CGEM-IT SOFTWARE STATUS

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on behalf of the software group

University of Torino & INFN

INDEX & GANTT CHART

- The GANTT chart on the software activities must be ready for the next CGEM workshop

- Discussion ongoing on HN since a while (*expecially Stefano & Liangliang*)

- I will show the last updated list of tasks and responsibles @ 15/10/2019

- The main topics are:
  - digitization
  - reconstruction
  - alignment
  - calibration
  - analysis of MC data
  - analysis of cosmic ray data

- for each topic, open issues, people involved and updates will be given

DIGITIZATION

```
*** Digitization ***
 Induction:
 - GTS Induction 1D (complete) - Lia
 - GTS Induction 2D (2/3 weeks) - Lia
 - Induction model based on Garfield simulation (2D, both T&Q, with magnetic field, complete) - Jingyi/Linghui

 TIGER response:
 - Circuit Simulation and modeling (almost done) - Fabio
 - Implementation of T-branch shaping (almost done) - Jingyi/Linghui/Liangliang
 - Implementation of E-branch shaping (2/3 weeks)   - Jingyi/Linghui/Liangliang
 - Implementation of thresholds/resolutions (2/3 weeks) - Jingyi/Linghui/Liangliang

 Digi tuning with cosmics data
 - Tuning of APV25 data (almost done?) - Riccardo
 - Tuning with CGEM+TIGER data - Jingyi/Linghui
```

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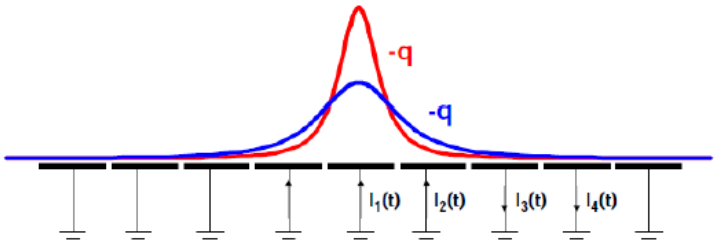
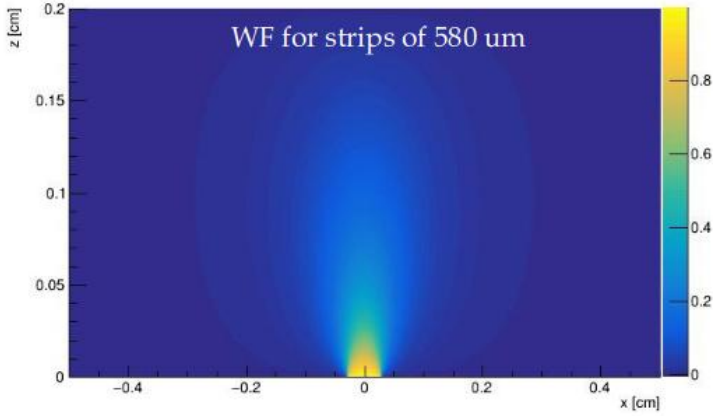
R. FARINELLI

GTS INDUCTION

• full induction 1D …….…….. **DONE**



FULL



$$i(t) = q_{e^-} \times v_{drift} \times W_{loc}$$

[W. Riegler, CERN seminar]

The current induced on a strip on the anode:
• depends on the position
• ends when the electron arrives on the strip

• Ramo's theorem
• electron steps = 1 ns
• weighting field analytical, 1D
• one-dimensional

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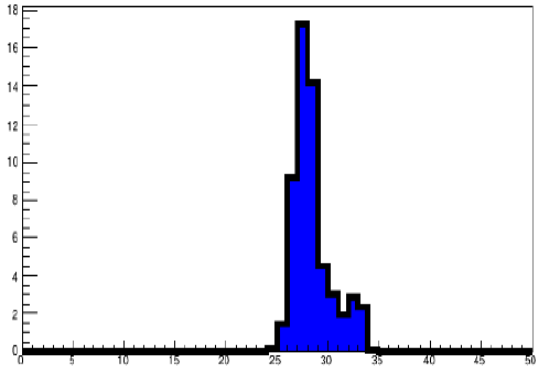
GTS INDUCTION

- full induction 1D ..... DONE
- fast induction 1D ..... DONE

Once **all the electrons** have arrived on the anode: [W. Riegler, CERN seminar]

- the signal is **finished**
- the charge on the *i-th* strip = the number of electrons collected by the strip

FAST →
- charge = # electrons collected by *i-th* strip
- time = time of arrival of the e^- on the *i-th* strip



Charge vs strip ID @ 45°

- *matching of charge distribution OK*
- *to do* – matching of time distribution

fast induction is x 30 faster than the full!

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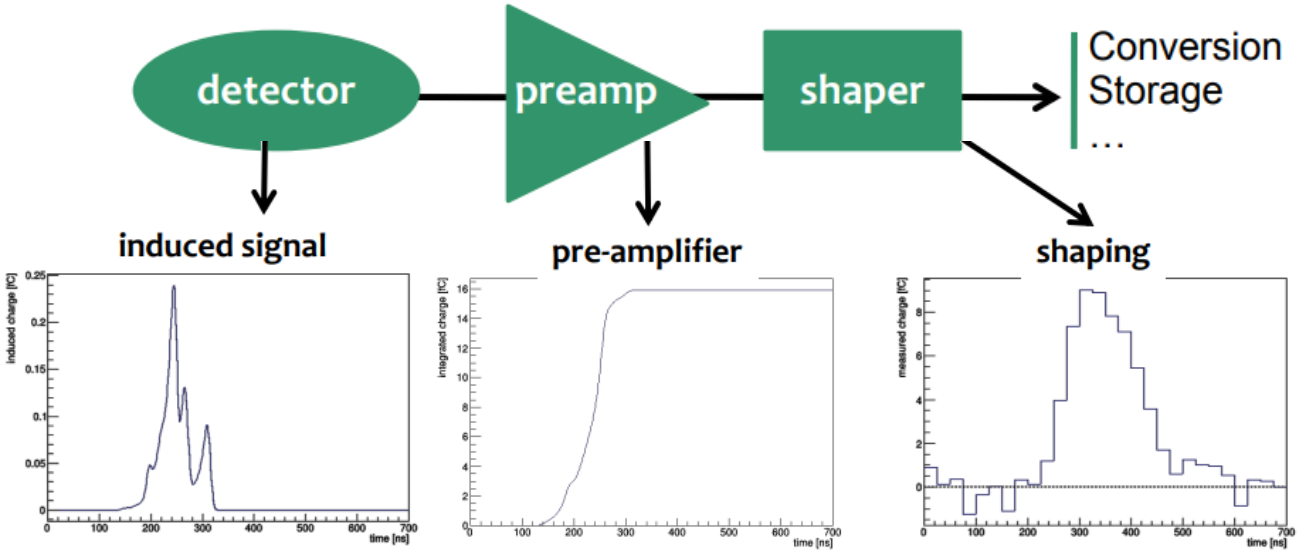
APV-25 ASIC

- full induction 1D ..... DONE
- fast induction 1D ..... DONE
- APV-25 ..... DONE



The **charge** is the peak value of the signal

The **time** comes from a Fermi-Dirac fit of the rising edge

as in real signal reconstruction

APV-25 ASIC

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R. FARINELLI

- full induction 1D ..... DONE
- fast induction 1D ..... DONE
- APV-25 ..... DONE
- two dimensions ..... TO DO

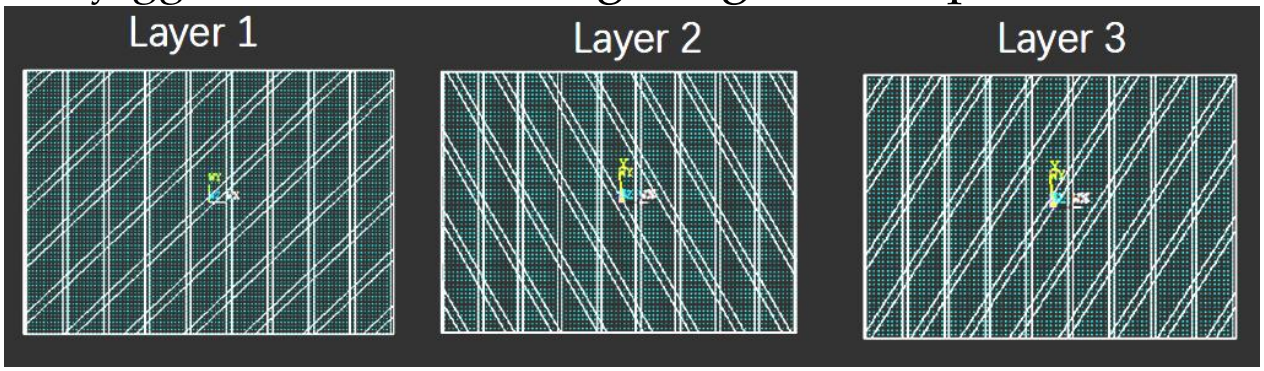
- the charge sharing can be accounted for with *ad hoc* multiplication factors (data driven)

- the focusing effect of the electric field and of the non-constant drift velocity can be accounted for with *ad hoc* multiplication factors (data driven)

GTS, renamed PARSIFAL, was presented @ RD51 Collaboration Meeting:
BIG SUCCESS!

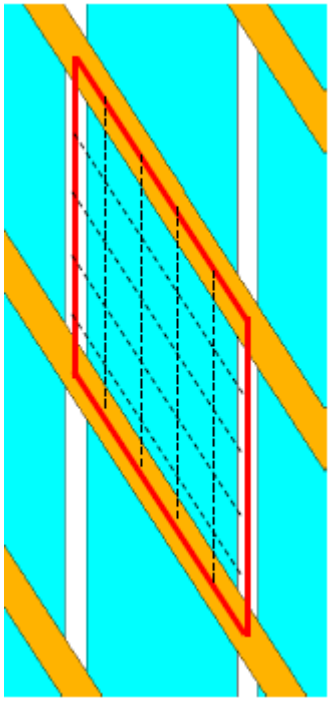
INDUCTION IN CGEMBOSS

- *non-jagged* anode and weighting field implemented



- usual procedure in signal formation, *i.e.:*
  - parametrize the signal for each electron position (GARFIELD++)
  - sum all the contributions from different electrons on one strip
- non-jagged *vs* jagged, no relevant changes in:
  - cluster size
  - charge
- evaluation of charge sharing: $\frac{Q_X}{Q_V} = 1.49 \Rightarrow 1.53$

Jagged Linear



EXPERIMENTAL 1.5-2
PRELIMINARY

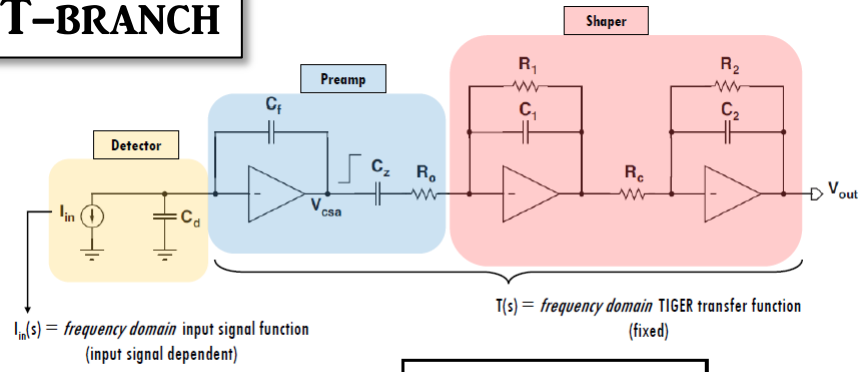
TIGER MODEL

- TIGER model ..... DONE

- The model:
  - ✓ takes into account the different duration and shape of input signals
  - ✓ well reproduces the T-branch shaper output
  - ✓ provides a good approximation for the E-branch shaper output
  - ✓ validated with "real" CGEM signals
  - ✓ faster than computer circuit simulator (requires *Laplace Transform* evaluation)
- To-Do:
  - ❑ Take into account the saturation of the front-end (signals > 50 fC will have a different response)

TIGER MODEL

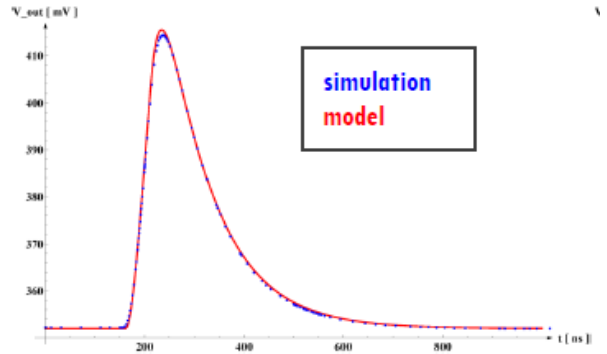
T-BRANCH



$$T(s) = \frac{1}{C_f} \cdot \frac{R_0 C_z}{(1 + sC_z R_0)} \cdot \frac{R_1}{(1 + sC_1 R_1)} \cdot \frac{1}{R_C} \cdot \frac{R_2}{(1 + sC_2 R_2)}$$

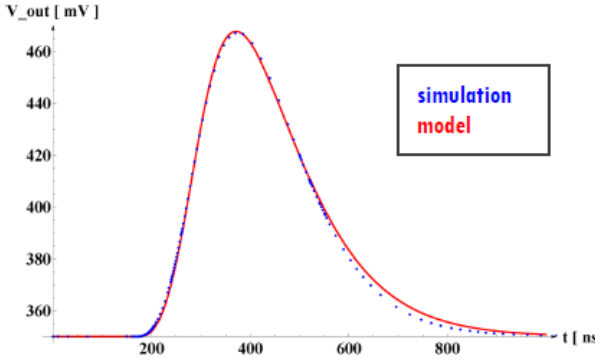
$$V_{out\_T}(s) = I_{in}(s) \cdot T(s)$$

Q_in = 5 fC, Ts = 50 ns (rectangular waveform)



rectangular waveform
$Q_{in} = 5$ fC
$T_s = 50$ ns

Q_in = 10 fC, Ts = 100 ns (rectangular waveform)



add 5ns delay to the model signals

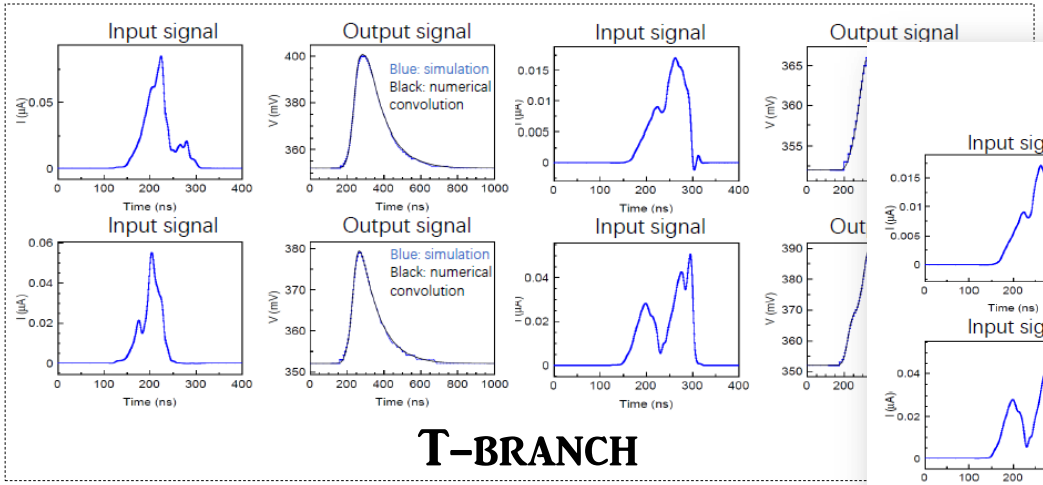
E-BRANCH

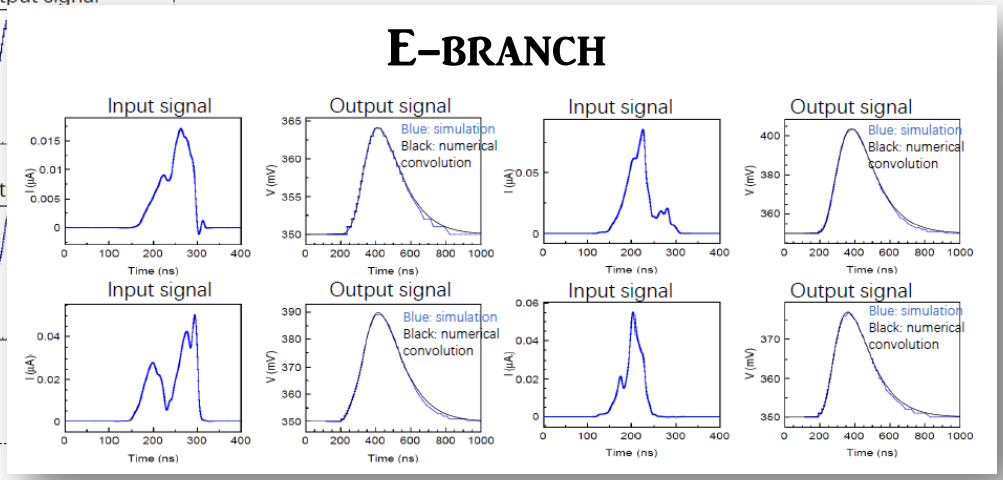
$$T(s) = \frac{C_z}{C_f} \cdot \left(\frac{G \cdot \omega_0^2}{s^2 + \frac{s \cdot \omega_0}{Q} + \omega_0^2} \right)^2$$

TIGER in CgemBoss

F. Cossio
JY. Zheng

- TIGER model ..... DONE
- TIGER in CgemBoss ..... ONGOING





Request - values of thresholds are needed, will be provided
The reconstruction of the signal of the TIGER still has to be implemented

TUNING

• to APV-25 data ……..…….. **DONE**

Scan (TB of April 2018)
particle incident angle [0°, 40°], B = 0
Tuning factor on
Gain, diffusion
Sentinel variables
• measured charge
• cluster size
• position resolution (charge centroid)
• position resolution (μ-TPC)

Procedure

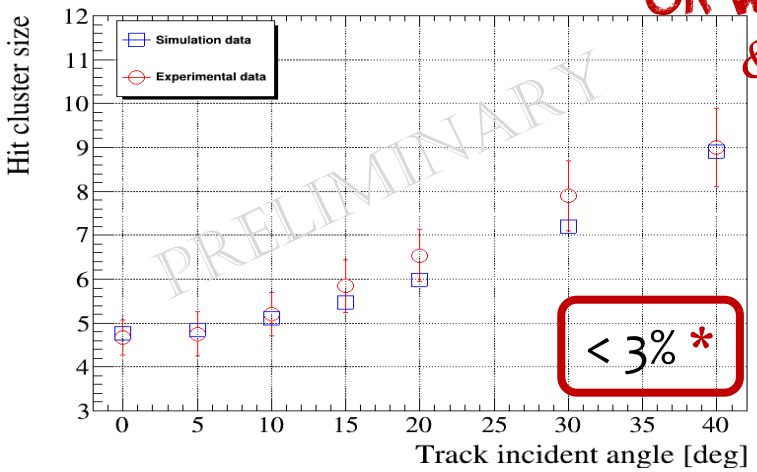
• for each gain and diffusion values, simulate 7 angles: 0, 5, 10, 15, 20, 30, 40
• for each angle, run 20k muons → statistical error around 1%
• compute $\chi^2 = \chi^2_{\text{charge}} + \chi^2_{\text{cl.size}} + \chi^2_{\text{CCresol.}} + \chi^2_{\mu-\text{TPCresol.}}$
• evaluate χ^2/NDF

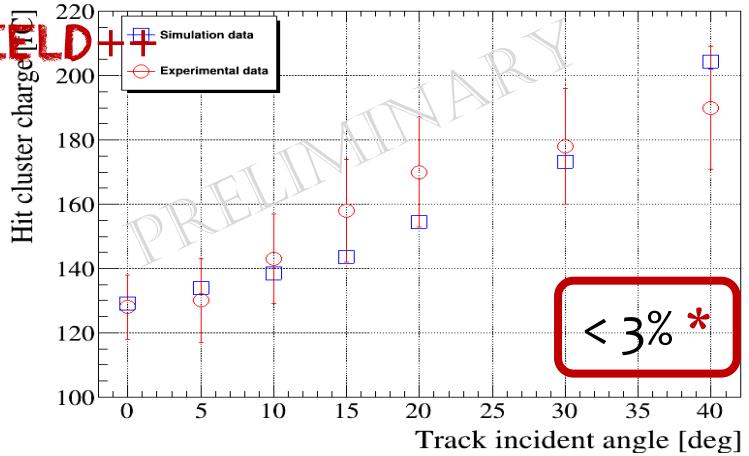
TUNING

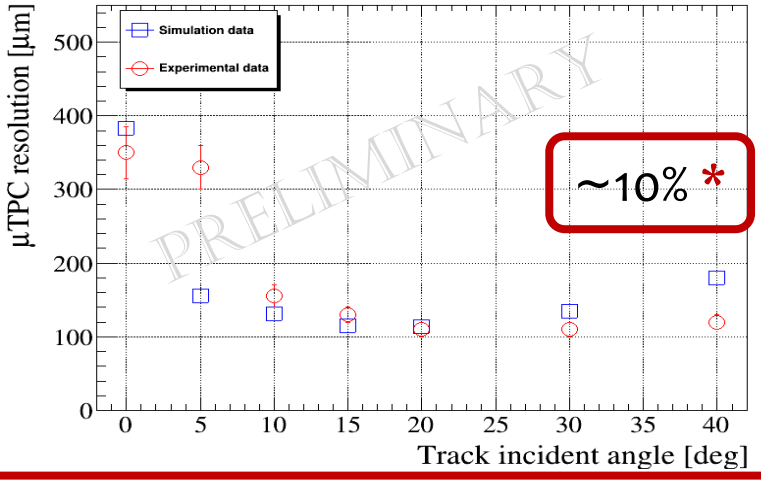
- to APV-25 data …….……. DONE

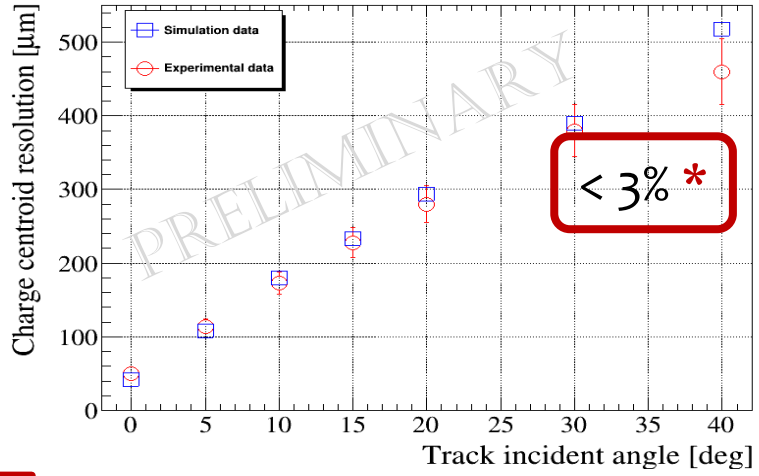
Best result χ^2/NDF ~ 3 ← *gain tuning = 6.8* ← *diffusion tuning = 1.5*

OK WITH LITERATURE & GARFIELD++









* (experimental – simulated)/experimental

DIGITIZATION

```
*** Digitization ***
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```

Missing:

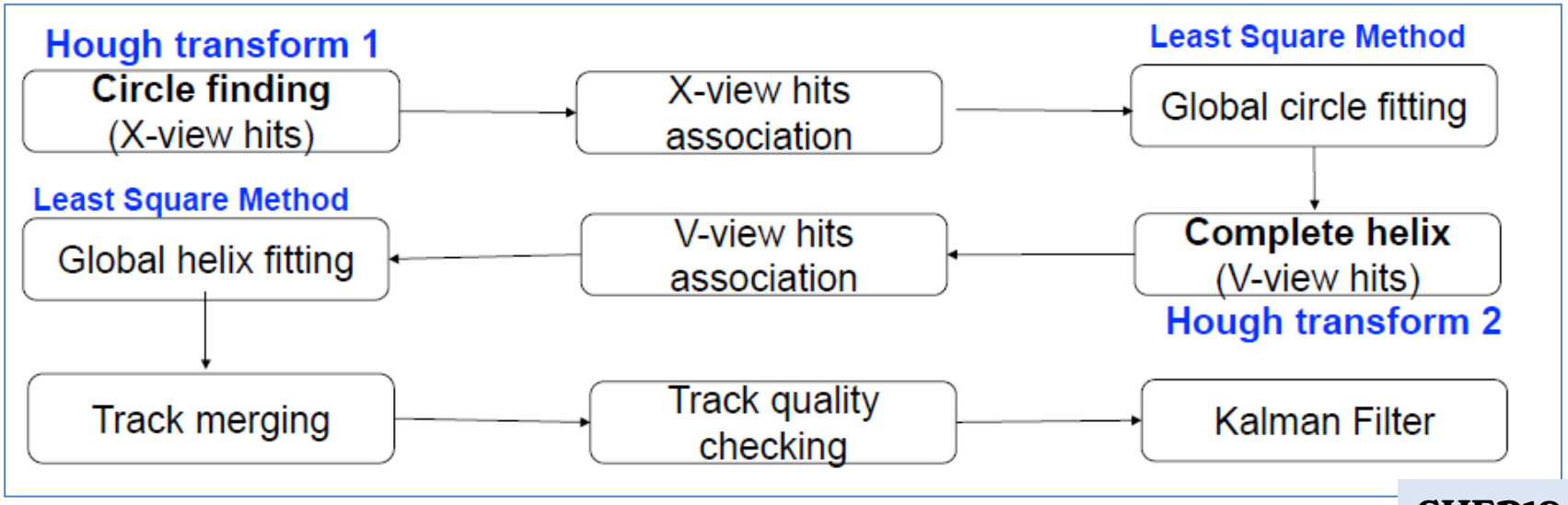
- tuning to TIGER data ……..…… **TO DO**
  - once the TIGER has been implemented in CgemBoss
  - once the cosmic data have been analyzed

RECONSTRUCTION

```
*** Reconstruction ***

Position reconstruction in u-TPC mode
- uTPC linear fit implementation - Riccardo/Xiaoling

Improved global track reconstruction with Hough Transform
- track fit quality improvement (4 weeks) - Zhen Huang/Liangliang

Merge CC+uTPC
- Mode with cluster size - Riccardo
- Mode with the incident angle - Riccardo
```

GLOBAL TRACKING

The global pattern recognition:
- wants to use *simultaneously* CGEM and ODC hits
- is *based* on Hough Transformation

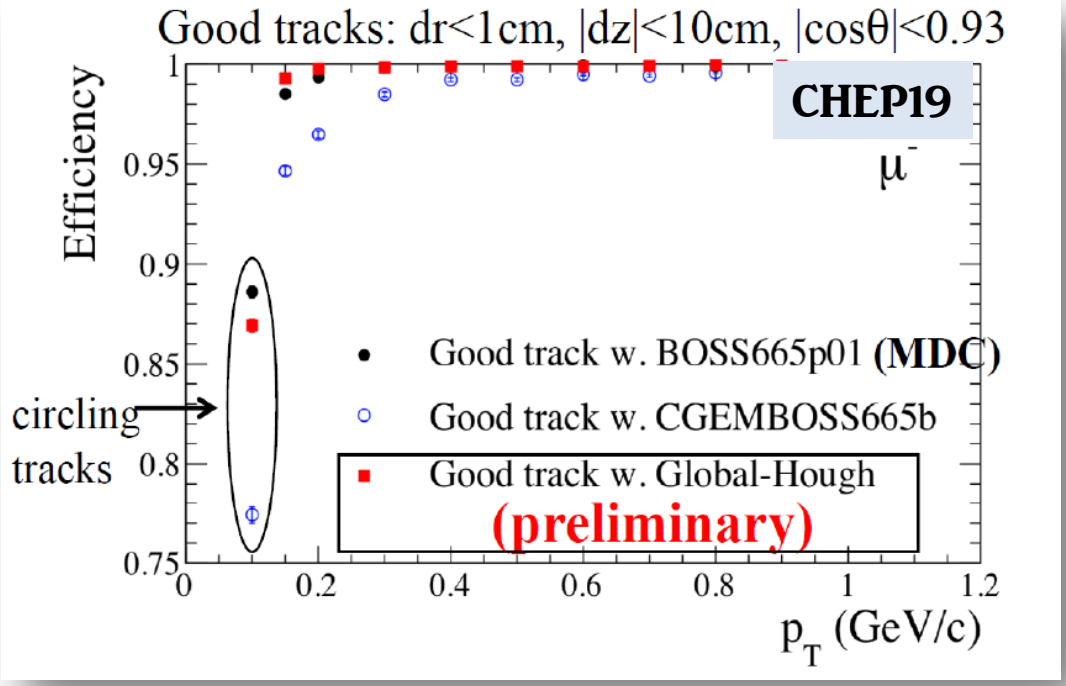


CHEP19

The status is the following:
- structure/design of the code …….…… DONE
- refinement of the binning of the histograms …… DONE
- continuous testing ……..…… ONGOING

GLOBAL TRACKING

- Unfortunately the last release was in 2018



SINGLE TRACK EFFICIENCY

- CGEMBOSS665b – April 2017
- CGEMBOSS665c – July 2018

- Actually a new release was foreseen for last week, but nothing happened
- Updates are ongoing, but the work is very slow due to the lack of manpower

GLOBAL TRACKING

- version v13 of the Hough Transform replaced v12
- shows a **better efficiency** for the benchmark channel
- …but not after χ^2 cuts

- Sample: $\psi' \longrightarrow J/\psi + \pi^+ + \pi^-$, $J/\psi \longrightarrow e^+ + e^-$

	Boss665p01	Hough V12	Hough V13
$\pi^+ + \pi^- + e^+ + e^-$ ①	65.71	58.55	63.67
4 good tracks events ②	63.25	60.16	62.68
4C fit events ③	57.84	52.68	54.20
4C fit($\chi^2 < 200$)	57.36	51.37	50.41
4C fit($\chi^2 < 60$)	38.70	30.14	25.36

Note:

① $\pi^+ + \pi^- + e^+ + e^-$: pid by momentum, p<0.8GeV→pion, p>0.8GeV→electron

② 4 good tracks: |dr|<1.0cm, |dz|<10cm, |cosθ|<0.93, total charge =0

③ Some other mass cut before 4C fit

GLOBAL TRACKING

- version v13 of the Hough Transform replaced v12
- shows a **better efficiency** for the benchmark channel
- …but not after χ^2 cuts

- **still two problems**:
  - **Kalman** filter failure rate

	Boss665p01	Hough V12	Hough V13
Kalman filter failure tracks	2.4%	4.58%	18.48%

- Memory leakage:

v13 uses global fitting procedure 16 times more often than v12!

→ there is some missing "delete" to release memory

GLOBAL TRACKING

The global pattern recognition:
- wants to use *simultaneously* CGEM and ODC hits
- is *based* on Hough Transformation

The status is the following:
- structure/design of the code ..... **DONE**
- refinement of the binning of the histograms ..... **DONE**
- continuous testing ..... **ONGOING**

To be done:
- fix Kalman filter issue ..... **TO DO**
- fix memory leakage issue ..... **TO DO**
- release the code for intensive testing ..... **TO DO**

manpower needed!

RECONSTRUCTION

```
*** Reconstruction ***

Position reconstruction in u-TPC mode
- uTPC linear fit implementation - Riccardo/Xiaoling

Improved global track reconstruction with Hough Transform
- track fit quality improvement (4 weeks) - Zhen Huang/Liangliang

Merge CC+uTPC
- Mode with cluster size - Riccardo
- Mode with the incident angle - Riccardo
```

Missing:

- μ-TPC in CgemBoss ..... **TO DO**
- merging in CgemBoss ..... **TO DO**

Alignment

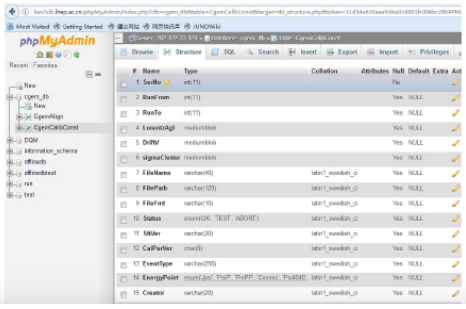
```
*** Alignment ***
- Validate the algorithm and work flow with MC (2-4 weeks) - Aiqiang/Linghui
- Optimize constraints and fit parameters for simple misalignment effects with MC (4 weeks) - Aiqiang/Linghui
- Validation by MC having complex misalignment effect and various statistics (8 weeks)  - Aiqiang/Will/Linghui
```

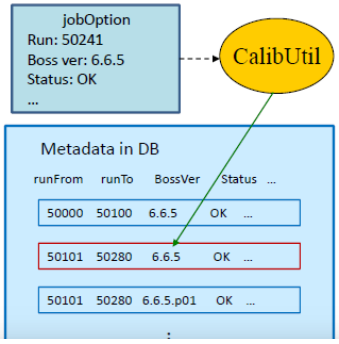
NO NEWS

CALIBRATION

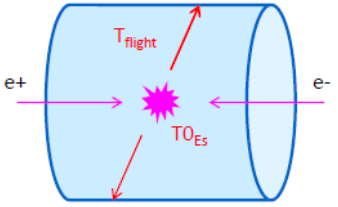
- framework ..... DONE
- database ..... DONE
- identify the calibration variables ..... ONGOING

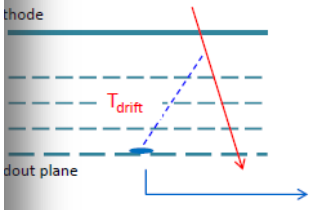
- Based on MySQL
- GUI client

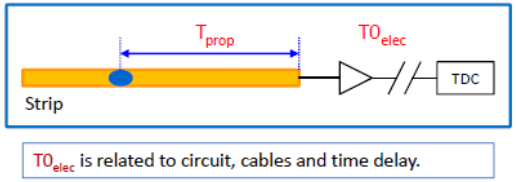




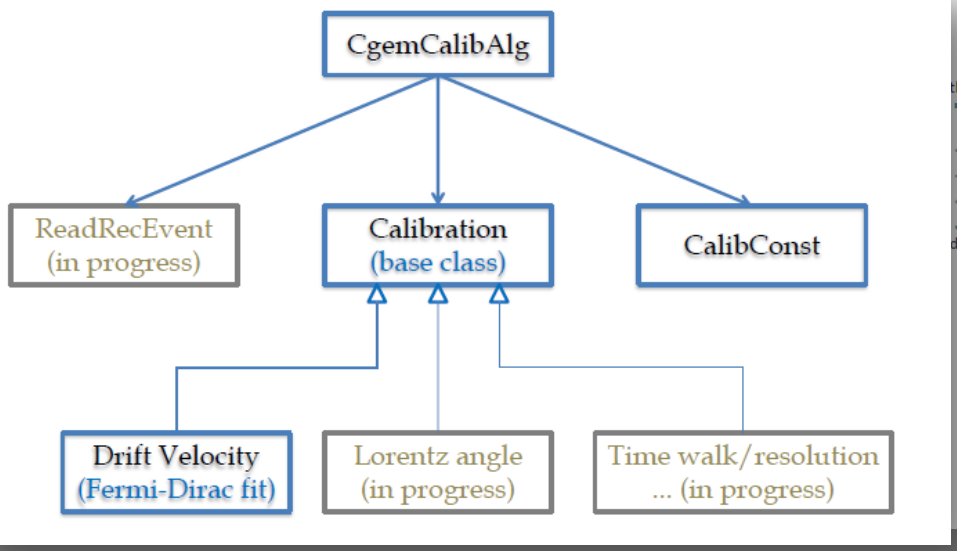
- $T_{TDC} = T0_{Es} + T_{flight} + T_{drift} + T0_{elec} + T_{prop}$
- Used in both reconstruction and digitization in the case of micro-TPC readout mode
- $T0_{elec}$ will be calibrated strip by strip
- T_{prop} is a function as layer, z & type of the strip (x or v)







$T0_{elec}$ is related to circuit, cables and time delay.



CALIBRATION

LH. Wu
et al.

STRATEGY ONCE THE COSMICS WERE AVAILABLE

DONE

Check basic T,Q distribution, hitmaps (2 weeks) - Jingyi/Linghui

TO DO

- Run the whole procedure and check the distributions - Jingyi/Linghui/Hongpeng/Liangliang
- Study the calibration methods and details - Jingyi/ Linghui
- Try the calibration procedure including the iteration of calibration and alignment - Jingyi/Aiqiang/Linghui

TIGER-SIDE CALIBRATION

Requested LUT for:

- global information ..... ONGOING
- strip information ..... ONGOING
- E branch ..... ONGOING
- T branch ..... ONGOING

GLOBAL

Name	Type	Description
first Run	int	
last Run	int	
HV LAYER1	float[7]	
HV LAYER2	float[7]	
HV LAYER3	float[7]	
integration time	int	integration time for S&H
time reference	int	T0 for electronics (trigger latency)
time walk correction	func/histo?	Depends on threshold and charge
energy mode	int	0/1 = ToT/S&H

STRIP

Name	Type	Description
layer ID	int	0-2
sheet ID	int	0-1
strip ID	int	
channel	int	0-63
GEM-ROC	int	0-22 ?
FEB	int	0-3
chip	int	0-1
strip capacitance	float	pF
strip quality	int	good, bad, disconnected, noisy…

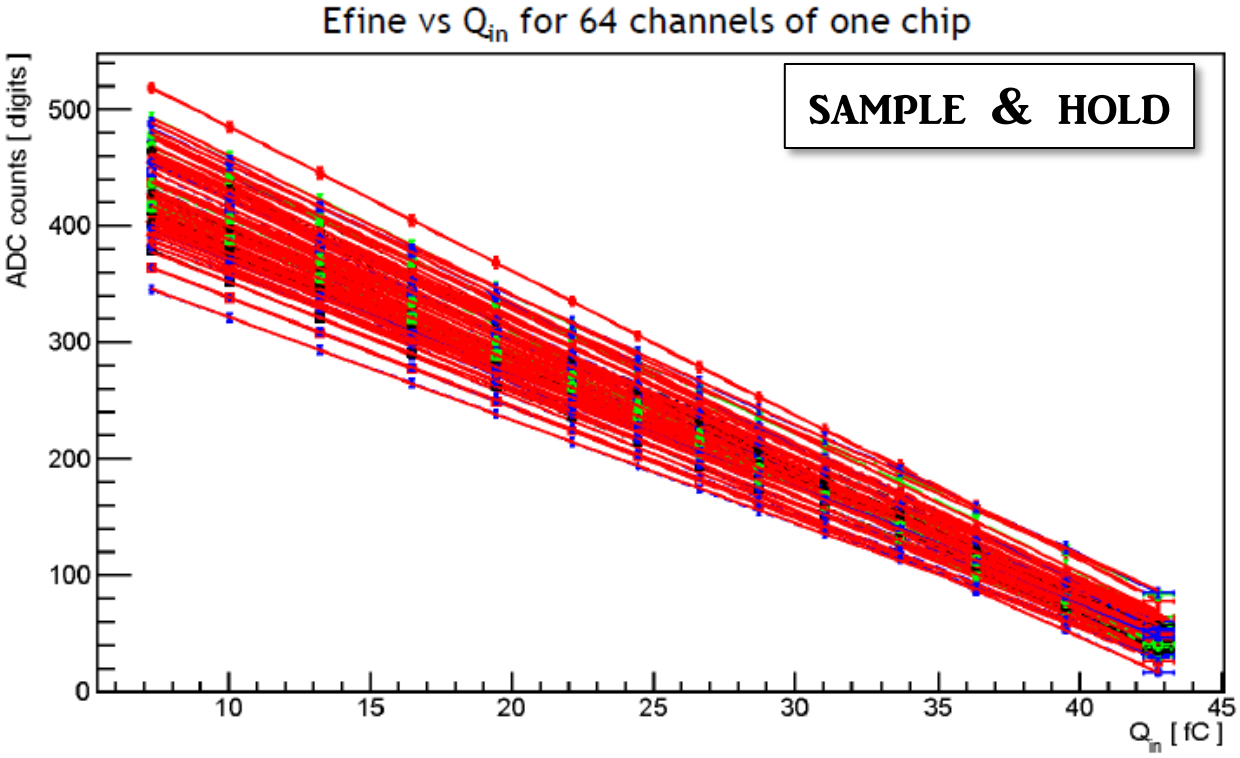
T-BRANCH

Name	Type	Description
noise T	float	mV *or* fC
threshold T	int	digit
T time min	int[4]	one value for each TAC - T branch
T time max	int[4]	one value for each TAC - T branch
time window	int[2]	time window to select signal (ROC-wise)

E-BRANCH

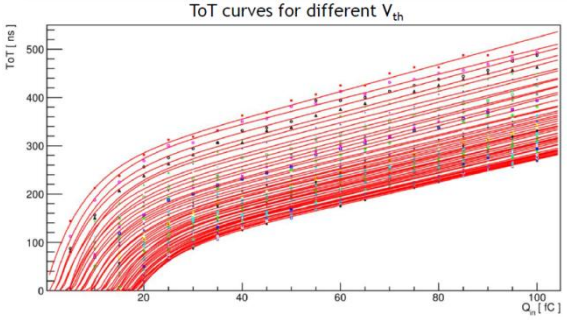
Name	Type	Description
noise E	float	mV *or* fC
threshold E	int	digit
E time min	int[4]	one value for each TAC – E branch
E time max	int[4]	one value for each TAC – E branch
E calibration slope	float	
E calibration offset	float	
Q cut	fC	threshold to select valid signals (software)

E CALIBRATION



SAMPLE & HOLD

TIME OVER THRESHOLD



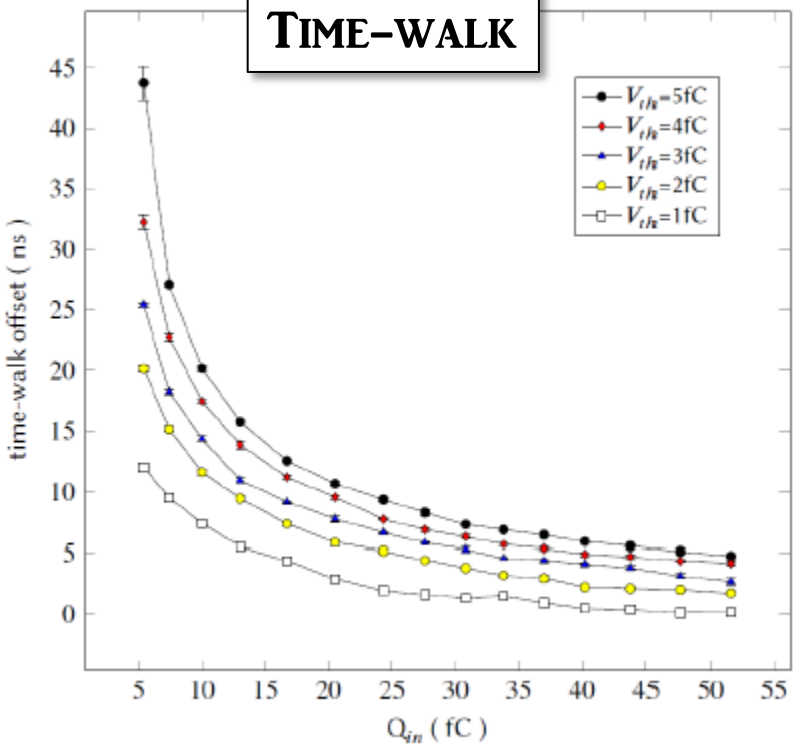
THRESHOLDS

LUT created by scans on each channel

- Threshold scans allow also to evaluate the noise for each channel (σ = noise)
- This information is used to set the threshold at a given value (e.g. 3σ) above the baseline in order to equalize the channels noise rate (few kHz)

T CALIBRATION

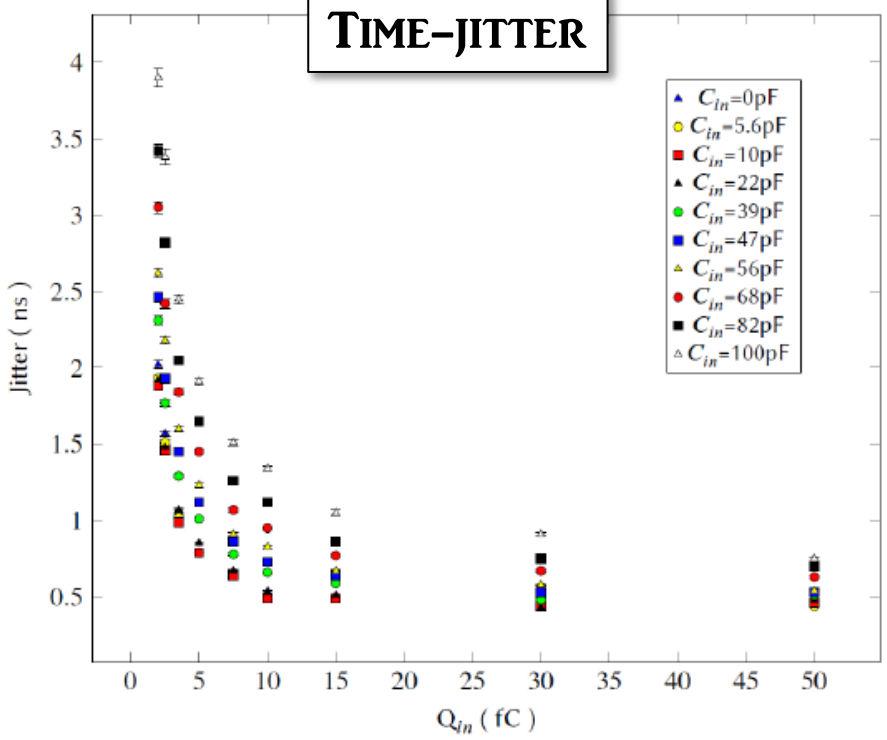
TIME-WALK



Depends on:
- input charge
- threshold level

→ for each channel

TIME-JITTER



Depends on:
- input charge
- input capacitance

→ for each strip

re-evaluation with longer signal times …….. **TO DO**

Analysis

```
*** Analysis ***

Validation with particle gun
- Single particle performances - Isabella/Peter?
- Multiparticle perfomances - Isabella/Peter?

Validation with benchmark channels
- ? (?) - Peter?/analysis people?

analysis of cosmic rays
- Data conversion (done) - Aiqiang
- Input/output tests (done) - Lia
- Mapping - Lia
- Check basic distributions including T, Q, hitmaps  (2 weeks) - Jingyi/Linghui
- Validation of uTPC reconstruction - Riccardo?
- Track (straight line) reconstruction - Hongpeng
- Integration, run the whole procedure and check the distributions  - Jingyi/Linghui/Hongpeng/Liangliang
- Study the calibration methods and details - Jingyi/Linghui
- Iteration of calibration and alignment - Jingyi/Aiqiang/Will//Linghui
- Performance studies (resolution, efficiency, occupancy)
```

COSMIC RAY DATA

It was decided that the cosmic data are pre-processed in **GRAAL** (since no official DAQ by now) →

1. upload **GRAAL** to CVS …….. **DONE**
2. provide the data files ……... **DONE**
3. provide information on the content of the files …. **DONE**

R. FARINELLI
G. MEZZADRI

DATA

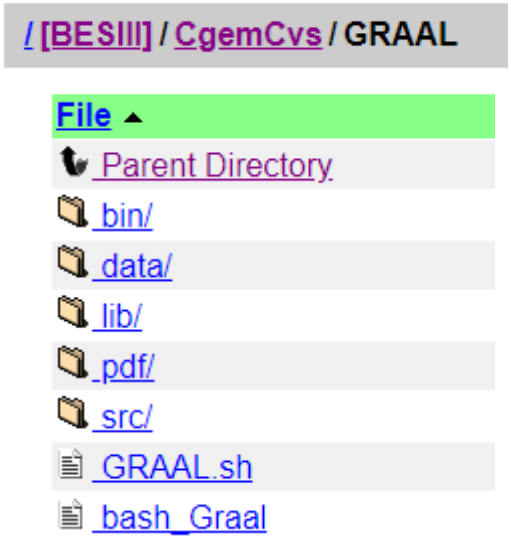
PROVIDED the data from L1+L2, of september 2019

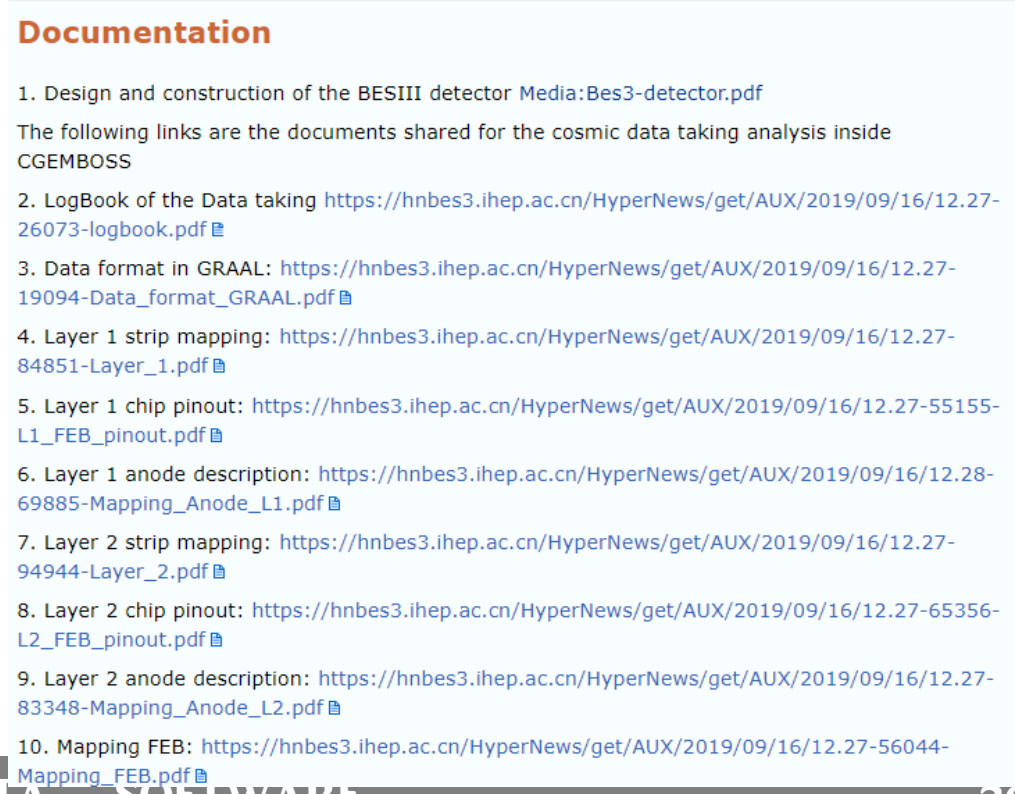
TO BE PROVIDED the new data, from L2 alone, of october 2019

COSMIC RAY DATA

R. FARINELLI
G. MEZZADRI

1. **GRAAL** on CVS
   https://docbes3.ihep.ac.cn/viewvc/cgi-bin/viewvc.cgi/BESIII/CgemCvs/GRAAL/
2. Data files are on IHEP machines in the folder: /bes3fs/cgemCosmic/data
3. Information about the files are in:
   https://docbes3.ihep.ac.cn/~cgem/index.php/Documentation





Documentation

1. Design and construction of the BESIII detector Media:Bes3-detector.pdf

The following links are the documents shared for the cosmic data taking analysis inside CGEMBOSS

2. LogBook of the Data taking https://hnbes3.ihep.ac.cn/HyperNews/get/AUX/2019/09/16/12.27-26073-logbook.pdf
3. Data format in GRAAL: https://hnbes3.ihep.ac.cn/HyperNews/get/AUX/2019/09/16/12.27-19094-Data_format_GRAAL.pdf
4. Layer 1 strip mapping: https://hnbes3.ihep.ac.cn/HyperNews/get/AUX/2019/09/16/12.27-84851-Layer_1.pdf
5. Layer 1 chip pinout: https://hnbes3.ihep.ac.cn/HyperNews/get/AUX/2019/09/16/12.27-55155-L1_FEB_pinout.pdf
6. Layer 1 anode description: https://hnbes3.ihep.ac.cn/HyperNews/get/AUX/2019/09/16/12.28-69885-Mapping_Anode_L1.pdf
7. Layer 2 strip mapping: https://hnbes3.ihep.ac.cn/HyperNews/get/AUX/2019/09/16/12.27-94944-Layer_2.pdf
8. Layer 2 chip pinout: https://hnbes3.ihep.ac.cn/HyperNews/get/AUX/2019/09/16/12.27-65356-L2_FEB_pinout.pdf
9. Layer 2 anode description: https://hnbes3.ihep.ac.cn/HyperNews/get/AUX/2019/09/16/12.27-83348-Mapping_Anode_L2.pdf
10. Mapping FEB: https://hnbes3.ihep.ac.cn/HyperNews/get/AUX/2019/09/16/12.27-56044-Mapping_FEB.pdf

Cosmic Ray Data

It was decided that the cosmic data are pre-processed in **GRAAL** (since no official DAQ by now) →

- upload **GRAAL** to CVS …….. DONE
- provide the data files ……... DONE
- provide information on the content of the files …… DONE

R. Farinelli
G. Mezzadri

- translation of the **GRAAL** info to the **CgemBoss** one … DONE
- input/output test ……..…….. DONE
- mapping consistency …….. ONGOING
- variable distributions …….. ONGOING

A. Guo
L. Lavezzi
JY. Zhang

COSMIC RAY DATA

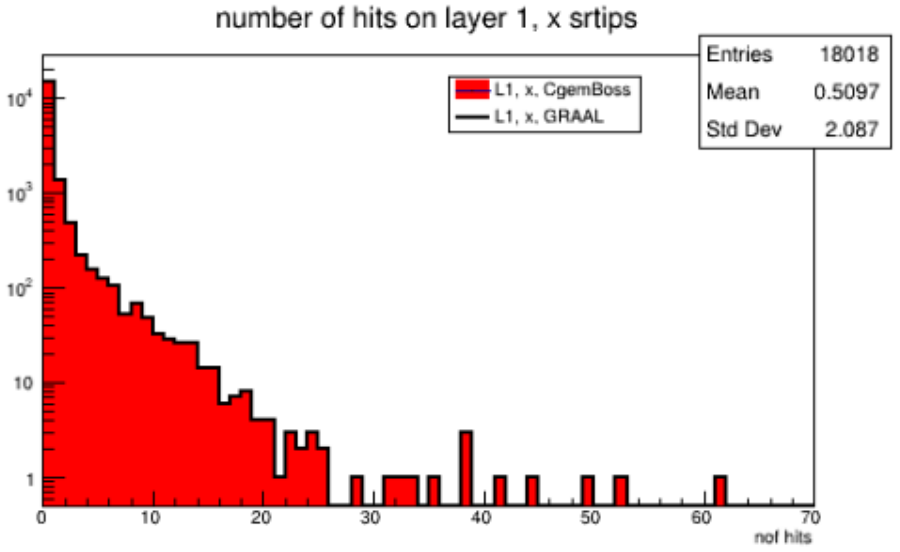
A. GUO
L. LAVEZZI

- ReadCosmicRayData package created and updated

/ [BESIII] / CgemBossCvs / Cgem / ReadCosmicRayData / src

File ▲
Parent Directory
components/
ReadCosmicRayData.cxx
TestInputOutput.cxx

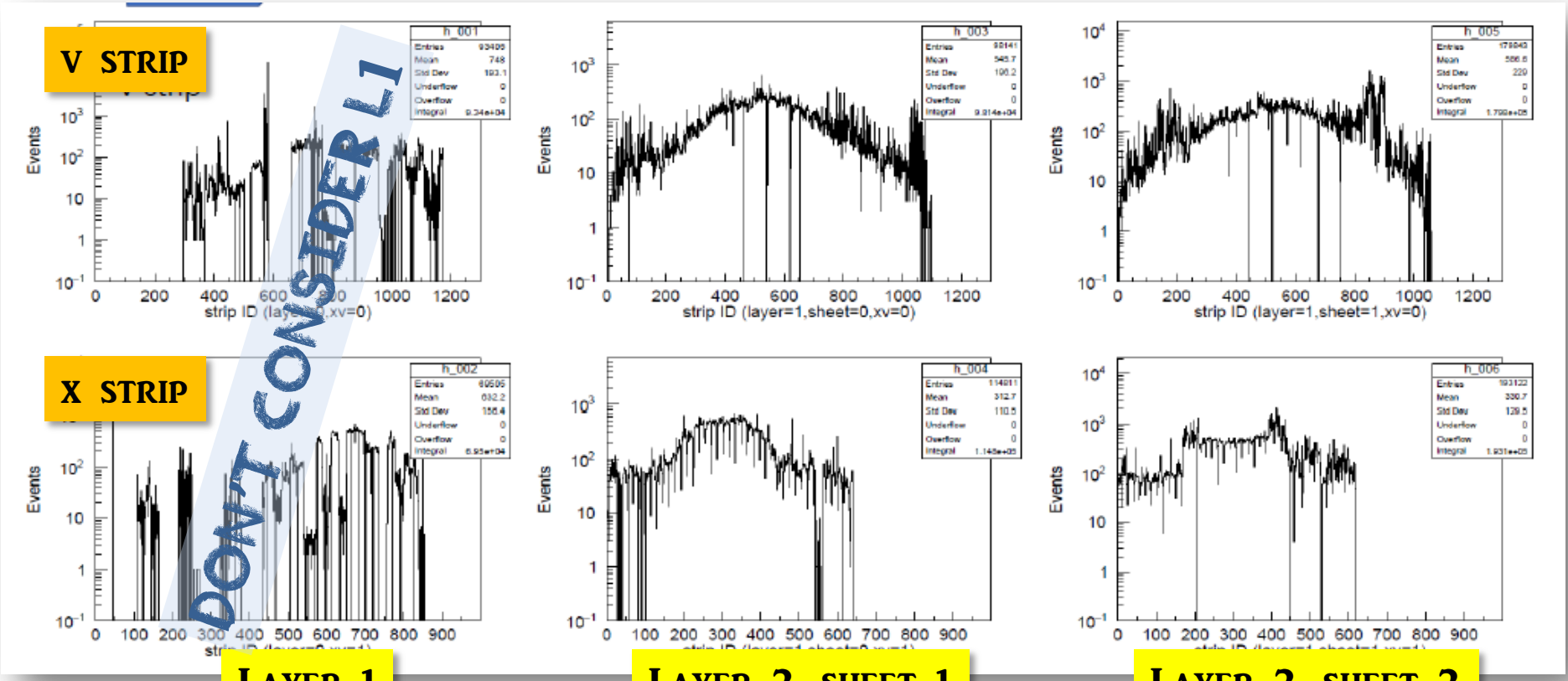
- Input/output succesfull on all the variables (∀ layer, strip type)
  - nof hits
  - strip ID
  - strip charge
  - strip time



- mapping consistency check ongoing

COSMIC RAY DATA

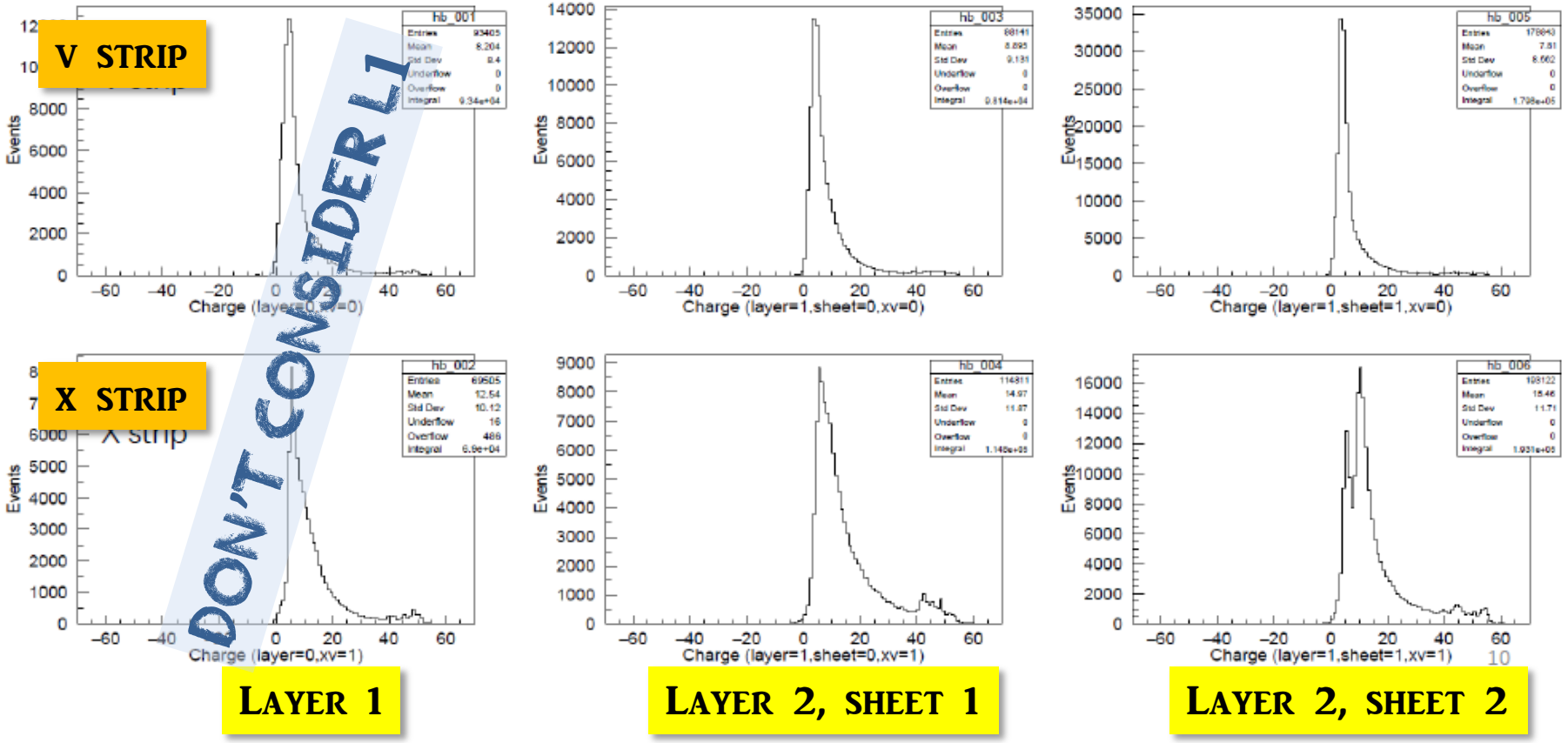
STRIP IDS (RUN 1)



- some strip ID are missing → they are from FEBs which have been replaced
- **request** - list of dead channel required …… TO DO
  - mapping strip ID –to – ROC/FEB/TIGER/channel ….. TO DO

COSMIC RAY DATA

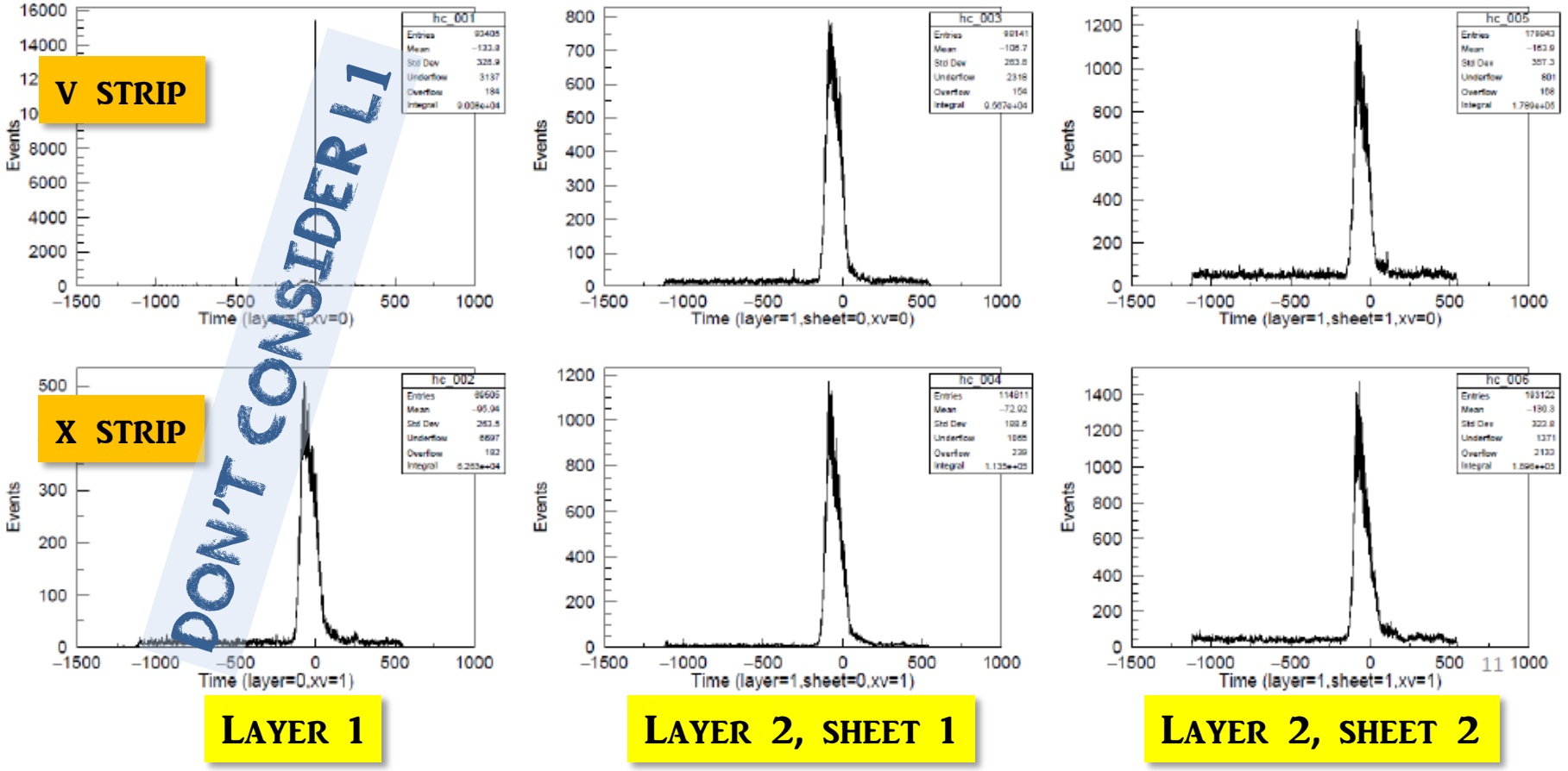
CHARGE (RUN 1)



- charge distributions look reasonable
- **request** - list of saturation values for each channel …… TO DO

COSMIC RAY DATA

TIME (RUN 1)



- time distributions look reasonable
- **request** - list of noisy channels ..... TO DO

COSMIC RAY DATA

It was decided that the cosmic data are pre-processed in **GRAAL** (since no official DAQ by now) →

- upload **GRAAL** to CVS …….. DONE
- provide the data files (data taking of *september*) …..... DONE
- provide information on the content of the files …… DONE

R. FARINELLI
G. MEZZADRI

- translation of the **GRAAL** info to the **CgemBoss** one … DONE
- input/output test ……..…….. DONE
- mapping consistency …….. ONGOING
- variable distributions …….. ONGOING

A. GUO
L. LAVEZZI
JY. ZHANG

Requests (to provide/implement in CgemBoss):

- mapping of stripID to ROC/FEB/TIGER/channel ….. TO DO
- list of saturation values for each channel ……....TO DO
- list of noisy/dead/disconnected channels …….. TO DO
- list of thresholds/noise for each channel ……TO DO

It is proposed to create a look up table and functions to read it

… *AND* 100K EVENTS FOR EACH LAYER, FOR EACH SHEET, IN THE SAME CONDITIONS

ANALYSIS

```
*** Analysis ***

Validation with particle gun
- Single particle performances - Isabella/Peter?
- Multiparticle perfomances - Isabella/Peter?

Validation with benchmark channels
- ? (?) - Peter?/analysis people?

analysis of cosmic rays
- Data conversion (done) - Aiqiang
- Input/output tests (done) - Lia
- Mapping - Lia
- Check basic distributions including T, Q, hitmaps  (2 weeks) - Jingyi/Linghui
- Validation of uTPC reconstruction - Riccardo?
- Track (straight line) reconstruction - Hongpeng
- Integration, run the whole procedure and check the distributions  - Jingyi/Linghui/Hongpeng/Liangliang
- Study the calibration methods and details - Jingyi/Linghui
- Iteration of calibration and alignment - Jingyi/Aiqiang/Will//Linghui
- Performance studies (resolution, efficiency, occupancy)
```

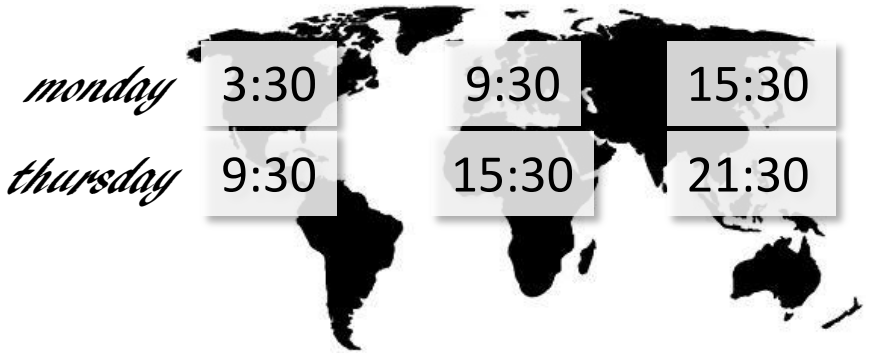
- MC data analysis all in standby …….. **STANDBY**
  until the global tracking will be released

cosmic ray data analysis is the main topic now!

INFORMATION SHARING

- regular software meetings (vidyo) –

  find a time good for China, Europe and US, not easy!
  We pick the best solution each time →
  (old time slots, updating…)



- **new!** CGEM wiki page
  https://docbes3.ihep.ac.cn/~cgem/index.php/Main_Page
- CgemBoss wiki page
  https://docbes3.ihep.ac.cn/~offlinesoftware/index.php/CgemBoss_information
- **new!** Hypernews - *specifically dedicated to CGEM software*
  https://hnbes3.ihep.ac.cn/HyperNews/get/cgemsft.html
- private e-mail exchange - *not so good, but sometimes happens!*

- list of contact persons ..... ONGOING
- GANTT ..... ONGOING

requests and bug reports are quite good right now

Warning to the "Bosses"

• **policy for poster/talks** to conferences is respected by everyone

• **we need a policy for publications**

At least three papers are going to be submitted to journals soon:

- one about the *chinese* digitization model
- one about the PARSIFAL (a.k.a. GTS) digitization
- one about the high rate (ok, maybe this is not within BESIII)

• in any case, since we have (since always) the problem of two digitizations, please **don't fix the rules in between the two articles**, otherwise one will be signed by only a part of the group and the other will be signed by everyone and this would not be fair!

THAT'S ALL FROM MY SIDE,

THANK YOU FOR THE ATTENTION!

BACKUP

Global Tracking

track finding
- segment finder in ODC and CGEM & matching
- not good for short tracks

CgemBoss665**b**

global track finding
- Hough transform in ODC + CGEM (v12)

global track fitting
least square method

CgemBoss665**c**

Track finding
- *updated* Hough transform

not yet released

Milestone 6 completed?

Tune what to what? ...and why?

comparison to the **test beam data** collected on **April 2018**

RD51 testbeam
- H4 beam line, SPS-NA (CERN)
- GOLIATH dipole magnetic field
- 150 GeV/*c* muons

triple-GEM specifics
- planar triple-GEM, 10 x 10 cm^2
- double view readout, APV-25
- gas: Ar:*i*-C_4H_{10} (90:10)
- HV: 275/275/275 V
- fields: 1.5/2.75/2.75/5 kV/cm
- magnetic field *off* or *on* (B = 1T)
- incident angle: 0°, 5°, 10°, 15°, 20°, 30°, 45°

Settings we kept in the GTS simulation
- conversion factor : 30 ADC = 1 fC (*)
- threshold : 45 ADC = 1.5 fC
- noise sigma: 15 ADC = 0.5 fC

(*) K. A. Ntekas, CERN-THESIS-2016-019