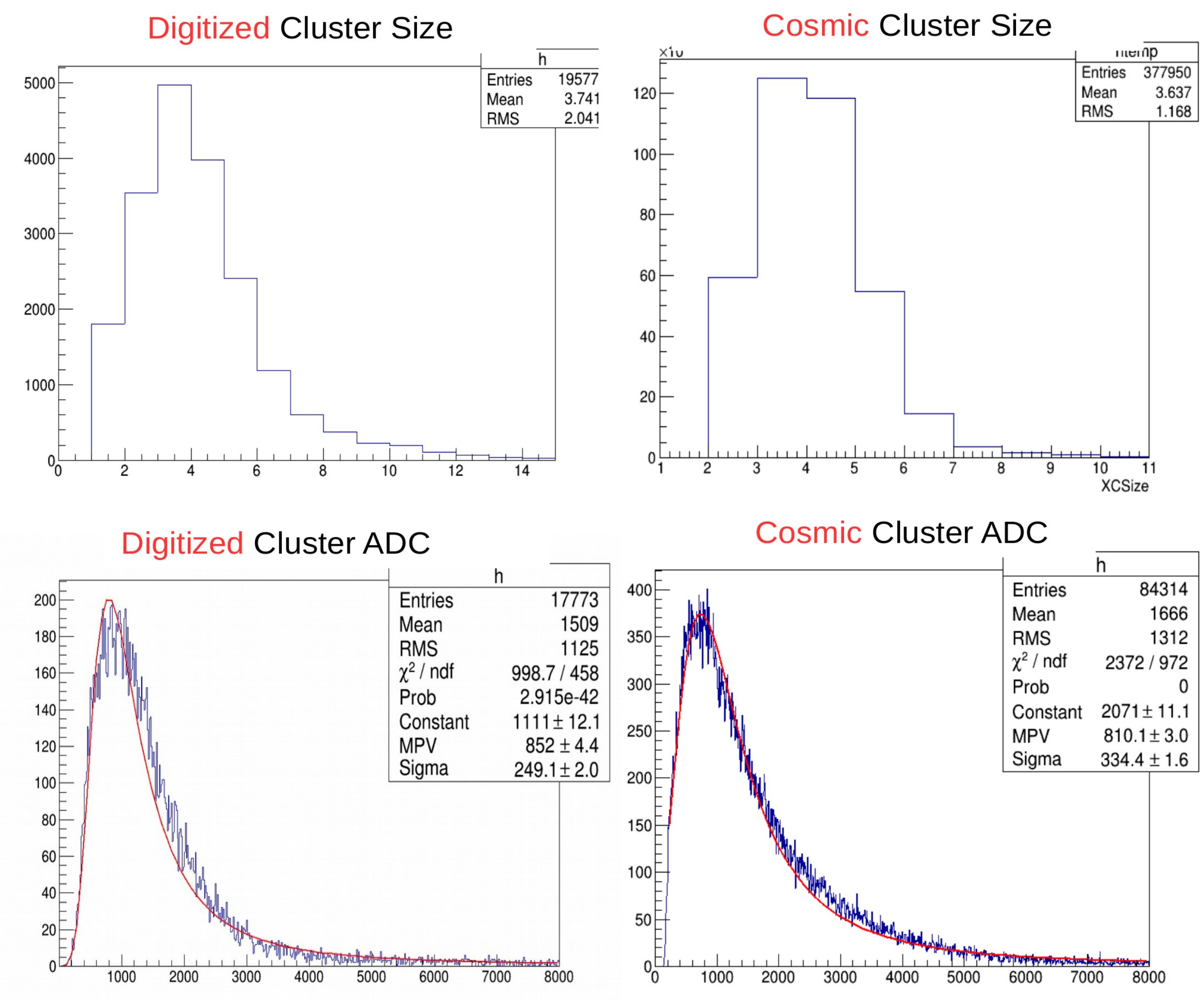
Tracking progress
Improvements and adjustments

GEM digitized strip by strip: use 6 ADC samples per strip;

Strip ADC calculation changed from deconvolution of first 3 samples to sum over the 6 samples;

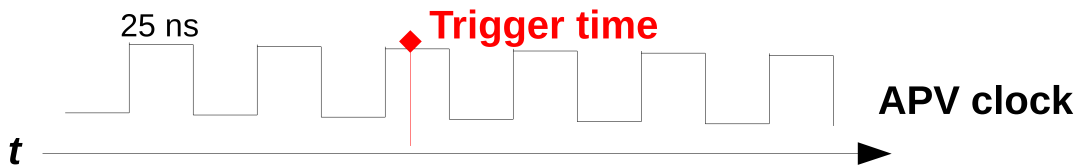
Tuned digitization algorithm and database to match ADC spectrum and hit size with cosmic data;

(Plot credit: **Danning Di**, SBS weekly, 2017/11/15)

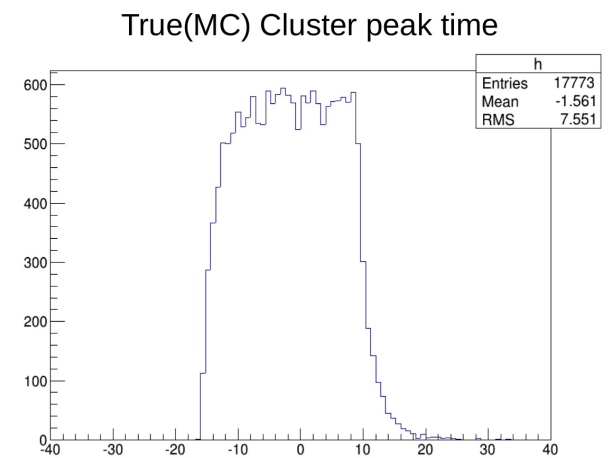


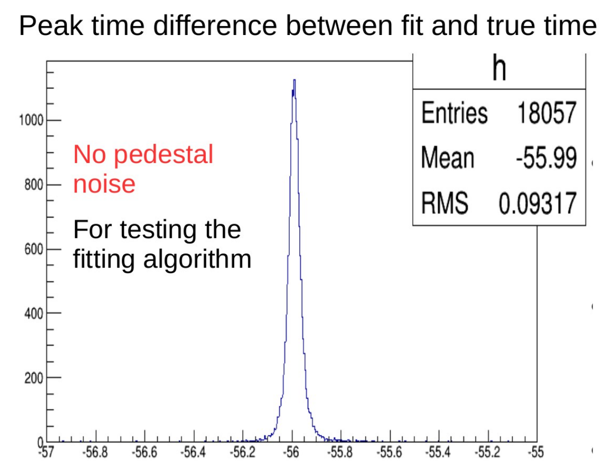
Tracking progress
Improvements and adjustments

Added a 25 ns APV-trigger "jitter" to the strips timing, to translate that APV chip and trigger time are not in sync;



Impletemented pulse shape fitting to determine the timing for each strip;





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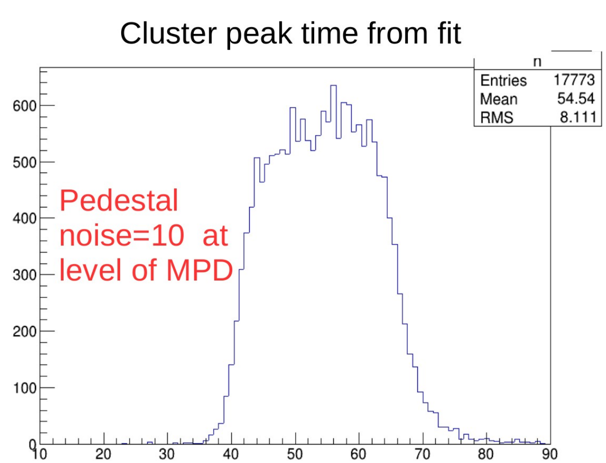
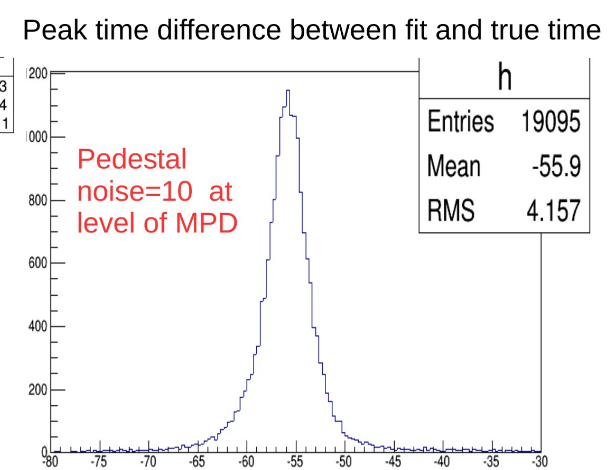




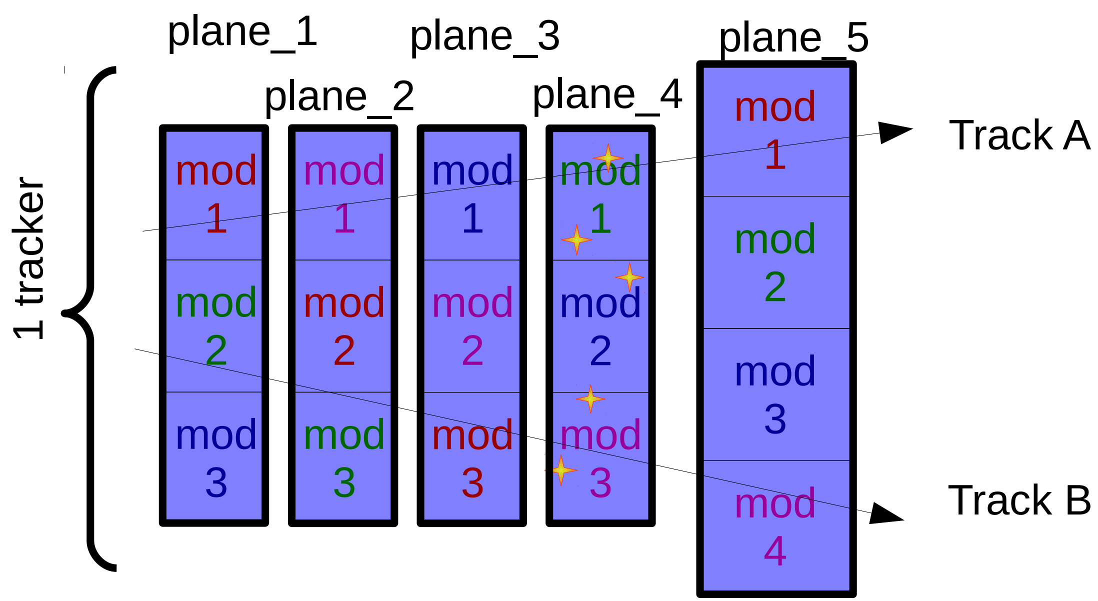
Tracking progress
Summary and next steps

Last summer:

The full simulation → digitization → analyis → analyzed data (clusters, tracks) was functional

What has been done since then:

- Added subdivision of “GEMPlane” (called "module"), to *allow for transverse segmentation* of one plane within one tracker, in both digitization and Treesearch library (did not exist before)



- Tune digitization database and digitization code to have simulated digitized hits similar to cosmic data ;

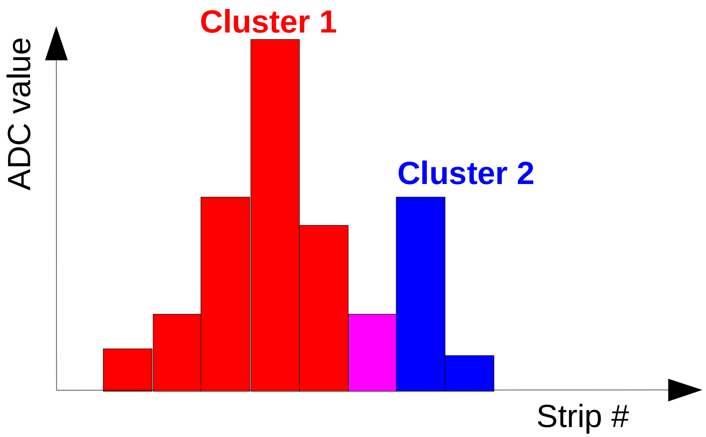
- Implement pulse fitting on sampled ADC to extract timing, and integrate ADC (instead of deconvoluting it), in compliance with what will be done for the experiment;

Tracking progress
Summary and next steps

TO-DO:

- Implement common mode (pedestal shift per APV) in digitization and common mode subtraction in Treesearch library; => This is necessary before we run digitization with background data.

- Improve cluster separation method: Add timing information to currently existing peak-valley-peak method ;
  => This is very important to analyze data with huge backgrounds.



- Cross talk removal in Treesearch library ;

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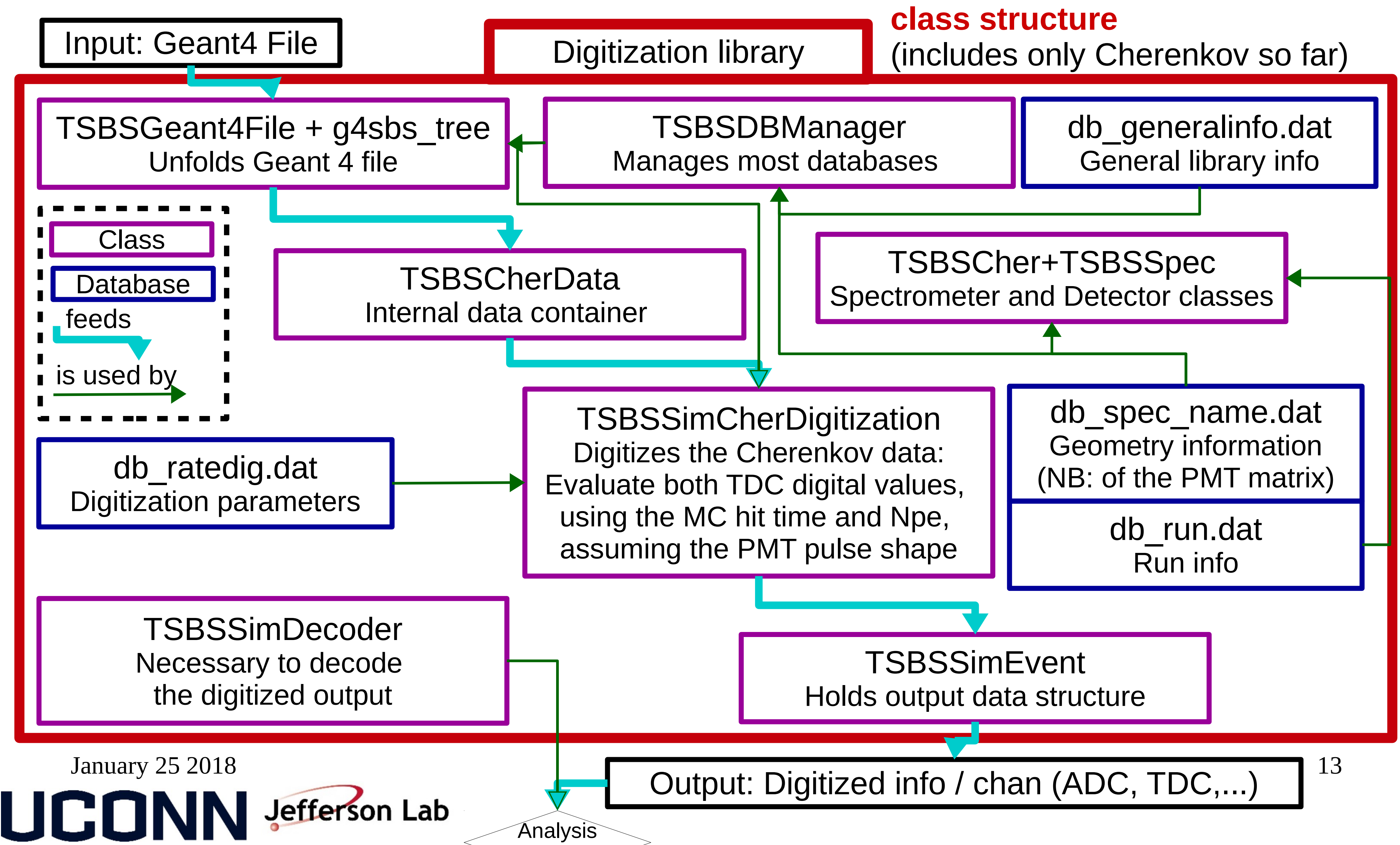
SBS Software progress:
Digitization (in progress)

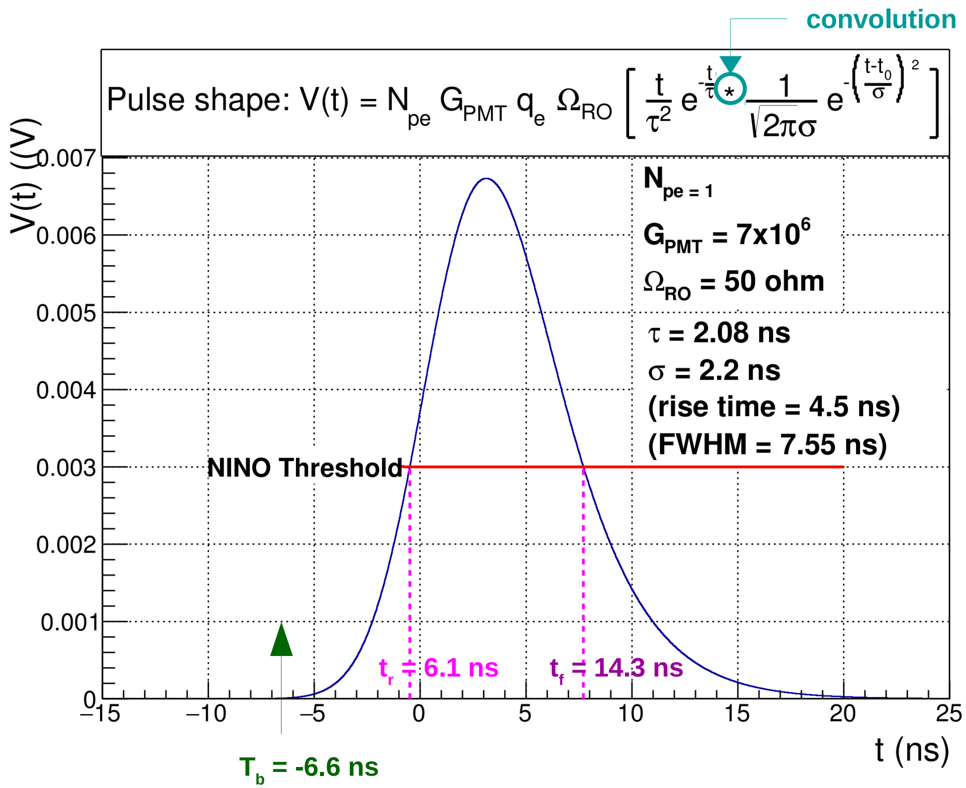
Purpose: Evaluate electronic response (ADC, TDC...) from G4SBS simulation output

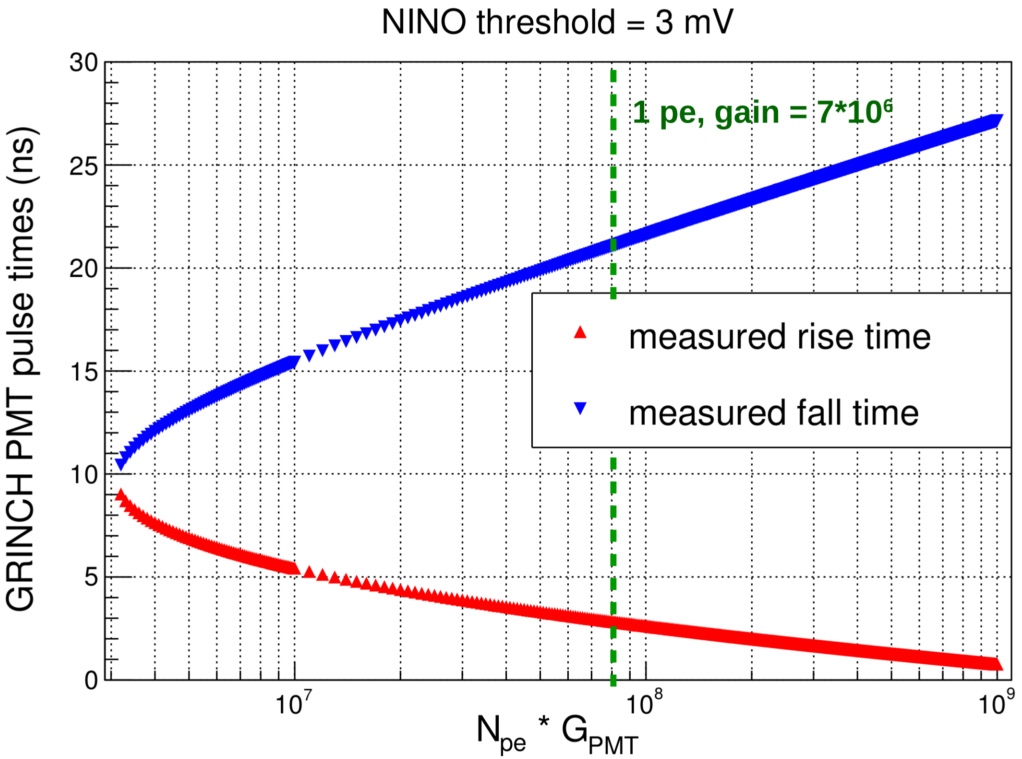
First step to interface simulation with analysis



Example of the GRINCH: Cherenkov detector readout by 510 PMTs (see Todd's talk)
GRINCH PMTs will be readout by NINO cards => record TDC values for PMT rise time and fall time (pulse amp. goes resp. over/under NINO thr ; estimation of pulse amp. with Time-over threshold).

To evaluate the times t_r and t_f at which the pulse will go over/under the threshold, we have modeled a normalized pulse shape (left);
We calculate tables for a given threshold, over a wide span of amplitudes (right)



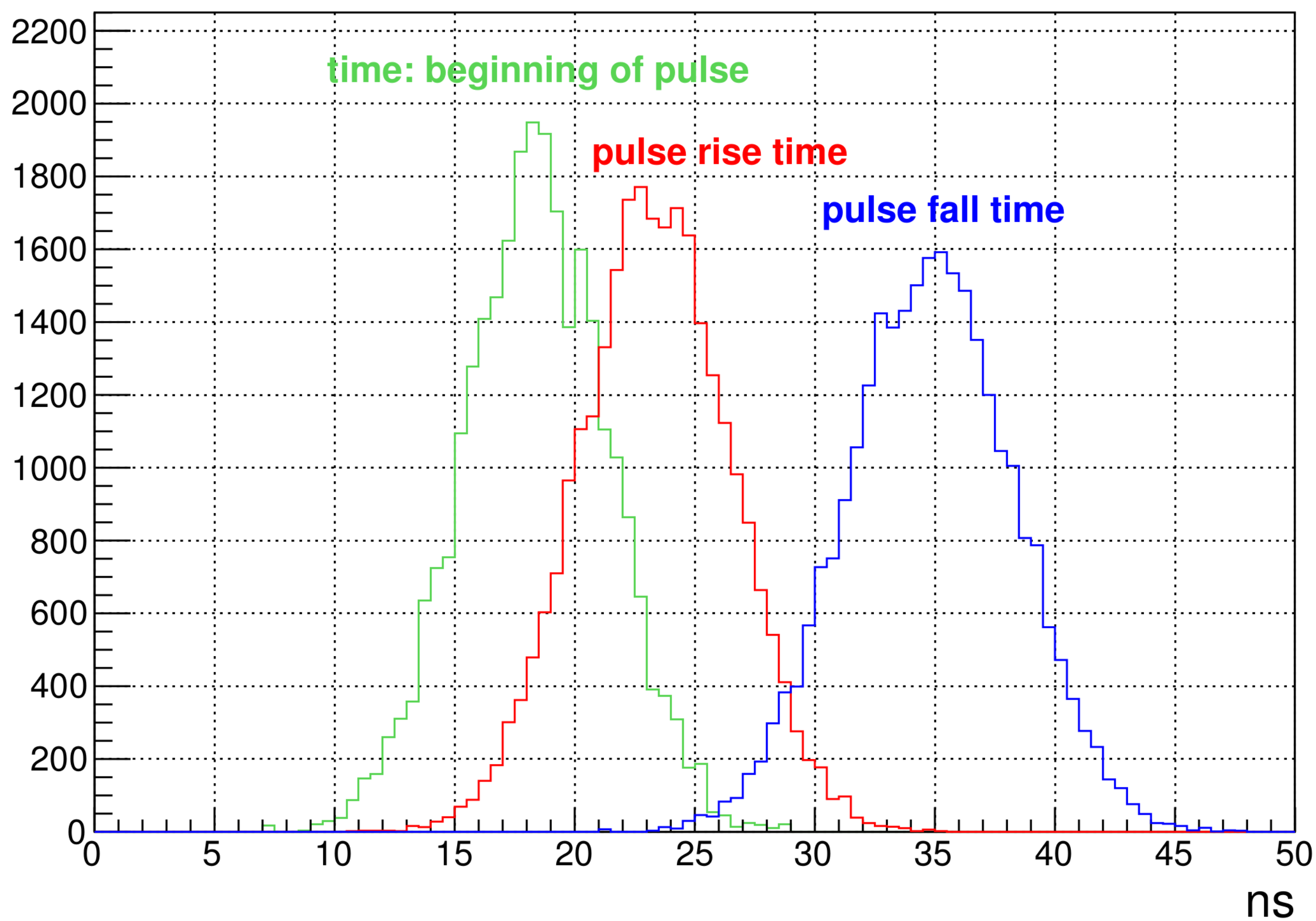


* Values plugged in the digitization library.
* Exponential extrapolation between 2 points to calculate t_r, t_f for any given amplitude;
* Easy to redo these tables provided a new pulse shape function or threshold;

SBS Software progress:
Digitization (in progress)

Example of the GRINCH: Cherenkov detector readout by 510 PMTs (see Todd's talk)
GRINCH PMTs will be readout by NINO cards => record TDC values for PMT rise time and fall time (pulse amp. goes resp. over/under NINO thr ; estimation of pulse amp. with Time-over threshold).

TDC times (relative to trigger time), NINO threshold: 3mV, Gain: $7*10^6$



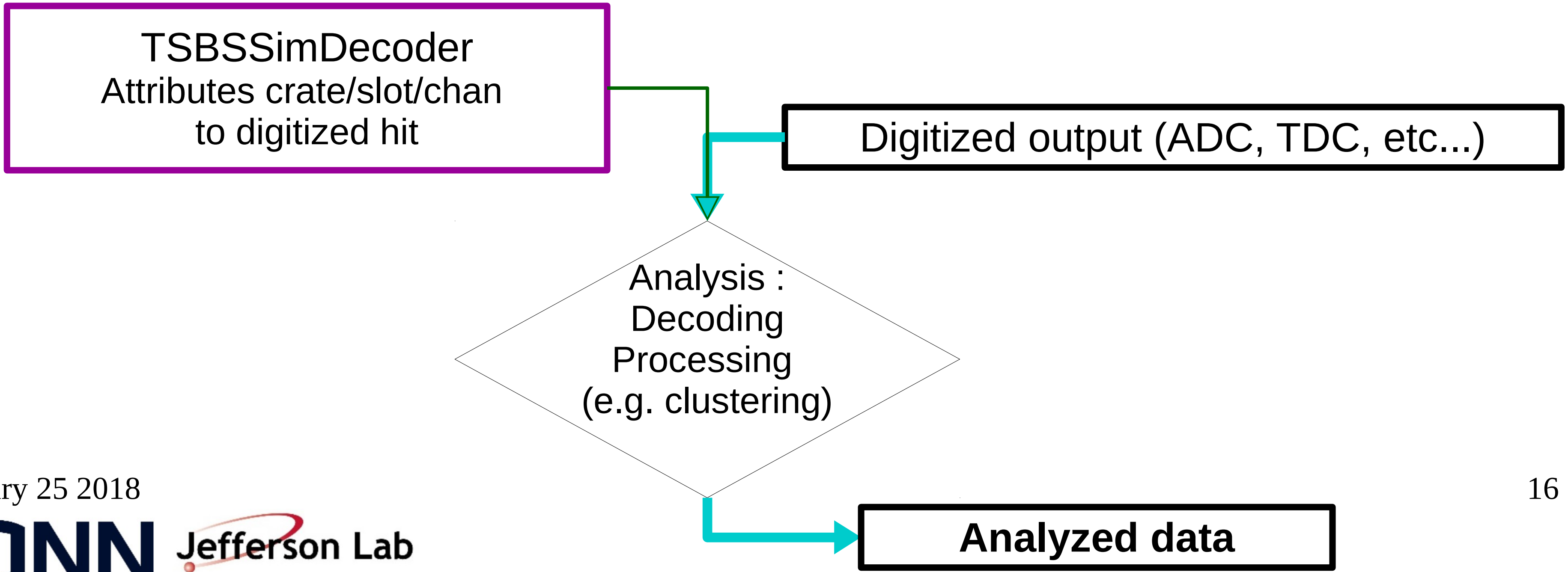
No background

SBS Software progress:
Analysis steps after Digitization (in progress)

Example : Data analysis steps for GRINCH (under development) **:**

- **SBSSimDecoder** to attribute to each hit its corresponding crate/slot/channel number
  => Exists for GEMs, being written for Cherenkov detectors, does not exist yet for Scinti, ECals;
  + we consider pulling SimDecoder out of the digitization library.

- **SBS-offline: Data decoding** (build the elemental hits from the raw/digitized data) + **Processing** (e.g. for GRINCH : clustering, cluster association with tracks, etc) in relevant detector class:
  => exists in principle for all subsystems, but may need some rewriting depending on the subsystem
  => operational for GEMs, almost operational for cherenkovs, need to be worked out for Scinti, ECals.



SBS Software progress:
HCal digitization (in progress)

HCal digitization is a special case: it cannot be digitized directly with the existing g4sbs output (g4sbs HCal hits are integrated to 1 hit/chan/evt, which is too "rough" for FADC250).

Digitizing HCAL PMT signal in G4SBS

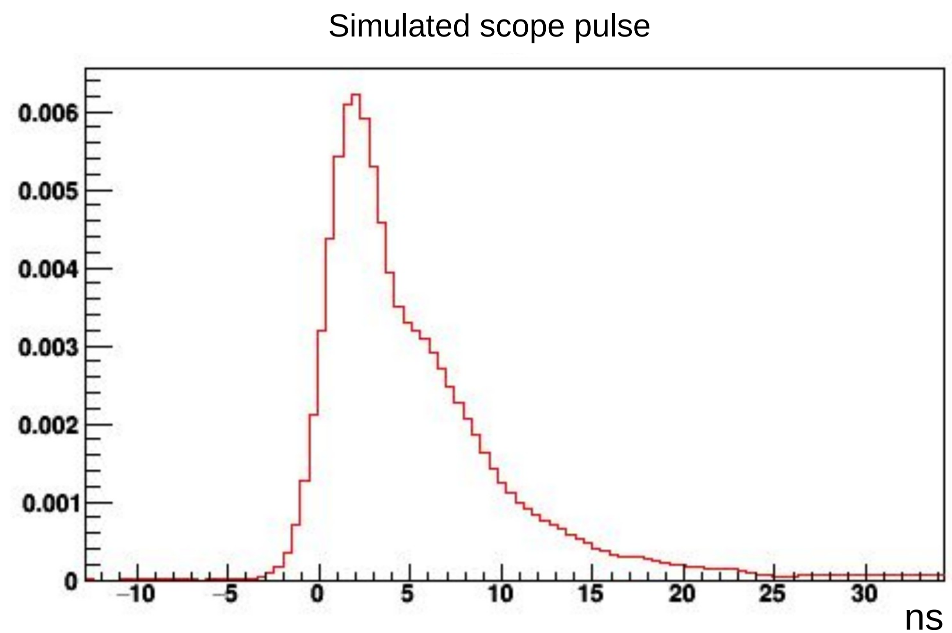
Build up simulated PMT signal for N photo-electrons using model of single-photo-electron.

- Use a model of an **ideal** single photo electron pulse.
- Not as realistic, but no timing corrections need to be performed.
- Easier to work with a TSpline.

I found this model that Vahe when he was working on the Light Guide design.

I don’t know the details of exactly how he made this one.

It can either be fit to many single-pe or just used Polya statistics to make it.

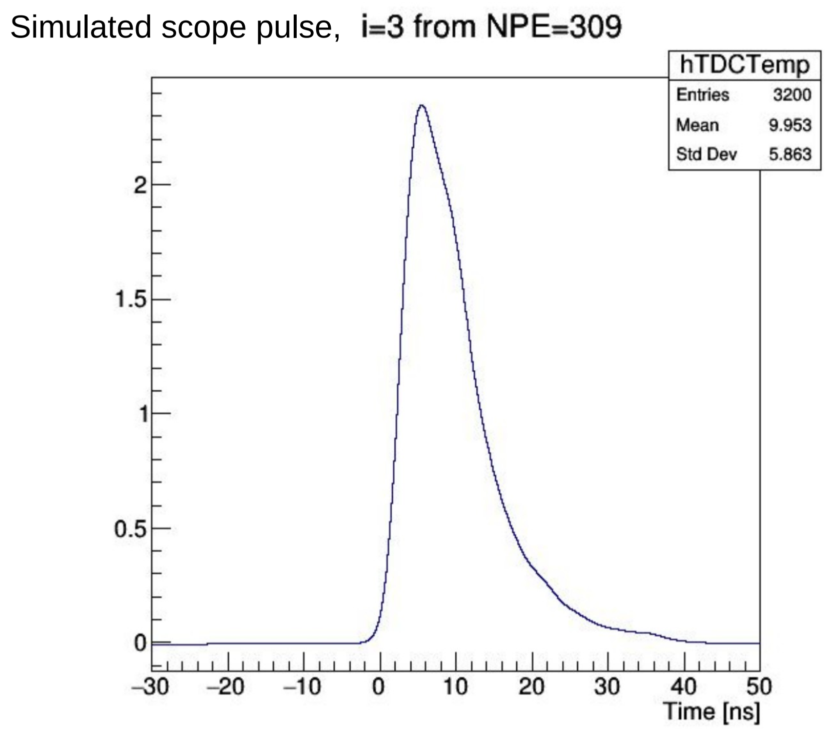


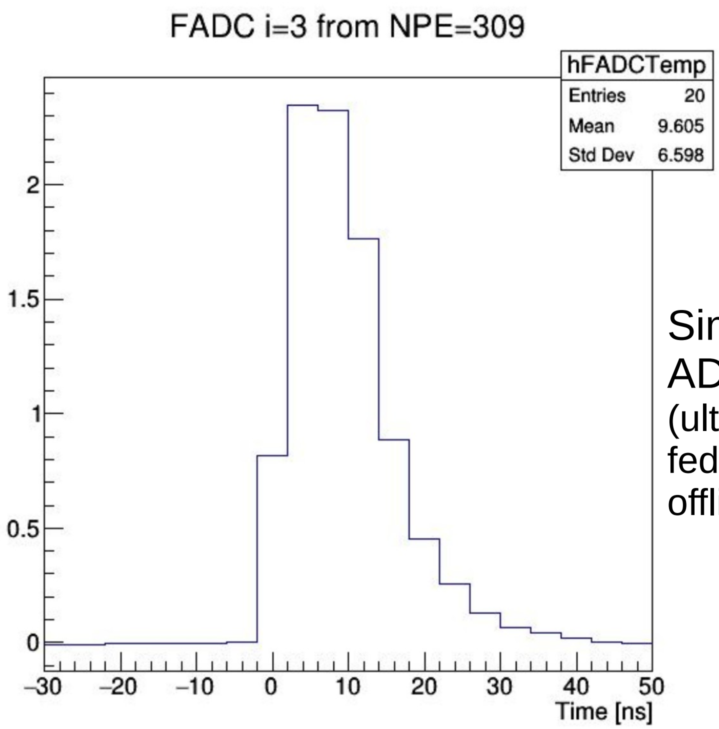
(Slide from **Juan Carlos Cornejo**, SBS soft/simu, 2017/12/13)

SBS Software progress:
HCal digitization (in progress)

Early comparisons of HCAL digitization with real cosmics

This is what a simulated signal looks like when built out of 309 photo-electrons



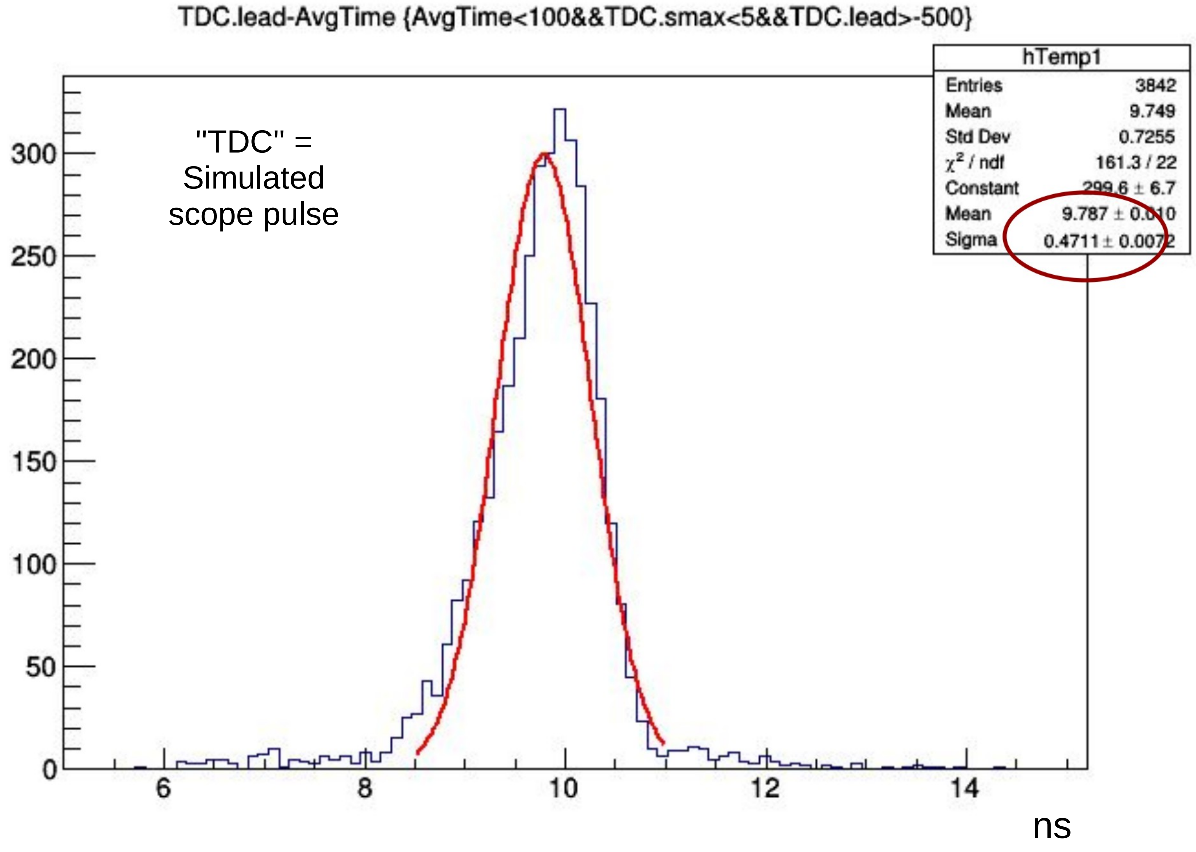


Simulated ADC sample (ultimately to be fed to SBS-offline)

(Slide from **Juan Carlos Cornejo**, SBS soft/simu, 2017/12/13)

SBS Software progress:
HCal digitization (in progress)

First attempt at timing with G4SBS (cosmic muon)



- Very basic timing by getting time of first bin above threshold.
- Need to do time-walk correction, and hope to get better timing with that.

(Slide from **Juan Carlos Cornejo**, SBS soft/simu, 2017/12/13)

SBS Software progress:
Summary and next steps

What has been done:

- The digitization library has been set up and is now mostly functional for Cherenkov detectors.

- The analysis for the GRINCH detector is mostly rewritten; the full chain should be functional soon for this specific detector;

- The digitization process for HCal is being worked out on its own; the interface between digitized simulation and SBS-offline still needs to be written.

TO-DO:

- Add in the library the digitization for other subsystems: Scintillators (hodoscope, CDet), ECals (Gep ECal, BB Ecal), and work out their respective analysis chains ;

- *At some point,* merge the digitization library with the GEM digitization library, and the TreeSearch to the SBS-offline;

- Refine the digitization: Pedestal noise, cross talk, properly manage background addition (pile-up), etc.

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*** Milestones have been rebaselined, based on accelerator schedule, actual progress and manpower;**

*** There is still long way to go: *Everyone is welcome to join!*;**

*** The GEM digitization and TreeSearch algorithm keep being improved; (thanks Danning)**

*** Main focus is now on digitization and analysis of subsystems; (myself + thanks Juan Carlos for HCal)**

*** In near future, will *also* focus on calibration scripts and event displays; for them to be ready this summer**

Thank you for your attention !

Software/simulation organization: responsibilities

General purpose software

Analyzer development	O. Hansen (JLab)
Front-end decoders	A. Camsonne (JLab)
Event Reassembly	JLab DAQ group

SBS specific

	Contact	Supporting groups
Repository maintenance	S. Riordan	JLab
Simulation maintenance	A. Puckett	UConn
MPD decoding	S. Riordan	SBU, JLab, UVA, INFN
GEM Tracking	A. Puckett	INFN, JLab, UConn
HCal Analysis	G. Franklin	CMU
ECal analysis	A. Puckett	UConn
CDet analysis	P. Monoghan	CNU
GRINCH analysis	T. Averett	W&M
BigBite analysis	S. Riordan	JLab

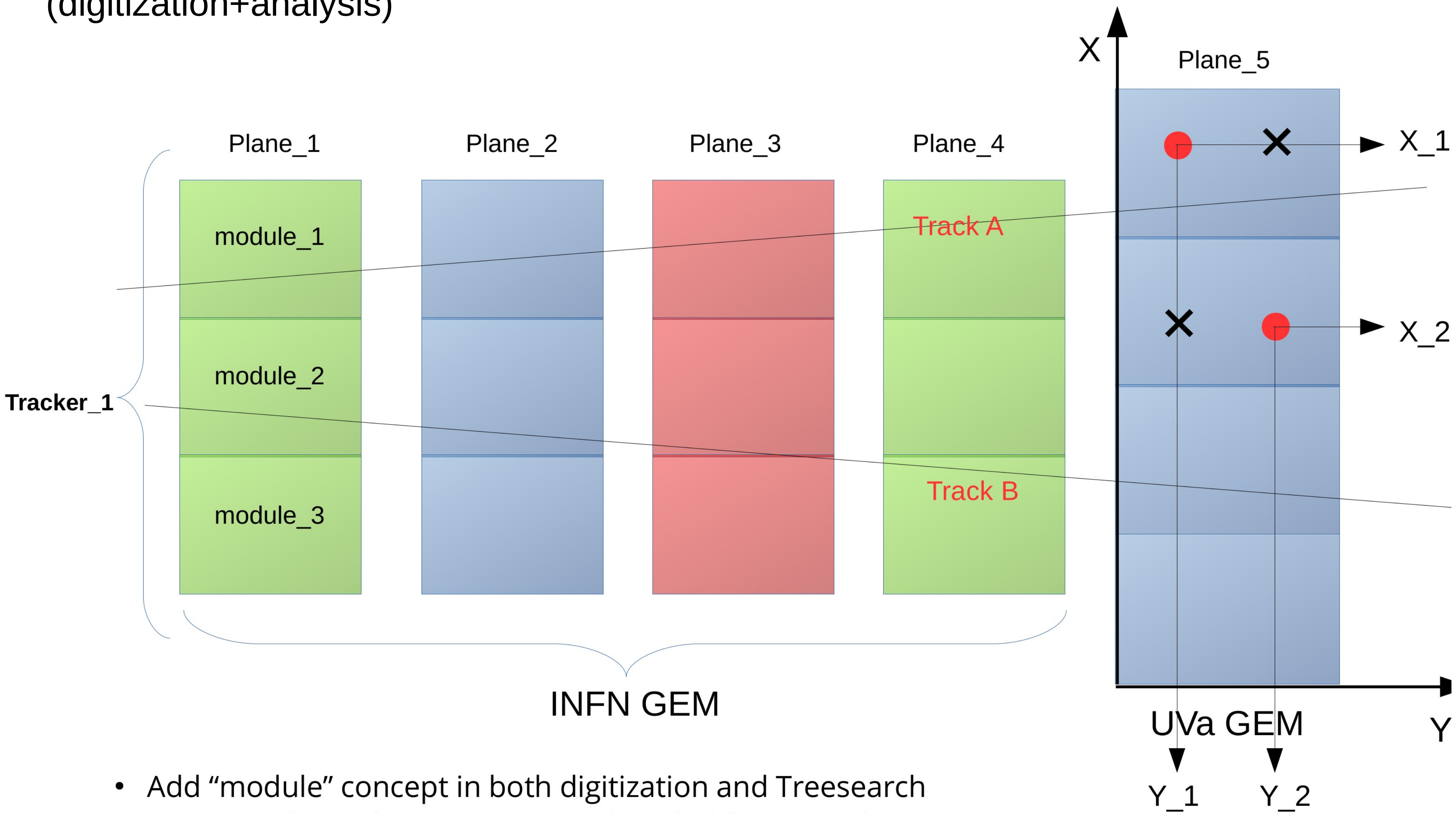
Experimental analysis

GMn	B. Quinn (CMU)	Bigbite, HCal
GEn	S. Riordan (SBU)	Bigbite, HCal, 3He target
GEp	E. Cisbani (INFN)	ECal, CDet, SBS w/ FT, FPPs GEM trackers
SIDIS	A. Puckett (UConn)	Bigbite, SBS w/ GEM trackers and RICH
TDIS	D. Dutta (SBU)	SBS e − w/ GEM trackers and RICH, LAC, RTPC

Tracking progress

Improvements and adjustments

Detector modelling => Current BigBite Tracker layout
(digitization+analysis)

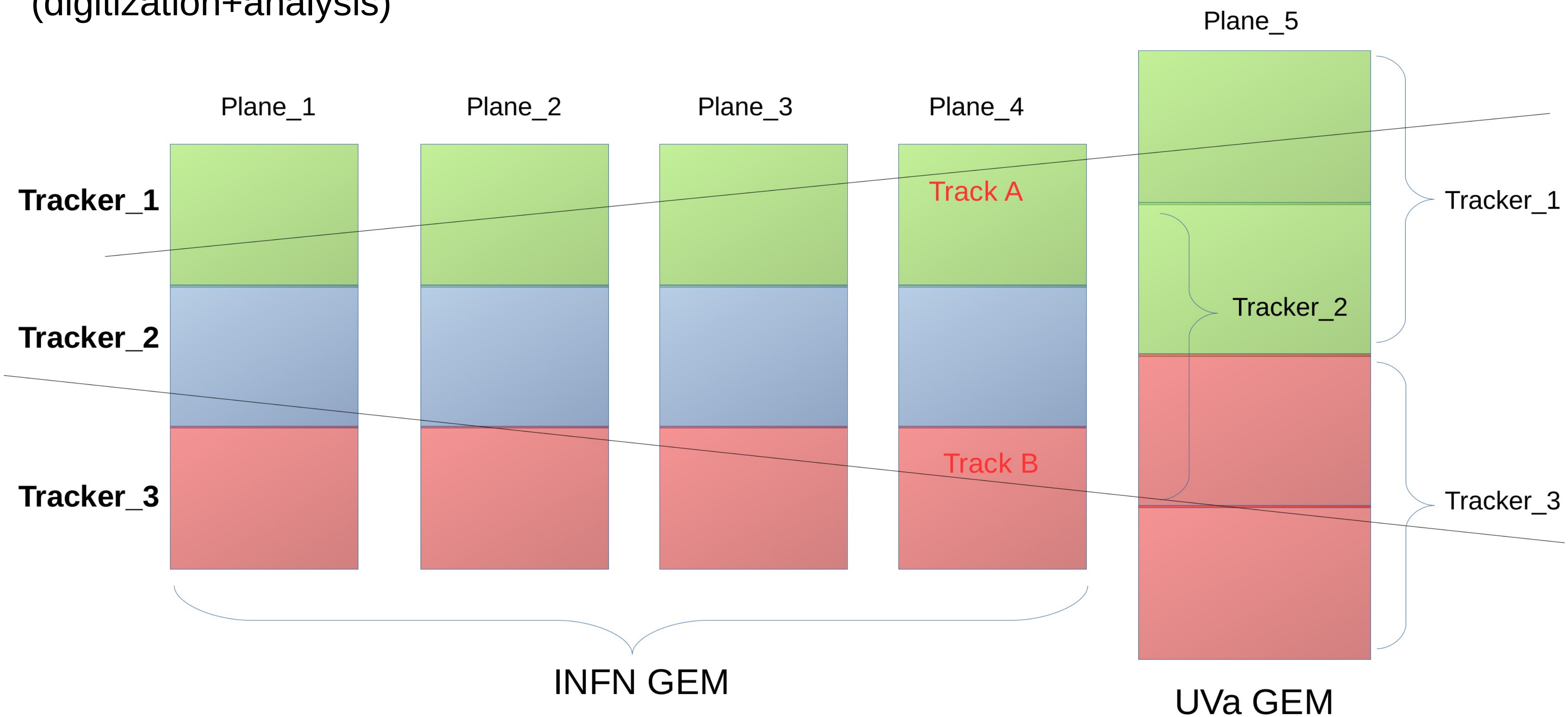


- Add “module” concept in both digitization and Treesearch library so that “plane” collect hits decoded from “modules” and function as a tracking plane
- Save “moduleID” in each hit for later 2D track matching
- New database format

Tracking progress
Improvements and adjustments

Detector modelling => (digitization+analysis)

Old BigBite Tracker layout



Hall A tracker had no subdivision, the "GEMplane" function as a detector and tracking plane

- Track A reconstructed
- Track B lost

(Slide from Danning, SBS weekly, 2017/11/15)

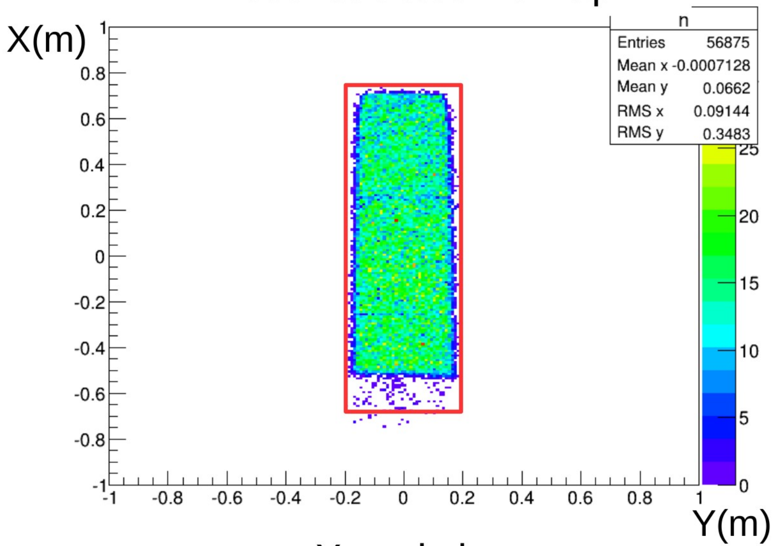
Tracking progress

Improvements and adjustments

Reconstructed hits after layout change

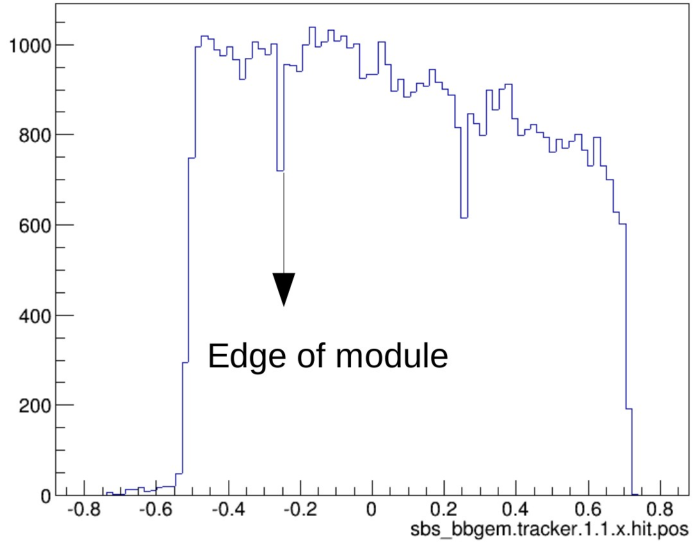
(Plot credit: Danning, SBS weekly, 2017/11/15)

Reconstructed hit map

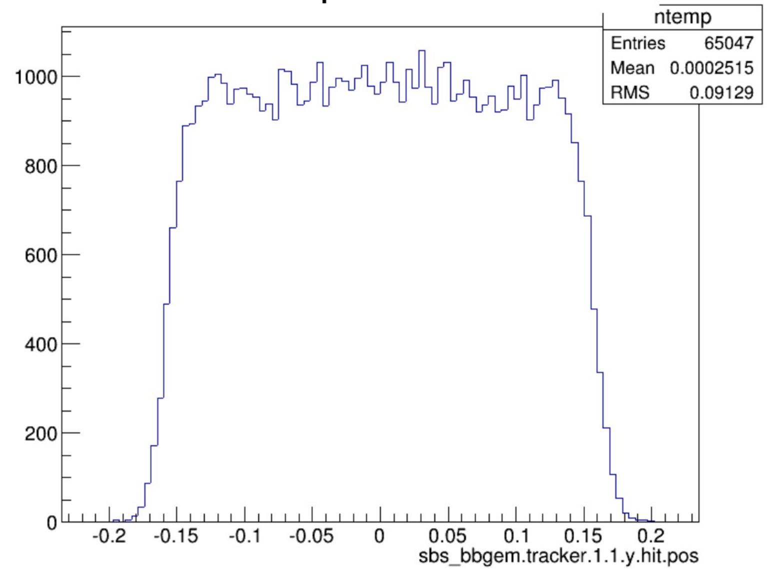


- INFN Plane size: (3x50cm)x40cm
- Edge of modules can be seen due to lost strips at the edge of module

X posistion

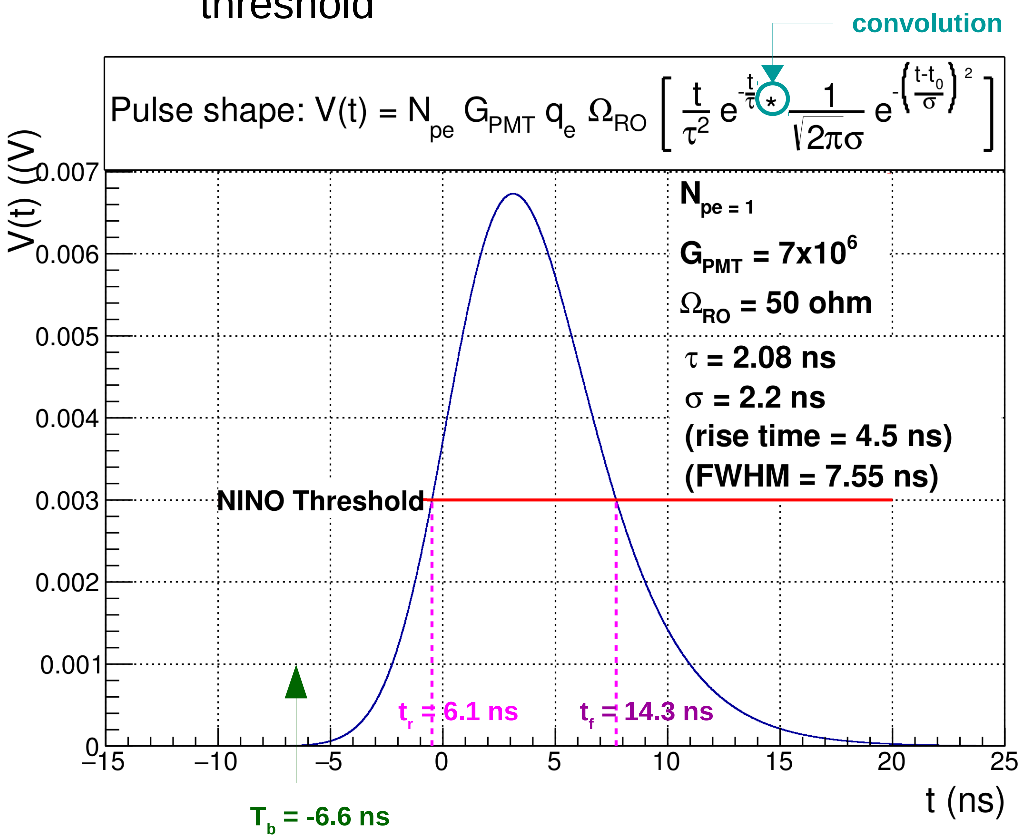


Y posistion



GRINCH PMT pulse shape

To evaluate the times t_r and t_f at which the pulse will go over/under the threshold, we need to know the pulse shape and its amplitude (see below);
The goal is to retrieve the GRINCH PMT timing characteristics (right panel), which has required the *convolution* of a exponentially decreasing function $\mathbf{t/\tau^2 \exp(-t/\tau)}$ with a gaussian.
Another issue is the normalization of this pulse, to evaluate at which moment it will cross the threshold



6 characteristics

	unit	min	typ	max
timing:				
single electron rise time	ns		4.5	
single electron (fwhm)	ns		7.5	
single electron jitter (fwhm)	ns		4	
transit time	ns		33	

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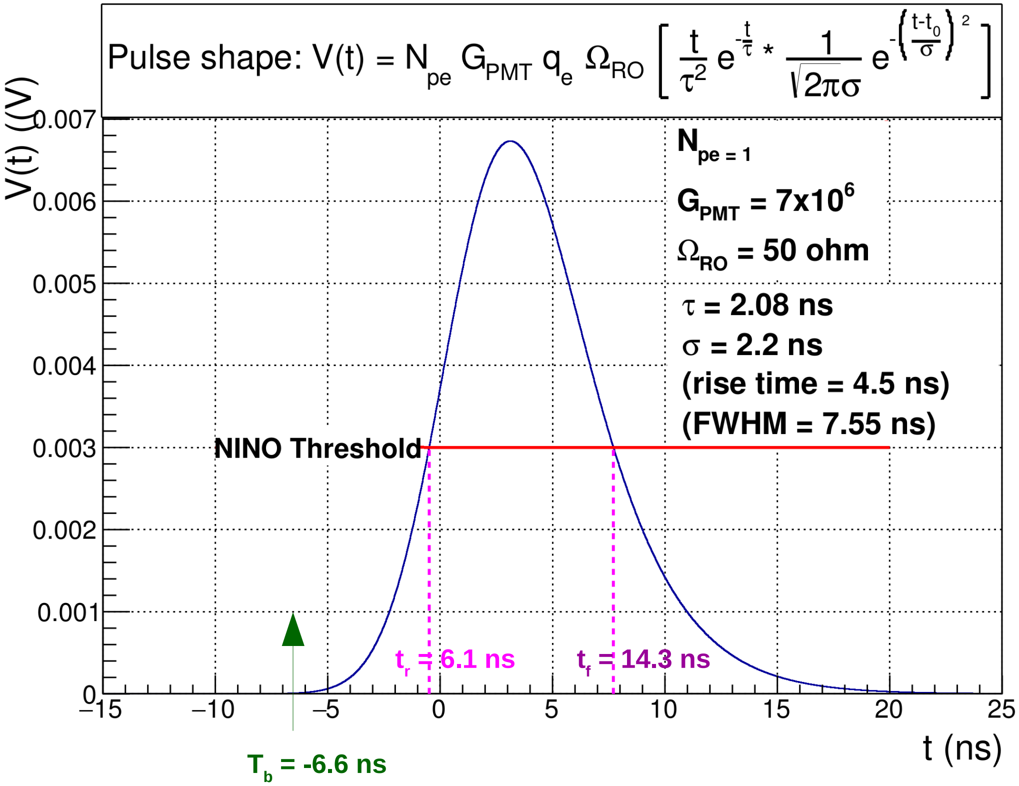
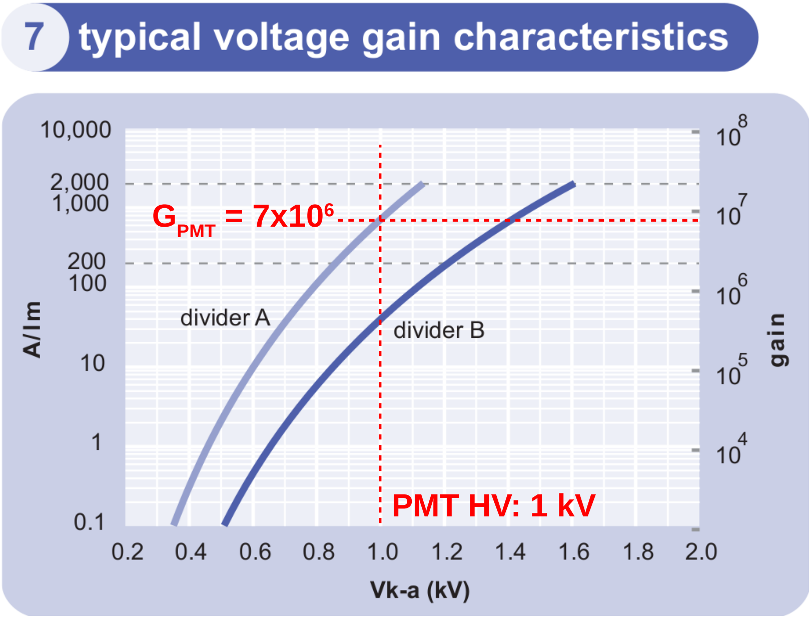
GRINCH PMT pulse normalization

The pulse integral contains N_{pe} G_{PMT} electrons, or N_{pe} G_{PMT} q_e coulombs.
Hence, the pulse function shall be an intensity function I(t), which just needs to be multiplied by the readout impedance Ω_{RO} to obtain a voltage function V(t).
PS : yes, my scale is in ns, and I have taken this into account in the normalization.
I get a similar pulse height if I use scale in seconds (instead of ns).





If this is normalization is correct, then it means the threshold should be lower (2-3 mV).

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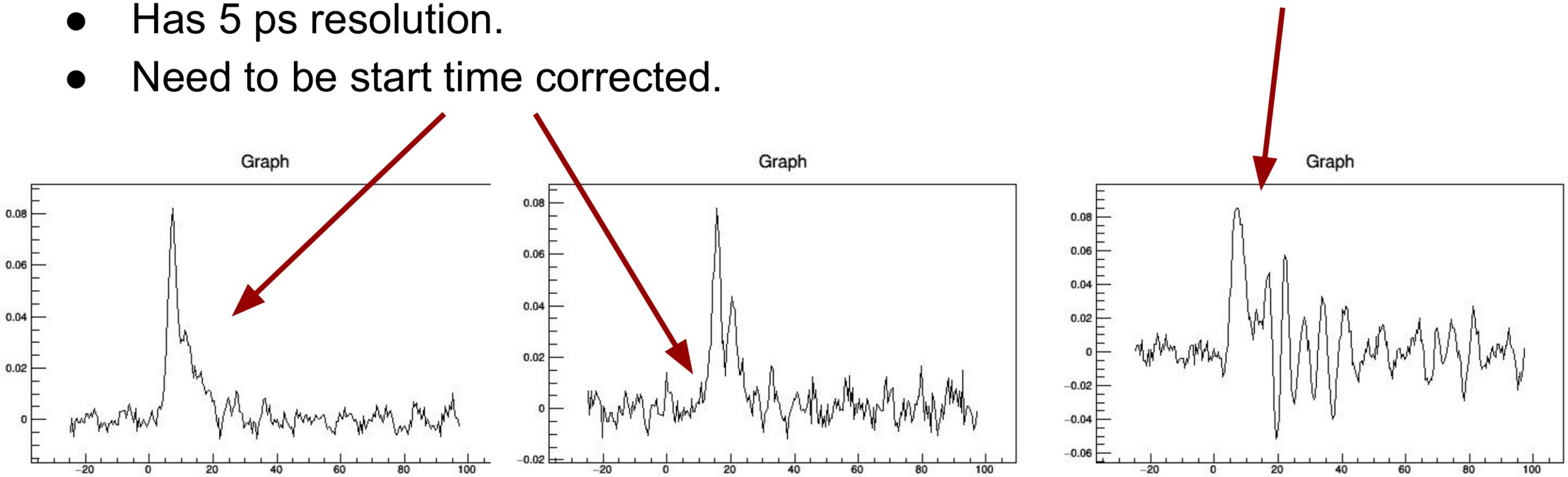
SBS Software progress:
HCal digitization

Option 1 for digitizing HCAL PMT Signal in G4SBS

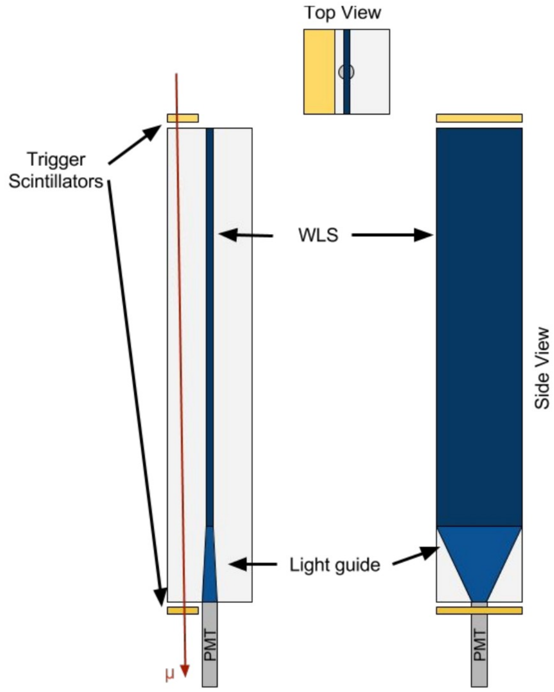
- Build up simulated PMT signal for N photo-electrons using model of single-photo-electron.
- Use scope images for single photo-electrons (Vahe took this using scintillator and one PMT).
- Can be more realistic since at single-pe pulses look very jagged
- Has 5 ps resolution.
- Need to be start time corrected.



(Slide from Juan Carlos, SBS soft/simu, 2017/12/13)

Early comparisons of Option 2 and real cosmics

- I am benchmarking using Option 2 (since it proved to be easier to work with) to simulate real cosmic data on a single HCAL module.

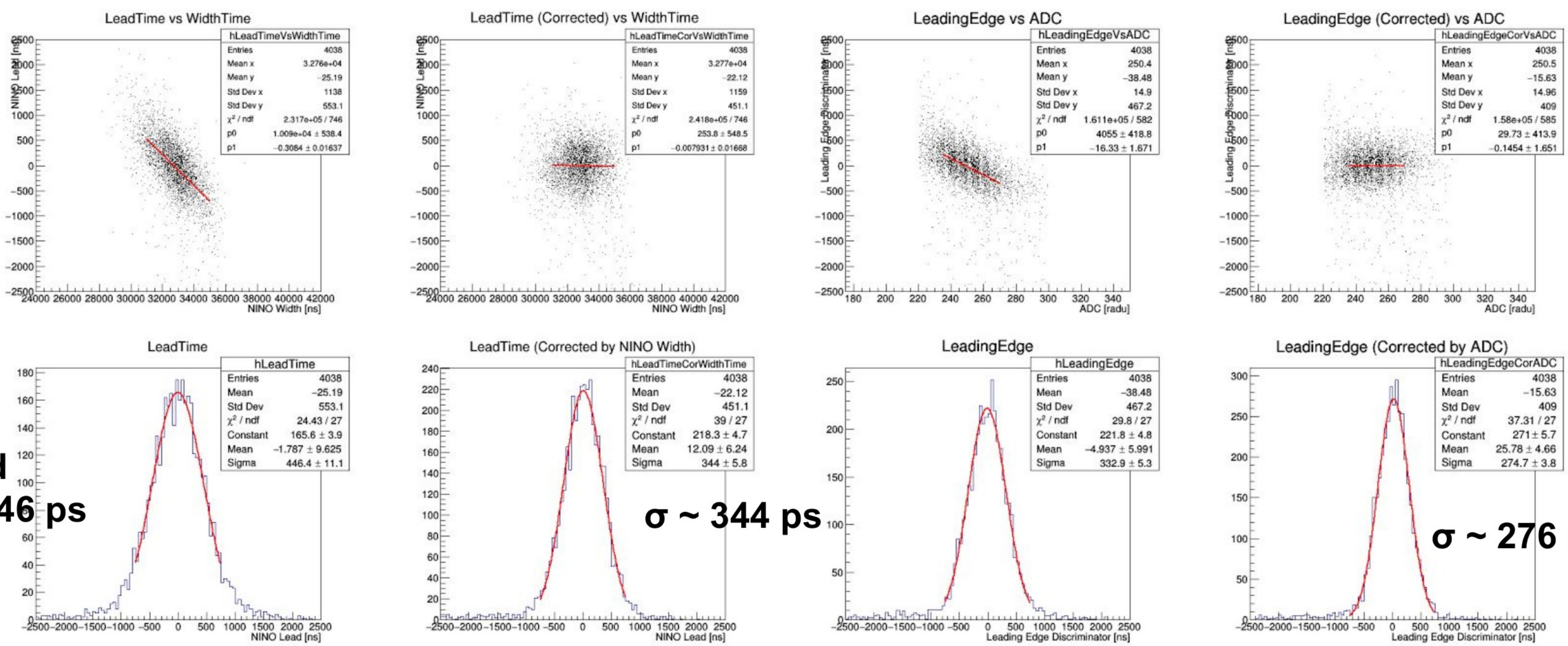


- Vertical module with two trigger scintillators above and below.
  - Positioned so that muons do not go through Wavelength Shifter
- Used similar setup in G4SBS and used gun to generate 4GeV muons.
- Took only muons that passed through similar region defined by trigger scintillators.

(Slide from Juan Carlos, SBS soft/simu, 2017/12/13)

Cosmic data timing (using NINO and Leading Edge)

Here is an example from Cosmic data (Left to graphs are using NINO, Right two graphs are using a leading edge discriminator



Uncorrected signal σ ~ 446 ps

σ ~ 344 ps

σ ~ 276 ps

(Slide from Juan Carlos, SBS soft/simu, 2017/12/13)