Discussion on the integrator specifications with comparison of the 3 options

Debriefing meeting at LPC , 28 April 2016

François Vazeille

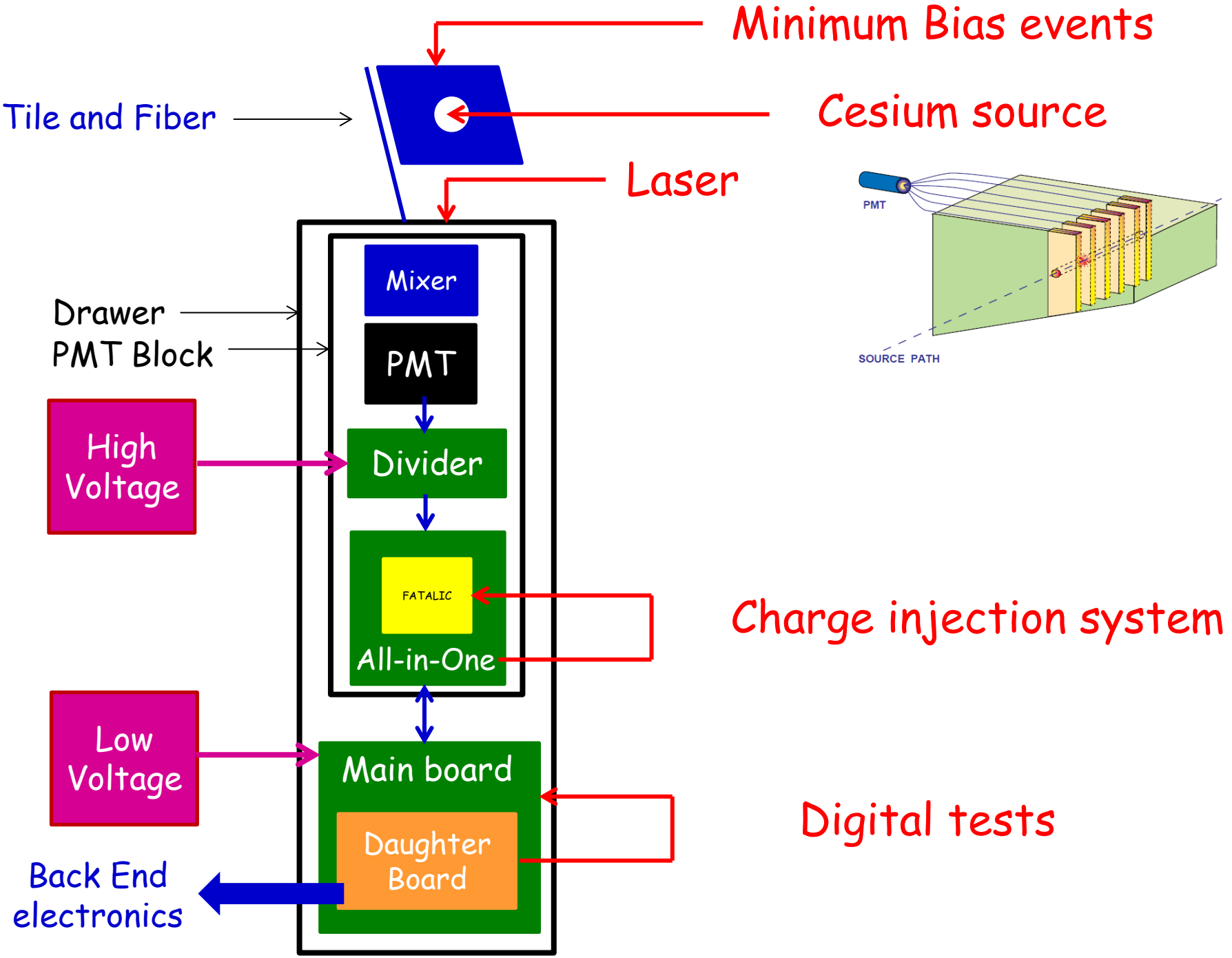
- Summary of the TileCal Calibration systems in the upgrade scheme.
- TileCal data for the Cesium source moving.
- TileCal data for the Luminosity measurements.
- Chicago integrator.
- Argonne integrator.
- Clermont-Ferrand integrator.
- Summary of specifications.

• Summary of the TileCal Calibration systems in the upgrade scheme

4 complementary systems acting at various levels of the whole electronic chain + likely a 5th system for the Back end electronics not shown here.

1. At the Tile/Fiber level: Cesium radioactive source and p-p Minimum Bias events.
2. At the Light Mixer/PMT level: Laser.
3. At the Very Front End electronics level: Charge Injection System.
4. At the Front End Board digital level: Digital tests.

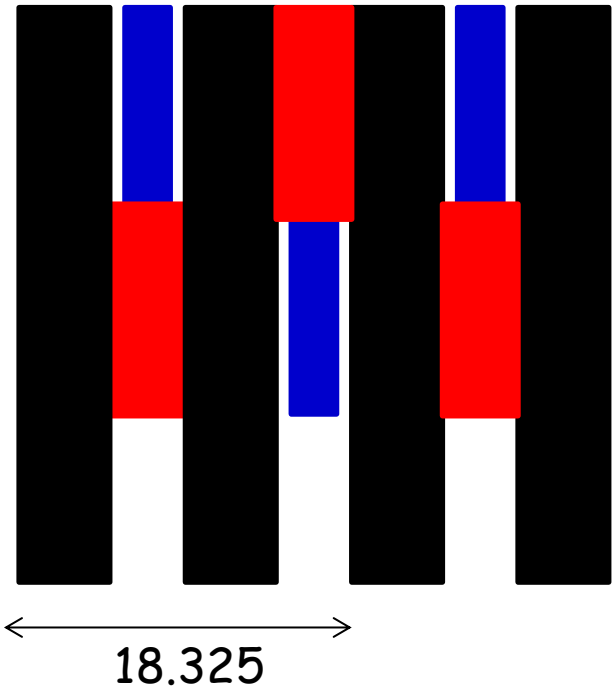
1. PMT gain adjustment/calibration and long term monitoring, plus calibration transport from the ATLAS Test Beam.
2. Short term monitoring and calibration.
3. Electronics calibration in pC.
4. Working tests of the Main Board/Daughter board communication.

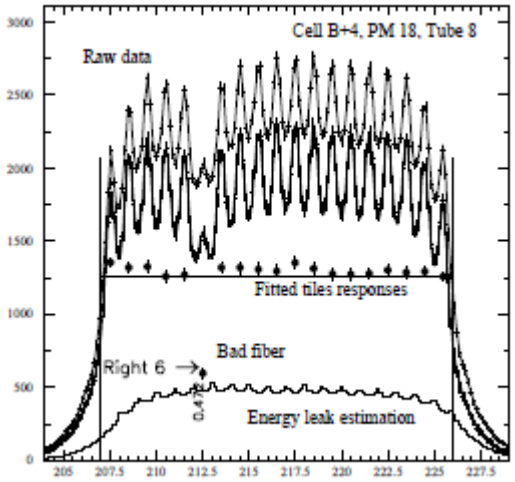

Minimum Bias events
Tile and Fiber
Cesium source
Laser
PMT
SOURCE PATH
Mixer
Drawer
PMT Block
PMT
High Voltage
Divider
FATALIC
All-in-One
Charge injection system
Low Voltage
Main board
Daughter Board
Digital tests
Back End electronics

• TileCal data for the Cesium source moving

- Source speed: 30 cm/s.
- TileCal scheme

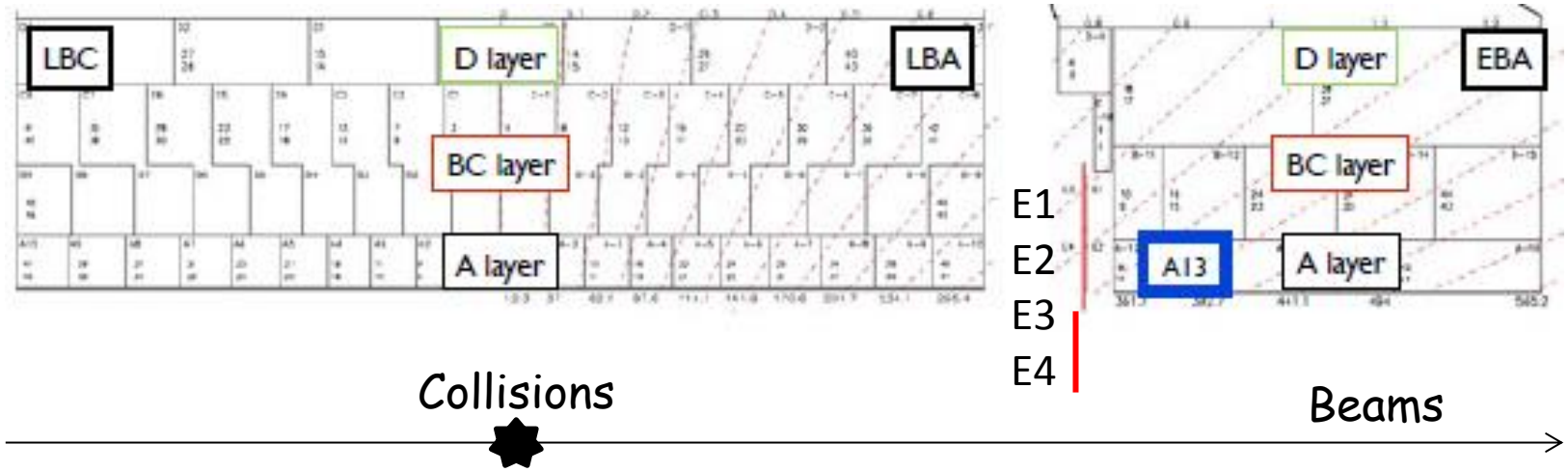
Steel Master = 5.0 mm
Steel Spacer = 4.05 mm
Plastic Tile = 3 mm
Period = 18.325 mm
= 5 + 4.05 + 5 + 4.05 + *G*
= 18.10 + *G* *G* = Glue





- Transit time:
  In a Tile: 0.3/30 = 0.01 s = 10 ms.
  From a Tile to the following one: 1.8325/30 = 61.08 ms.
- The optimum integration time is 10 ms,
  that can be increased by two means:
  - Digital sum without any problem.
  - Analog integration using different time constants.

- Orders of magnitude from Ilya's talk



By taking into account the non-replacement of the sources (Decreased activity)

- Cells A to D: 60 to 90 nA.
- Cells E1&E2: ≤ 4 nA.
- Cells E3&E4: ~ 0.06 nA.
  but no Cs in them

} Improvements of scintillators/Dividers are possible.

Comment: for the E cells, the constraint of 10 ms with respect to adjacent Tiles is no longer relevant ⇒ digital sums are possible, and/or use of a 20 ms time in the analog mode in order to reach these low values.

• TileCal data for the Luminosity measurements

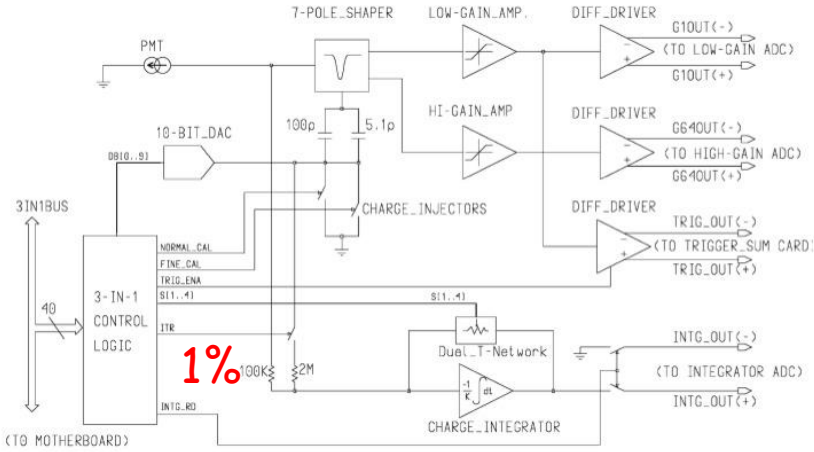
- Orders of magnitude from Ilya's talk

♦ Maximum value at the highest Luminosity:
- A13 cell: 8 μA.
- E cells: 100 μA $\Rightarrow$ no saturation for Argonne and Clermont-Ferrand.

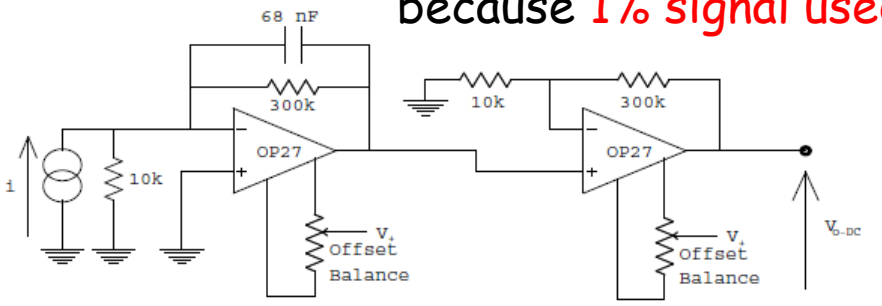
♦ Minimum value for the vdM scan at very low Luminosity:
up to 0.02 nA to cover almost all the A and E cells and part of B cells, if not 0.05 nA.
with which accuracy?
1% is impossible,
5 % ? 3% ?

• Chicago integrator

- **Principle** (Present ATLAS scheme): in 2 steps

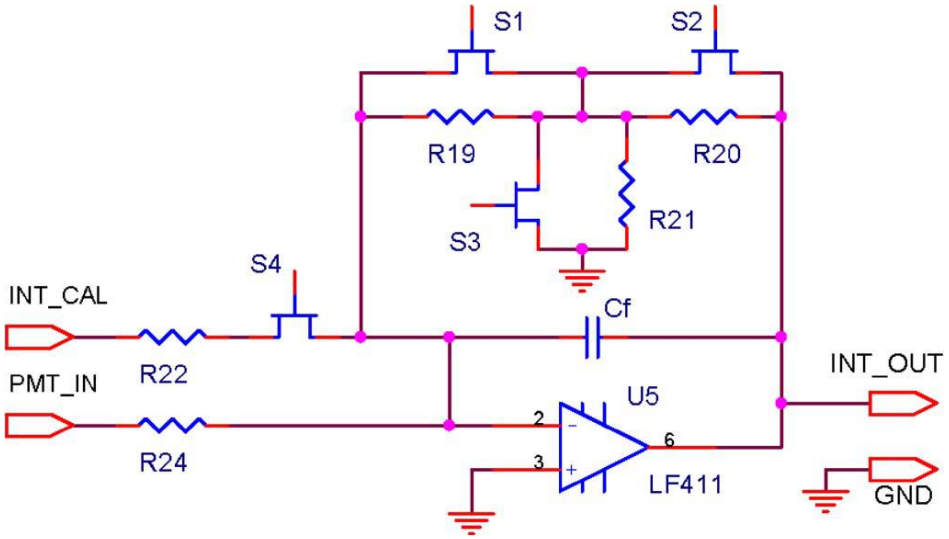


Amplification
because 1% signal used



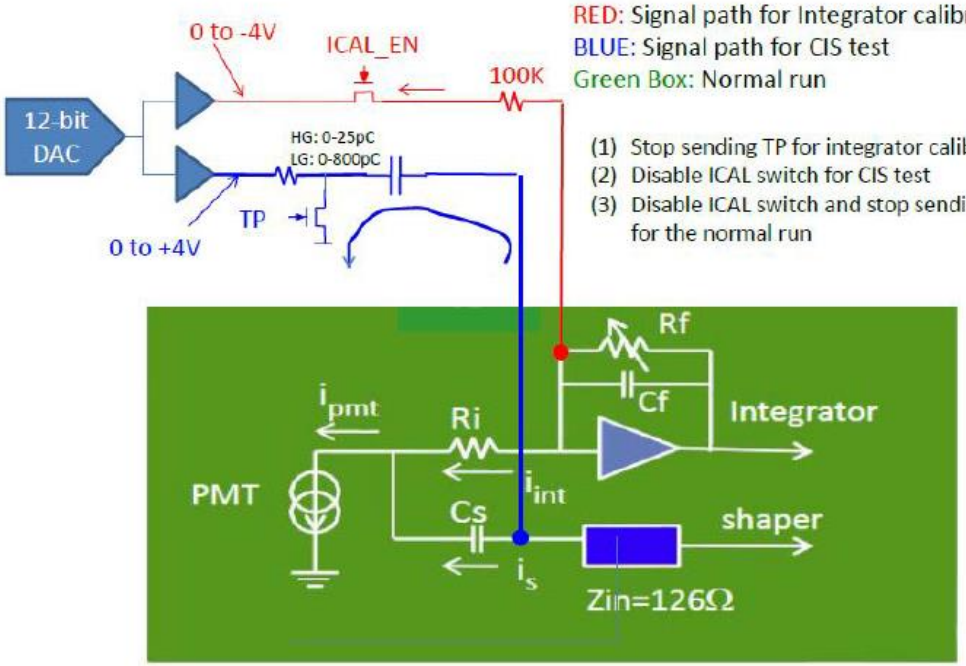
Integration time
from feedback capacitance/resistor

Combination of switches to control
- Timing and Gain.
- DC injection for calibration.



T = 10 + RC in ms, with C=0.1 10^{-9}
From Ilya (Present 3-in-1): R from 2.7 to 100 MΩ
⇒ 10. 27 ms to 20 ms. (Ilya said 10.3 to 20).

Integrator and CIS Calibrations and Normal Run



RED: Signal path for Integrator calibration
BLUE: Signal path for CIS test
Green Box: Normal run

(1) Stop sending TP for integrator calibration
(2) Disable ICAL switch for CIS test
(3) Disable ICAL switch and stop sending TP for the normal run

PMT Current Distribution over Shaper/Integrator

Case I: Cs calibration (f<17Hz)

$$\omega \ll \frac{1}{(Ri + Zin).Cs}$$

$$Is \rightarrow 0$$

$$I\ \text{int} \rightarrow Ipmt$$

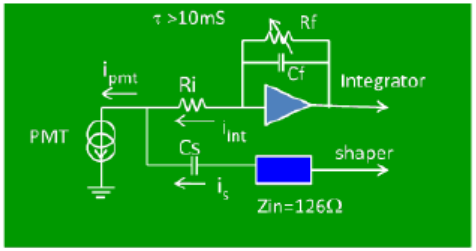
Case II: Minimum current bias:

$$\omega \gg \frac{1}{(Ri + Zin).Cs}$$

$$Is = Ipmt \cdot \frac{Ri}{Ri + Zin}$$

$$I\ \text{int} = Ipmt \cdot \frac{Zin}{Ri + Zin}$$

For Ri=100K, Cs=0.1u, Zin=126, ω = 100rad/s.
Shaper cut-off frequency: 1.4KHz at low end.



R_f: sets integrator gain (6 settings).
R_fC_f: suppresses output ripple.

PMT has an output capacitance of <40pF, it is not shown in above schematic and formulas.

- Performances

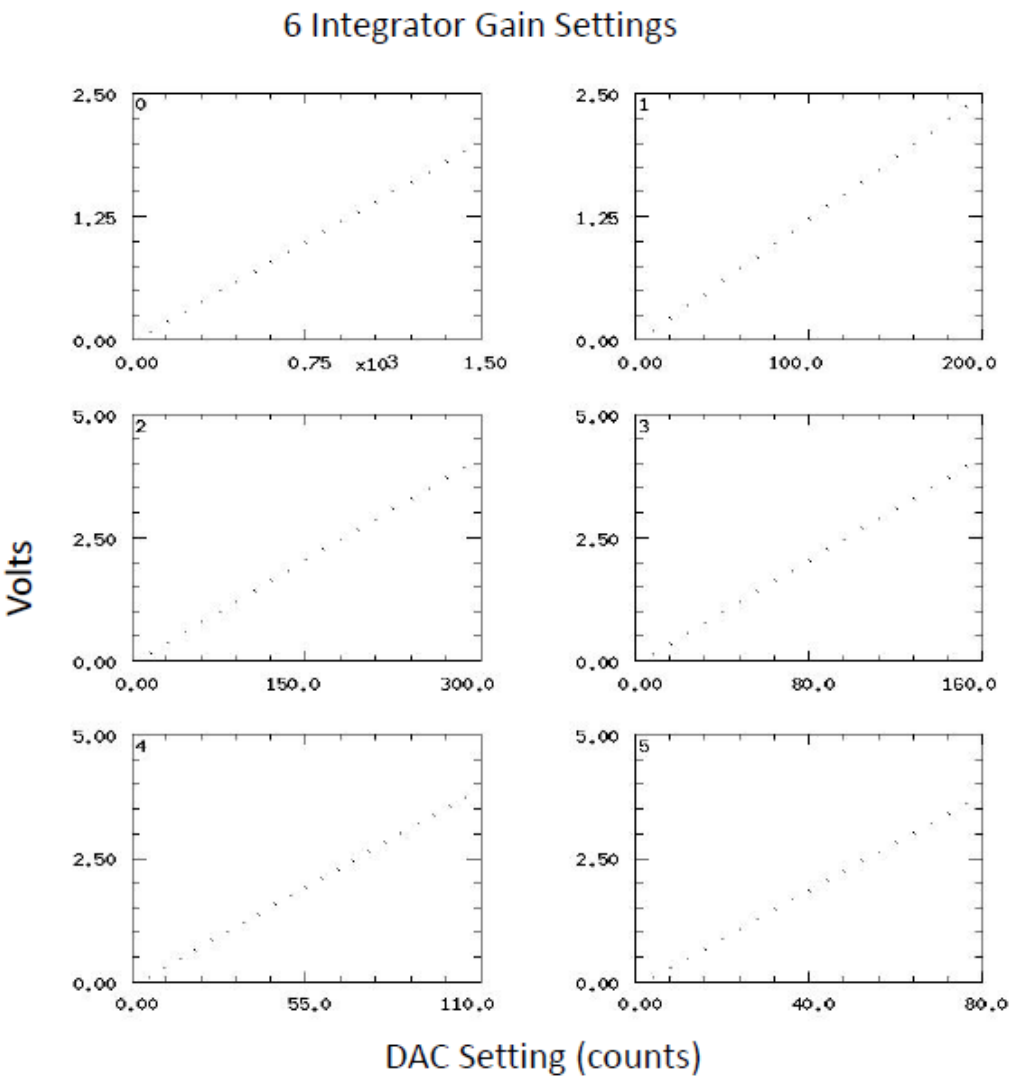
Present ATLAS scheme (from TIPP 2011 Chicago)

- Range 0.01 nA-1.4 μA.
- Non linearity < 1%.
- 12 bit ADC.
- Signal noise 0.003 nA

Not credible
(never demonstrated)

The PMT dark current is ≤ 2 nA at 800 V, well above this noise !

Upgrade scheme



- 6 gains … not given in current (as for the present ATLAS)
  - 0: 0-750
  - 1: 0-200
  - } 0-2.5 V
  - 2: 0-300
  - 3: 0-160
  - 4: 0-110
  - 5: 0-80
  - } 0-5.0 V

DAC counts

- Does not correspond to python soft sent by Kelby very recently

maxval = [3200,180,300,120,160,90]
minval = [64,6,4,4,4,9]

For times > 20 ms ⇒ summations

Example of a reply of Ilya to a question of FV about current of 0.5 nA
in the current ATLAS scheme.

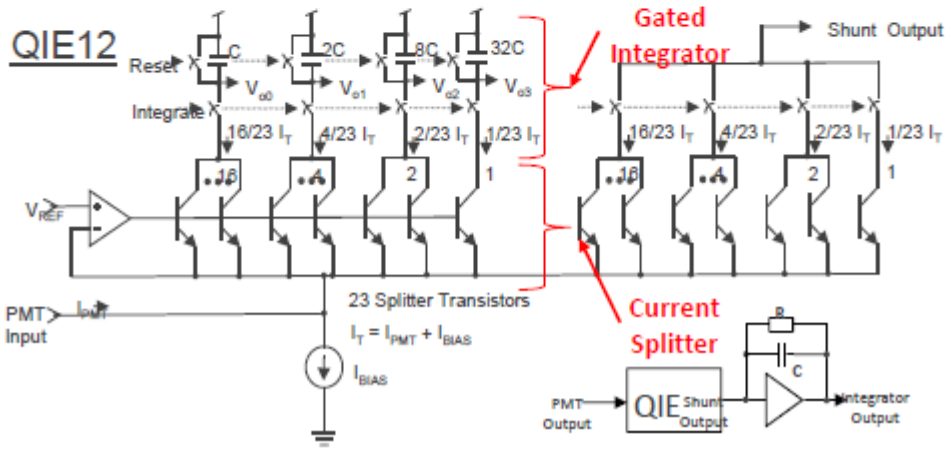
Hi Francois, yes, these points are averaged over about 10 measurements
each having the int.time of 20ms.
So effectively the int.time is about 200ms on this plot.
Best,
Ilya

On Fri, Apr 8, 2016 at 1:20 PM, François Vazeille <vazeille@clermont.in2p3.fr> wrote:
Hello Ilya, looking at your very interesting and useful talk on the Cs system,
I have a question about the VdM scan through the cell A13 (slide 6) where you measured
a current of 0.5 nA.
What was the integration time of this measurement?
Did you add several measurements in order to increase the integration time?
With my best regards,
François

- Argonne integrator
  - Up to 8 μA: external

≥ 40% signal used

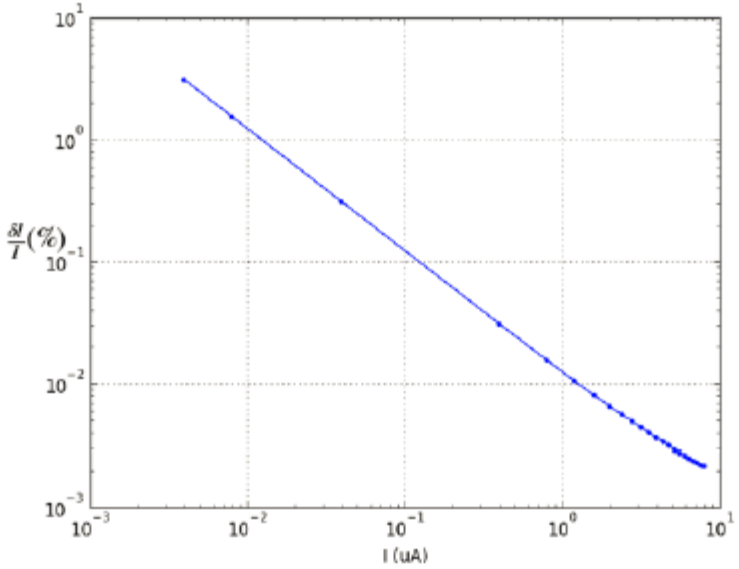
- **Current Integrator Part 1: External Circuit**
  - Uses the Shunt Output Circuit on the QIE
    - The Dump Circuit is another set of splitter transistors that can be switched in through the slow control interface to the chip
    - Up to 60% of the input current can be diverted to an output pin. The integrator circuit would receive as low as 40% of the collected charge.
    - The saturation of the QIE is 875 pC/25 ns when the current splitter is turned on.
    - Everything works as specified. The electronic noise with the splitter enabled is < 2 fC.
  - Digitization
    - The shunt current is processed & digitized by an external integrator, 16 bits
    - The maximum range will be ~8 uA - ~les than half of Range 0 Range of the QIE



- Integration time of 2 ms, but will be fixed later at a constant value (10 ms ?).
- 16-bit ADC range, having 122 pA/count → That does mean it is the accuracy.

Above 8 μA: internal from digital sum

- **Current Integrator Part 2: Digital Integration**
  - For currents above 8 uA, will use Digital Integration of the QIE data
    - Digital integration simplifies the design on the analog integrator (fewer ranges).
    - The fractional uncertainty for the digital is less than 0.2% for currents > 0.1 μA (μ=2.5).
    - This is easily implemented in pre-processor (along with the Look-up Table for the QIE data)



- It is a simulation.
- The integration time is not indicated, but it is 10 ms from Ilya.

- This plot goes up to 6 nA, but with an error of about 4%.
- 0.2% above 100 nA but the noise level is very optimistic.
- Used in fact above 8 μA.

• Clermont-Ferrand integrator

- Accuracy calculations on digital sum from the present noise performance

- Noise over the whole frequency spectra: 8 fC. (and not 7 fC HF noise only).
- For a realistic pulse shape (triangular), it corresponds to 400 nA, or 50 nA/fC.
- A "sum number" of 1 corresponds to the sum of 400 000 samples at 40 MHz.

	Cell value	Time (ms)	Sum number	Accuracy %
Cesium scan	A to D 60 nA	10	1	1.05
	A to D 90 nA	10	1	0.70
	E1-E2 < 4 nA	10	2	> 11.2
	E3-E4 ~ 0.06	Impossible, no Cs		
	Limit 1% 63 nA	10	1	1.0039
	Limit 1% 45 nA	10	2	0.9938

- For cesium scan, OK for A to D above 45 nA with an accuracy of 1% or better.
- E scintillators are likely thicker than Tiles
  $\Rightarrow$ a time > 20 ms could be chosen , but not too much.

- For Luminosity scans, larger times can be used.
- We must consider two extreme case: HL-LHC (7 10^{34} cm^{-2} s^{-1})
  and vdM scans (some 10^{30}).
- For vdM scans, we take a time of 2 minutes imposed by Luminosity blocks.

	Cell value	Time (ms)	Sum number	Accuracy %
Luminosity scan	HL minimum > 100 nA from (B-C)	10	1	< 0.63
	vdM A-B 0.02 nA	10	12000	28.9
	vdM A-B 0.05 nA	10	12000	11.5
	A, Limit 1% 0.58 nA	10	12000	0.9954
	A, 3% 0,192 nA	10	12000	3.007
	A, 5% 0.115 nA	10	12000	5.02

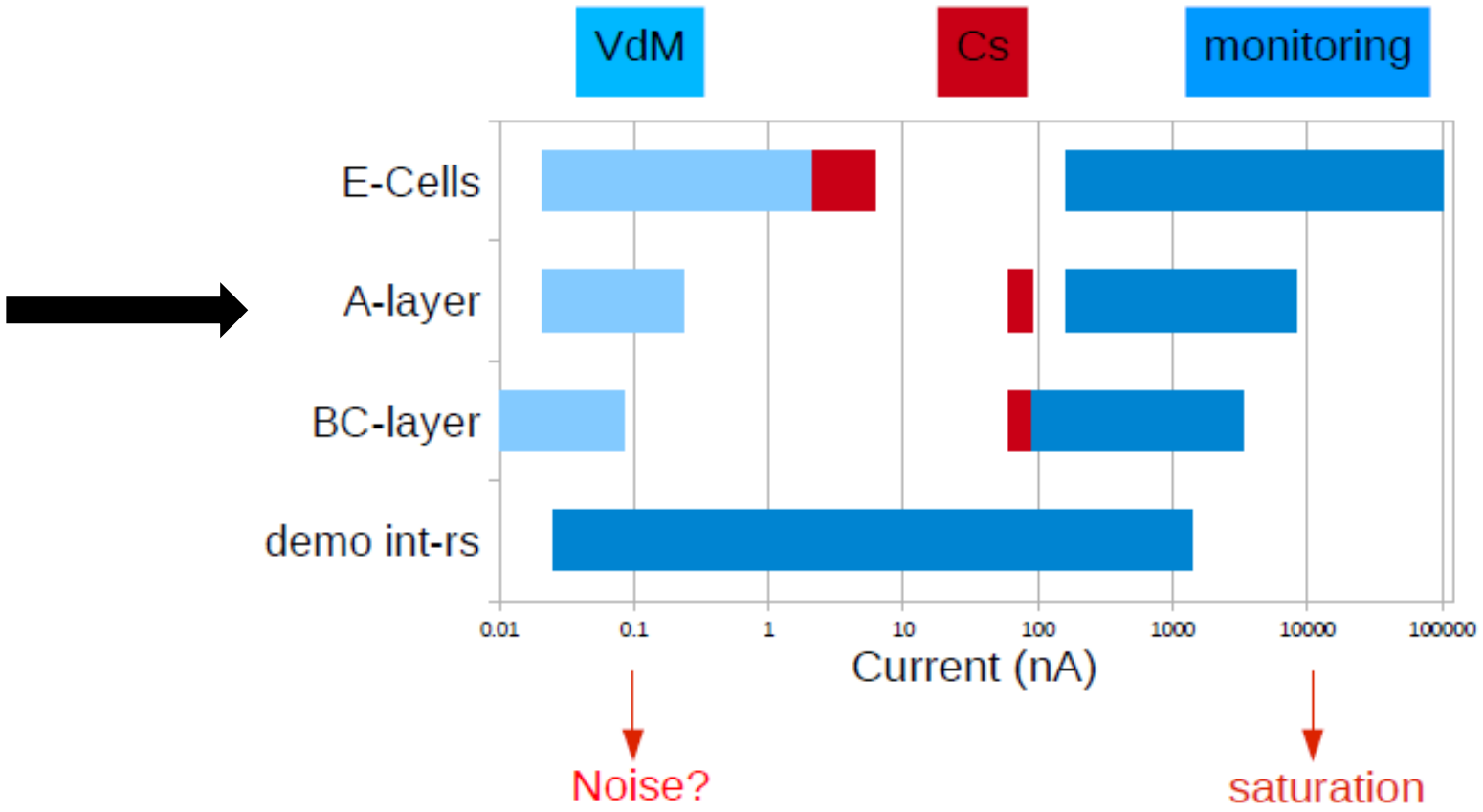
- No problem for HL scans, up to the 100 μA value on E cell without saturation.
- vdM scan possible for A cells with an accuracy ≥ 3%.

- Requirements on Analog measurements

♦ For Cesium scans with times of 10 or 20 ms
- Must overlap the Digital approach ⇒ Maximum value of 150 nA.
- Must reach low values up to some nA for E1-E2.

♦ For Luminosity scans at Low Luminosity:
to reach 0.05 nA in order to scan the B cells with an accuracy of 3% over durations of 2 minutes.

Dynamics from 0.05 nA on means to 150 nA in 10 or 20 ms.


VdM
Cs
monitoring
E-Cells
A-layer
BC-layer
demo int-rs
0.01
0.1
1
10
100
1000
10000
100000
Current (nA)
Noise?
saturation

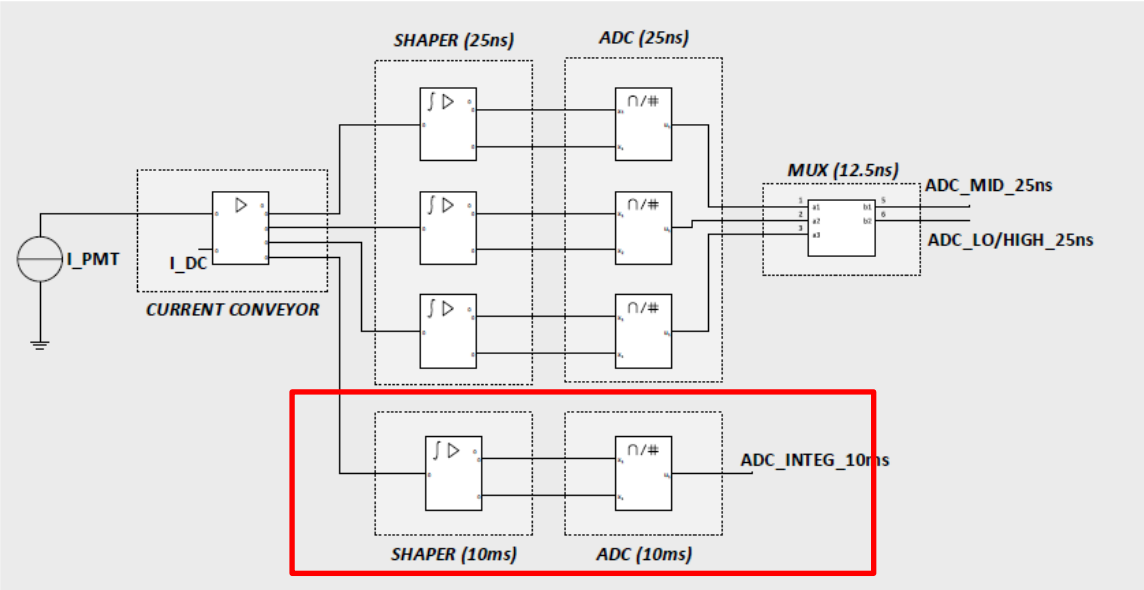
- TileCal data for the Cesium source moving
  - Recommendations from Ilya's talk

Check-List for any system to replace the current integrators

→ How do you transfer the EM scale, what would be the error?
→ Do you do Cs as good as before, 1% per measurement (10ms)?
→ Do you do Cs in E1&E2 to 1% accuracy on integral?
→ can you measure the currents upto 8uA (in A cells) and upto 100uA in E cells?
→ can you monitor the currents down to 0.02nA (w 1% per lumi block noise)?
→ can you have linearity (after all the corrections) between 1nA and 8uA within 1%?

Our specifications for the Analog approach

- A fourth current copy
 with the ADC inside the chip.
- A DAC calibration
 via current injection.



- Possibility of 2 integration times: 10 ms and 20 ms.
- Is it possible to use the same DAC ?
- Dynamics for Cesium scans
  - Maximum: 150 nA.
  - Minimum: 0.5 nA for E1-E2 cells.
- Dynamics for Luminosity scans
  - Maximum: no constraint $\Rightarrow$ we keep 150 nA and saturation accepted above.
  - Minimum: means are possible over 2 minutes $\Rightarrow$ to reach 0.05 nA.