Additional shielding for muon phase 2 upgrade and ongoing RD for future detector

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contributions from:
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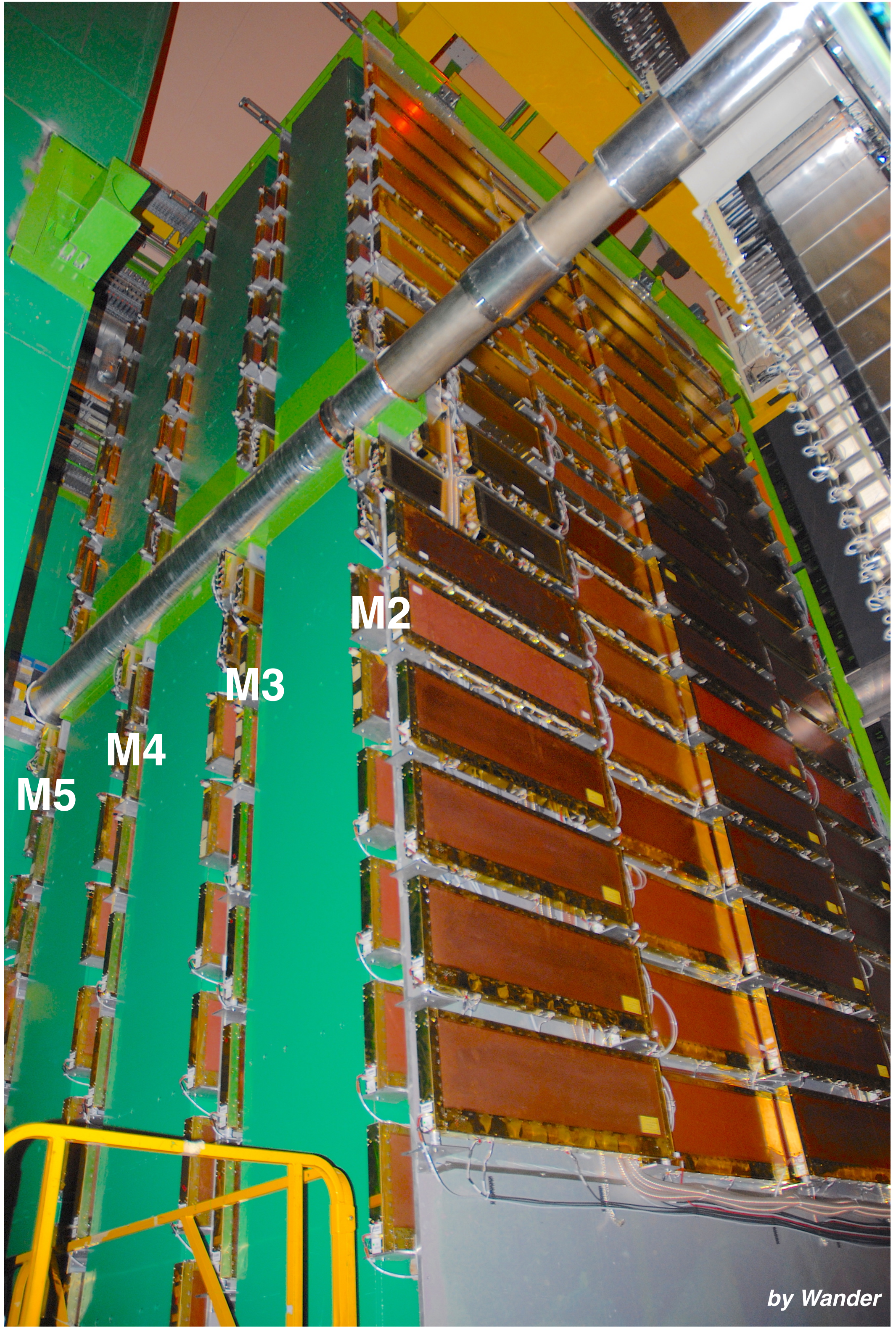
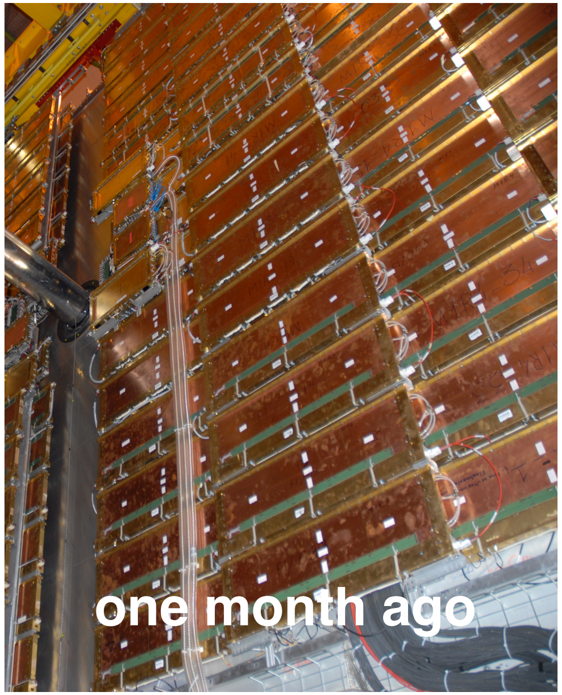
Upgrade II workshop, Amsterdam April 9th, 2019



Muon upgrade I is proceeding!

- M1 dismantling



- New readout boards and a new HCAL beam plug are being produced
- M2-M5 chambers are fully efficient and do not show sign of ageing

Performances at Upgrade I:

- Dead time induced inefficiency from rate increase, especially on inner regions (e.g. max rate on M2R1 ~ 600kHz/cm^2) : ~ 8% loss on dimuon events at beginning of Run 3, will be mitigated down to ~4.5% with the installation of new PAD cambers (MWPC) in M2R1,2 and M3R1 at LS3, or before.

LHCb-INT-2017-019

Towards phase 2 upgrade

The following max rates for phase 2 are obtained by scaling x10 the phase 1 extrapolations

	kHz/cm^2		kHz/cm^2		kHz/cm^2		kHz/cm^2
M2R1	5600	M3R1	1900	M4R1	650	M5R1	550
M2R2	850	M3R2	220	M4R2	85	M5R2	55
M2R3	90	M3R3	19	M4R3	9	M5R3	7
M2R4	20	M3R4	5	M4R4	3	M5R4	4

- average values approx 1/2 max values
- present official figure for phase 2 lumi is 1.5×10^{34}, but we're considering 2×10^{34} in this presentation

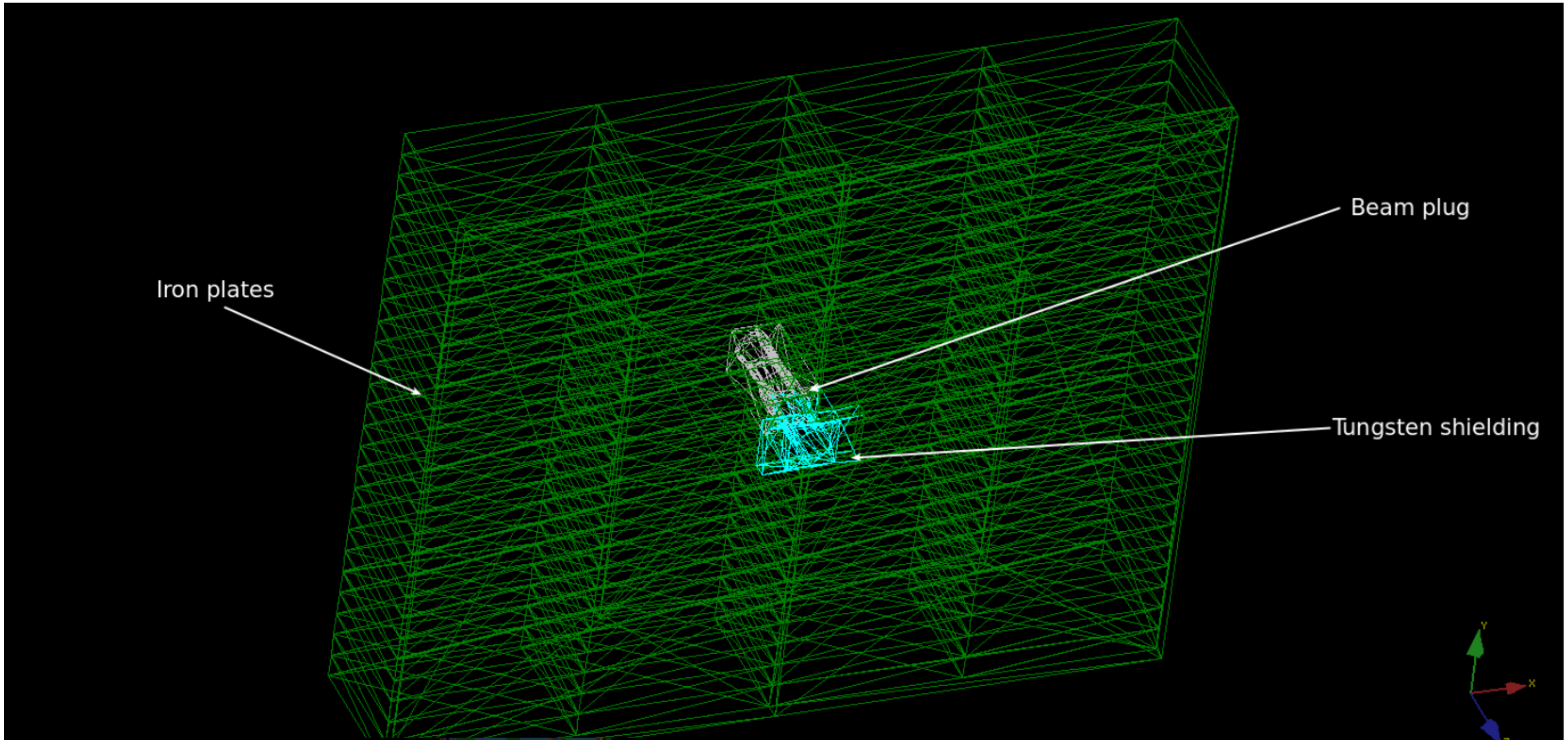
We would benefit a lot from additional shielding in front of M2

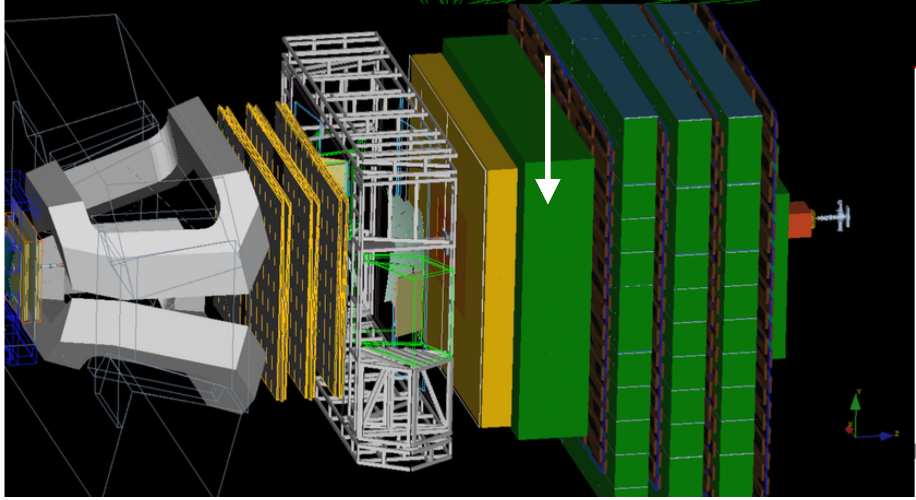
In addition:

New detectors, more tolerant to radiation and with an order of magnitude higher readout granularity are also needed for the inner regions

A new electronics for all of the other chambers will be needed, since the presently installed one will be 25 years old at the beginning of phase 2;
the replacement of most of the chambers in the detector due to ageing is to be carefully considered

Rate reduction: additional iron wall





Since HCAL will be no longer used in the trigger, we could replace with up to 1.7 m of Iron : additional 4.5 interaction lengths with respect to present configuration

simulation work by A. Sarti, P. Griffith

Prospects for iron wall installation

Possibility to reuse iron from Opera spectrometer

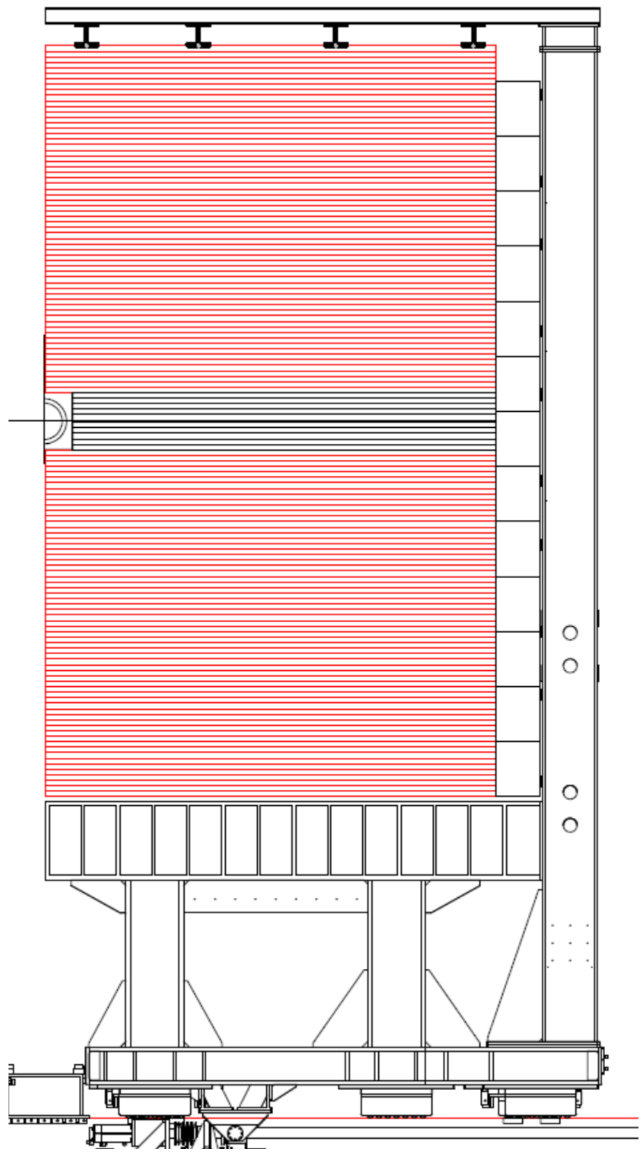
336 slabs 125x50x820 cm^3, 4 tons each

Several drawings have been already prepared, with different balance btw machining, reuse of HCAL mechanical structure, amount of iron

A manifestation of interest was sent by Guy to INFN in 2016; there's also interest from SHIP

Iron is presently stored at LNGS, less pressure for a quick decision than one year ago, but we must finalise soon our design to be ready for it

If there's a clear path to phase 2 upgrade, then it would be nice to profit of LS3 (2024) to install the iron wall; provided we can demonstrate that it is harmless at 2x10^{33}



A. Cardini, S. Saputi

https://indico.cern.ch/event/542822/contributions/2203984/attachments/1294310/1929234/A_New_Iron_Shielding_for_the_LHCb_Upgrade_v0.2.pdf

Simulation validation

Before starting any optimisation of the wall shape, we checked the data/MC comparison using Run 2 noBias data

- MC configuration: low energy thresholds used for bkg simulation (non standard MC production, only few x10^3 evts); optimised M1 description; latest additions on shielding behind M5 + splitter magnet

Average multiplicity for each region/station on no bias Run 2 events, for nPV=1

	DATA	MC	lData-MCl/MC
M2 R1	29.09+- 0.02	23.64 +- 0.06	0.23
M2 R2	17.44 +- 0.02	15.28 +- 0.05	0.14
M2 R3	5.824 +- 0.008	6.69 +- 0.03	0.13
M2 R4	2.700 +- 0.006	3.97 +- 0.02	0.33
M3 R1	9.61 +- 0.01	8.14 +- 0.30	0.19
M3 R2	3.938 +- 0.007	3.41 +- 0.02	0.15
M3 R3	1.112 +- 0.004	1.44 +- 0.01	0.21
M3 R4	0.488 +- 0.002	0.67 +- 0.01	0.25
M4 R1	3.371 +- 0.006	2.21 +- 0.02	0.55
M4 R2	1.529 +- 0.004	1.12 +- 0.01	0.36
M4 R3	0.594 +- 0.003	0.613 +- 0.009	0.31
M4 R4	0.229 +- 0.002	0.308 +- 0.007	0.26
M5 R1	3.406 +- 0.006	1.83 +- 0.02	0.86
M5R2	1.408 +- 0.004	1.07 +- 0.01	0.32
M5 R3	0.841 +- 0.003	1.08+- 0.01	0.22
M5 R4	1.064 +- 0.004	1.37 +- 0.01	0.22

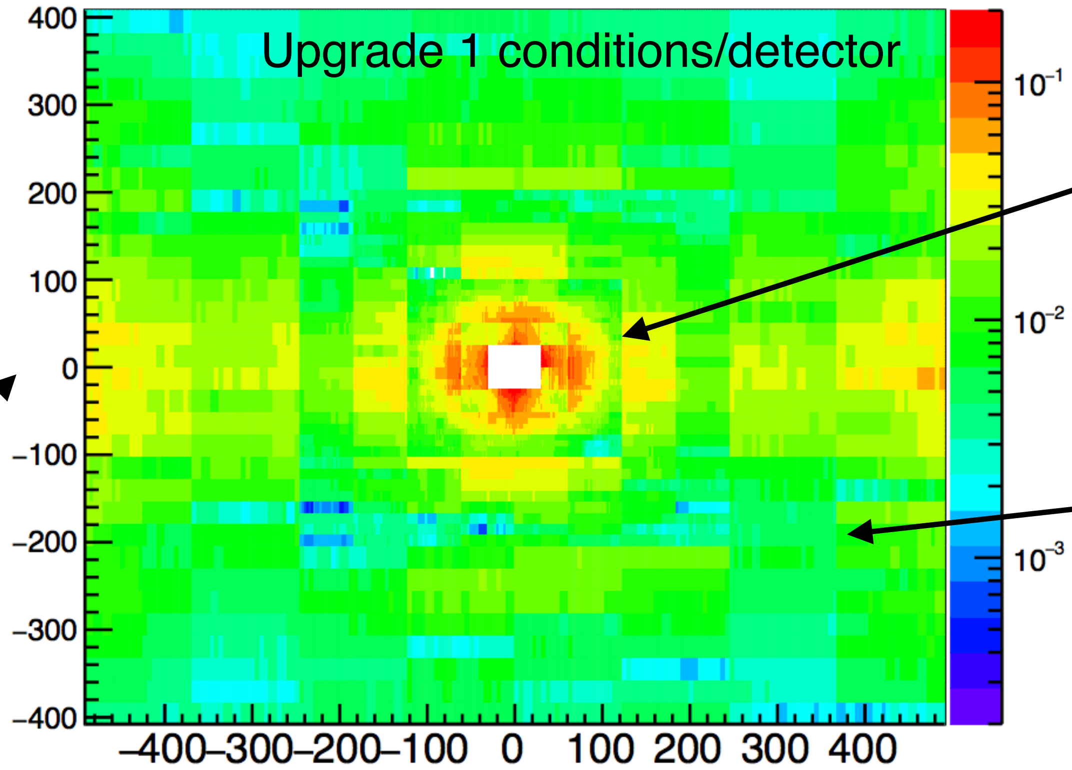
Decent agreement in M2 and M3, which is most important for the iron wall simulation study

Comparison looks worse in M4 and M5, and especially in R1

Optimization of the shielding wall

Below the inefficiency map on M2 extrapolated from data, for phase 1 upgrade and with present detector granularity; even if the phase 2 detector will be different, this is of great help in visualising the hot/cold spots

G. Graziani



maximum possible thickness

we should reduce the iron thickness here, to minimize muon losses

we can profit and extend the iron filter here

In the next slides will show the results from the different wall configurations which have been simulated

all summarised in LHCb-INT-2019-009

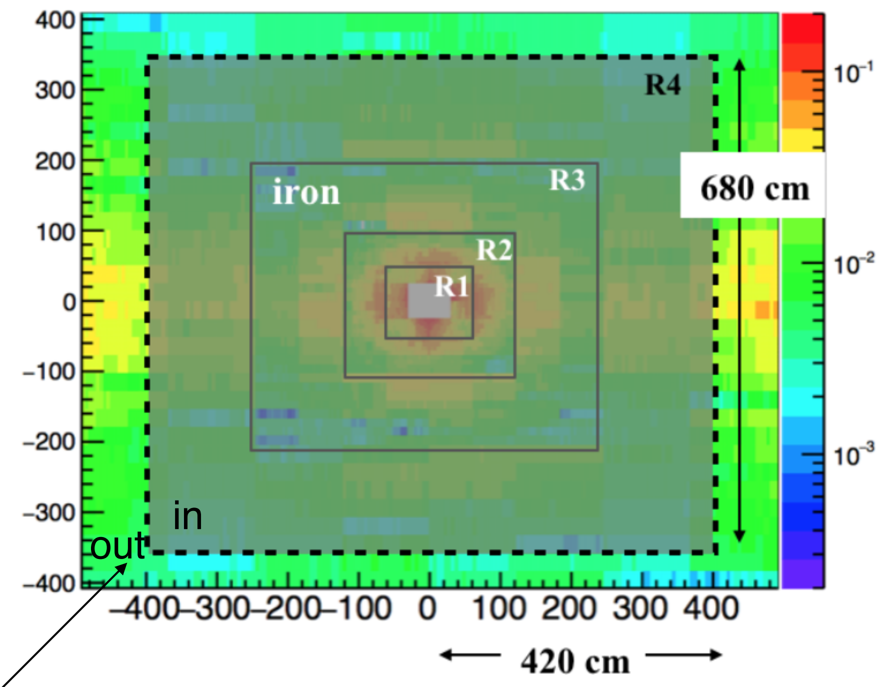
1) Full HCAL iron wall

In the 1st simulation, we replaced the HCAL (as it is) by full iron, 1.7m thick: 5.6 $\lambda_I \Rightarrow$ 10.1 λ_I

Average multiplicity for each region/station on MC minimum bias events, simulated in upgrade I conditions

	Run 3	Iron wall	
M2 R1	54.5	34.8	x0.64
M2 R2	42.1	17.0	x0.40
M2 R3	19.0	8.0	x0.42
M2 R4in	6.1	3.7	x0.61
M2 R4out	6.6	6.0	x0.91
M3 R1	34.2	31.9	
M3 R2	17.3	16.2	
M3 R3	11.0	10.4	
M3 R4	6.0	5.5	
M4 R1	9.6	9.3	
M4 R2	5.2	5.1	
M4 R3	3.2	3.1	
M4 R4	1.3	1.2	
M5 R1	7.6	7.4	
M5 R2	3.8	3.6	
M5 R3	2.1	2.0	
M5 R4	0.8	0.8	

scale factors wrt 1st column



R4 splitted into "in" and "out" to separate the regions covered or not by the HCAL volume

- 40% - 60% rate reduction in M2, modulated by the proximity to the beam pipe or the outer edge
- No effect in the other stations

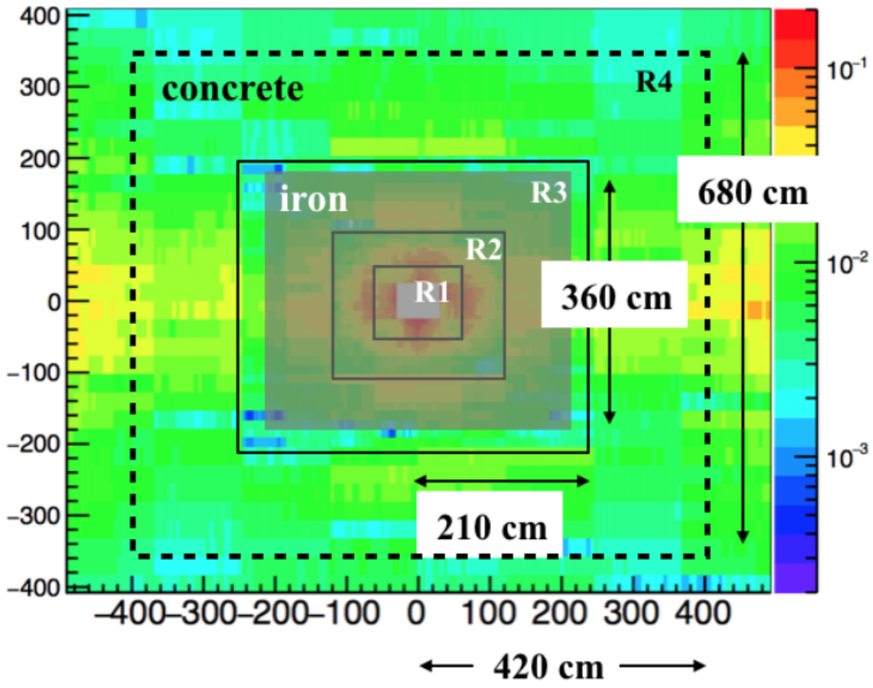
2) Iron core + concrete

With the idea of saving iron (and money), and to improve the muon efficiency on R4, where more shielding is not needed, we replaced the full iron wall with an iron core surrounded by concrete:

- HCAL inner by an iron core 1.7 m : 5.6 $\lambda_I \Rightarrow$ 10.1 λ_I
- HCAL outer by concrete 1.7 m: 5.6 $\lambda_I \Rightarrow$ 4 λ_I

Of course keeping HCAL in the outer region (or even in front of R3) would be perfectly acceptable, feasibility and complexity to be understood

	Run 3	Iron wall		Iron core + concrete	
M2 R1	54.5	34.8	x0.64	32.6	x0.60
M2 R2	42.1	17.0	x0.40	14.7	x0.35
M2 R3	19.0	8.0	x0.42	9.0	x0.47
M2 R4in	6.1	3.7	x0.61	15.2	x2.49
M2 R4out	6.6	6.0	x0.91	11.2	x1.70

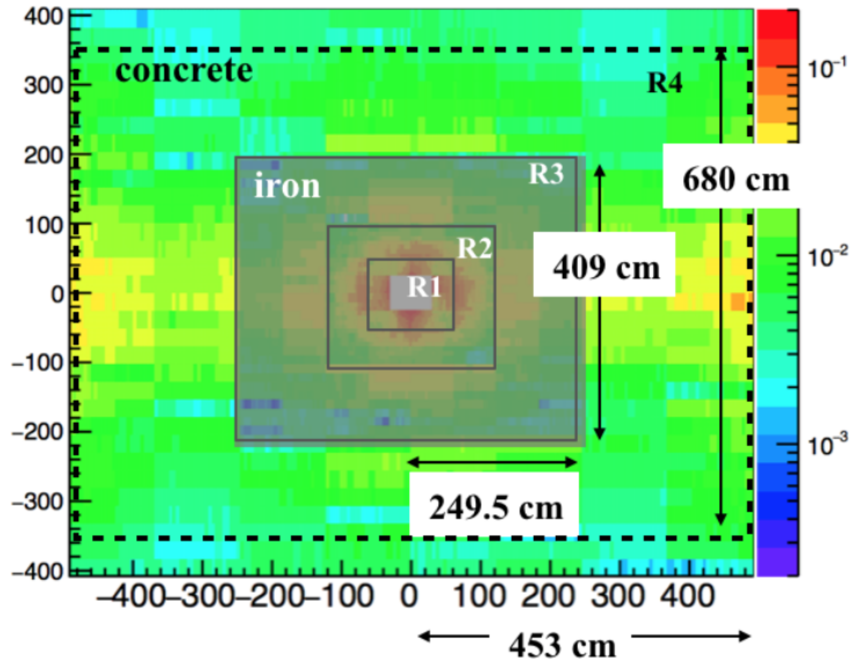


- M2 R1, R2 and R3 same as iron wall: OK
- Large increase in R4: not a problem in absolute terms (rate is low), but bad for granularity

3) Iron core + concrete: expanded

Improvement wrt previous configuration: iron core expanded to optimise the cuttings of Opera slabs, and concrete wall expanded up to the full HCAL carriage dimensions, to have a better coverage on the outer edge

	Run 3	Iron wall	Iron core + concrete	Iron core + concrete expanded
M2 R1	54.5	34.8 x0.64	32.6 x0.60	32.5 x0.60
M2 R2	42.1	17.0 x0.40	14.7 x0.35	13.2 x0.31
M2 R3	19.0	8.0 x0.42	9.0 x0.47	7.0 x0.37
M2 R4in	6.1	3.7 x0.61	15.2 x2.49	12.0 x1.97
M2 R4out	6.6	6.0 x0.91	11.2 x1.70	5.9 x0.89



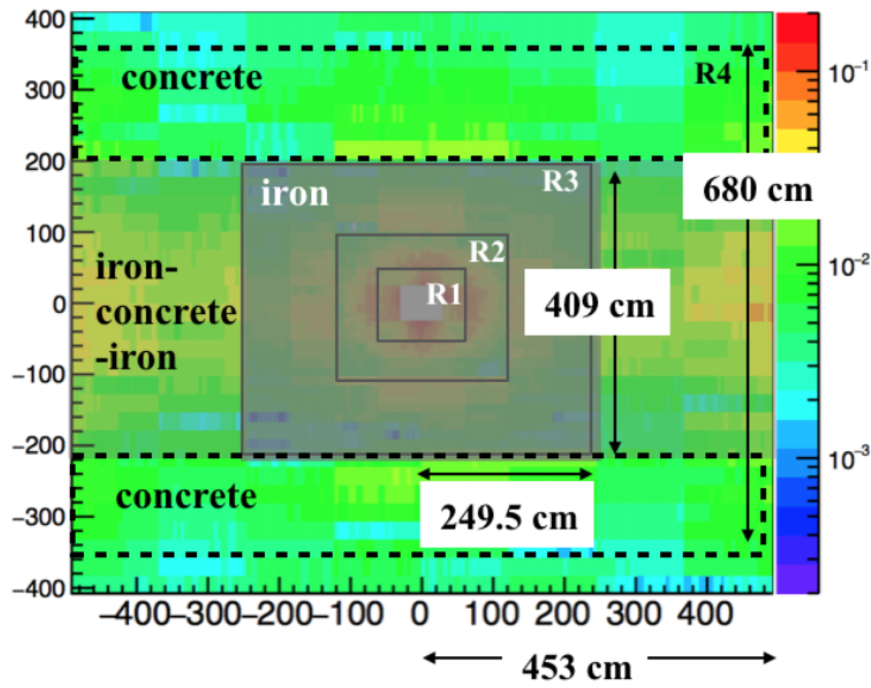
➡ Slight improvement on R3 from the wider iron core and sizable reduction of bkg in R4out, because of better coverage of the outer acceptance; still large bkg increase in R4in

4) Iron core + concrete-iron sandwich

Iron-concrete sandwich in front of the M2R4 mid-plan, to have a similar thickness wrt present HCAL

- ➡ same iron core as before
- ➡ iron/concrete/iron = 30/110/30 cm = 6.2 λ_I on the middle plane as in figure

	Run 3	Iron wall		Iron core + concrete		Iron core + concrete expanded		Iron core + concrete-iron sandwich	
M2 R1	54.5	34.8	x0.64	32.6	x0.60	32.5	x0.60	31.3	x0.58
M2 R2	42.1	17.0	x0.40	14.7	x0.35	13.2	x0.31	13.2	x0.31
M2 R3	19.0	8.0	x0.42	9.0	x0.47	7.0	x0.37	6.8	x0.36
M2 R4in	6.1	3.7	x0.61	15.2	x2.49	12.0	x1.97	7.5	x1.2
M2 R4out	6.6	6.0	x0.91	11.2	x1.70	5.9	x0.89	5.1	x0.8



- ➡ Large reduction in R4in, as expected from the increased thickness:

Impact on muon efficiency

The muon efficiency with the additional shielding is compared with HCAL using MC $K_S \rightarrow \mu^+\mu^-$ events, and for different regions of the detector. Inner (outer) regions correspond to higher (lower) momenta. Effect of dead time is not included in this computation.

HCAL

single muon effi (%)

all regions	97.5 ± 0.2
R1	93.1 ± 0.9
R2	98.2 ± 0.3
R3	99.1 ± 0.2
R4	96.9 ± 0.4

double muon effi (%)

94.8 ± 0.4

Iron wall

single muon effi (%)

all regions	92.9 ± 0.3
R1	92.4 ± 0.9
R2	98.7 ± 0.2
R3	96.9 ± 0.3
R4	82.6 ± 0.7

double muon effi (%)

88.0 ± 0.5

Iron core + concrete

single muon effi (%)

all regions	97.7 ± 0.2
R1	93.4 ± 0.8
R2	98.7 ± 0.2
R3	97.4 ± 0.3
R4	98.8 ± 0.2

double muon effi (%)

95.4 ± 0.3

- R1, R2 are not affected by the iron shielding , since the highest momenta are interested, R3 it is marginally; for R4 a 15% efficiency drop is instead observed
- The efficiency is fully recovered by the use of concrete
- The configuration with iron-concrete sandwich is still to be simulated, expect similar results

Performance vs complexity and cost

SUMMARY OF FINDINGS FROM SIMULATION:

- An iron core (1.7 m) in front of R1, R2 and R3 reduces the multiplicity by factors ~0.6, 0.4 and 0.4, respectively.
- Use of iron in front of R4 has a similar effect, but reduces the efficiency on muons by ~15%.
- Replacement of iron with concrete restores the muon efficiency, but at a cost of a factor of ~2 in multiplicity in R4.
- Use of a sandwich iron-concrete to reproduce the same HCAL thickness in the middle plane of R4 gives a similar multiplicity as it is now.

A. Saputi prepared drawings and cost projections for all configurations (all details in EDMS 2068799)

	Iron wall	**Iron core + concrete**	**Iron core + concrete-iron sandwich**
Number of OPERA slabs (out of 336)	252	68	92
Number of concrete blocks	0	12	12
Total weight (tons)	2×1150	2×225	2×293
Total cost + 20% contingency (kEUR)	1122	246	324

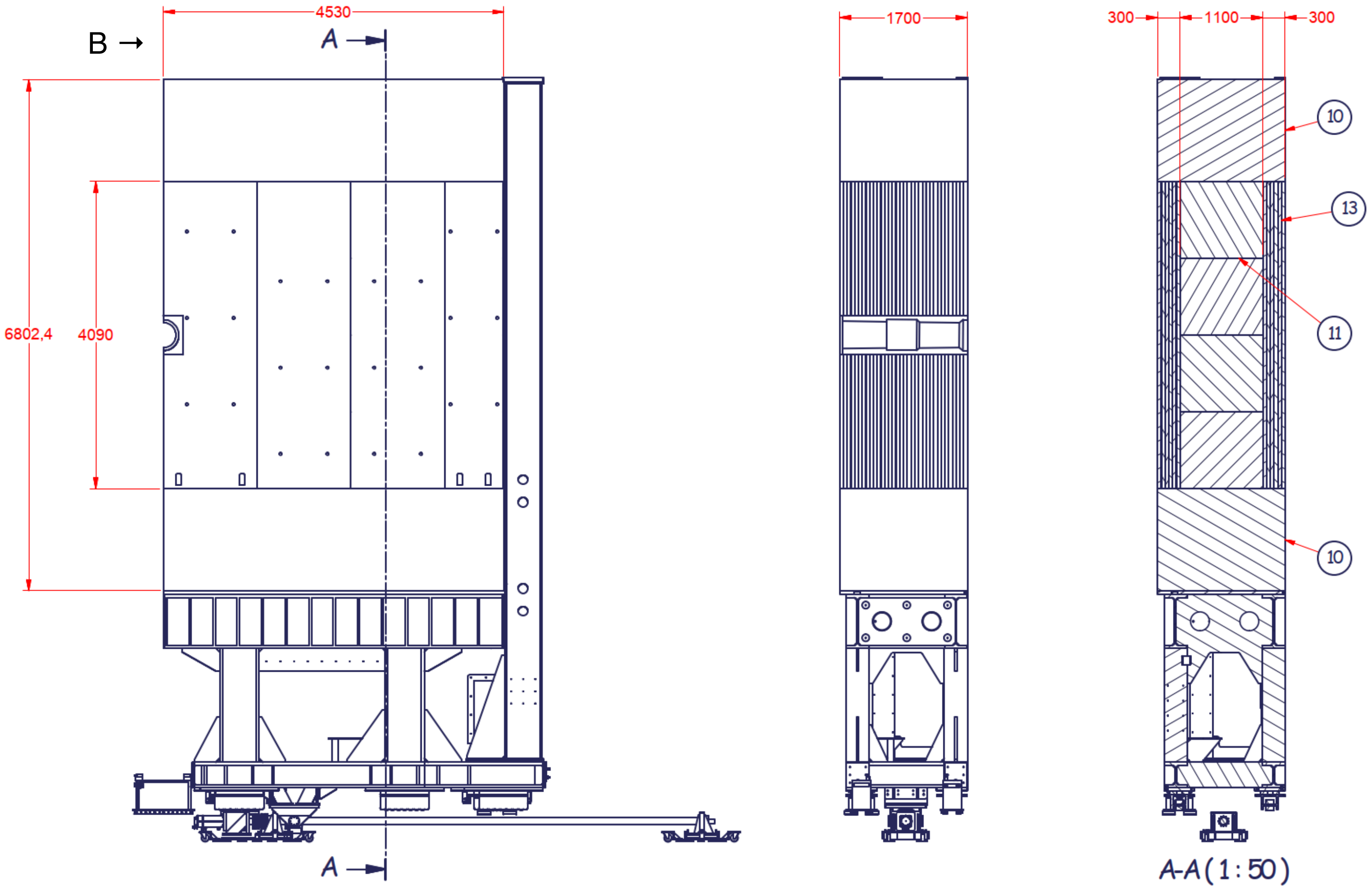
Use of concrete and iron/concrete sandwich decreases dramatically the number of iron slabs and weight, and therefore the complexity and cost. In particular, the HCAL carriage can be reused with minimal modification (structural verification with ANSYS).

Mechanical drawings

Iron core + concrete-iron sandwich

Section in B

Section in A



A. Saputi EDMS 2068799

Impact on combined muon PID (1)

- Best muon PID performances are obtained combining the info from MUON, RICH, ECAL and HCAL

- We evaluated separately the contribution of the different PID detectors to understand the impact of HCAL removal

Table 6: Pion misID for 90% muon efficiency obtained by cutting on the sum of different PID detector DLLs, as indicated in the first column; results are averaged in two different momentum intervals.

Combined likelihood (data control samples)

	$3 < p < 10$ GeV	$p > 10$ GeV
MUON	17.2×10^{-3}	4.4×10^{-3}
MUON+RICH	8.2×10^{-3}	4.0×10^{-3}
MUON+RICH+ECAL	7.4×10^{-3}	3.6×10^{-3}
MUON+RICH+ECAL+HCAL	6.4×10^{-3}	3.3×10^{-3}

When using the uncorrelated sum of subdetector likelihoods, the expected increase of misID from HCAL removal is 16% (9%) below (above) 10 GeV.
Of course one could expect a worsening at higher momenta.

Impact on combined muon PID (2)

Muon DLL has been replaced by a BDT which makes use of the same muon track residuals, but including correlations and multiple scattering; RICH, ECAL and HCAL DLLs have been added to the BDT as input variables; training on data control samples of muons and pions

with HCAL

w/o HCAL

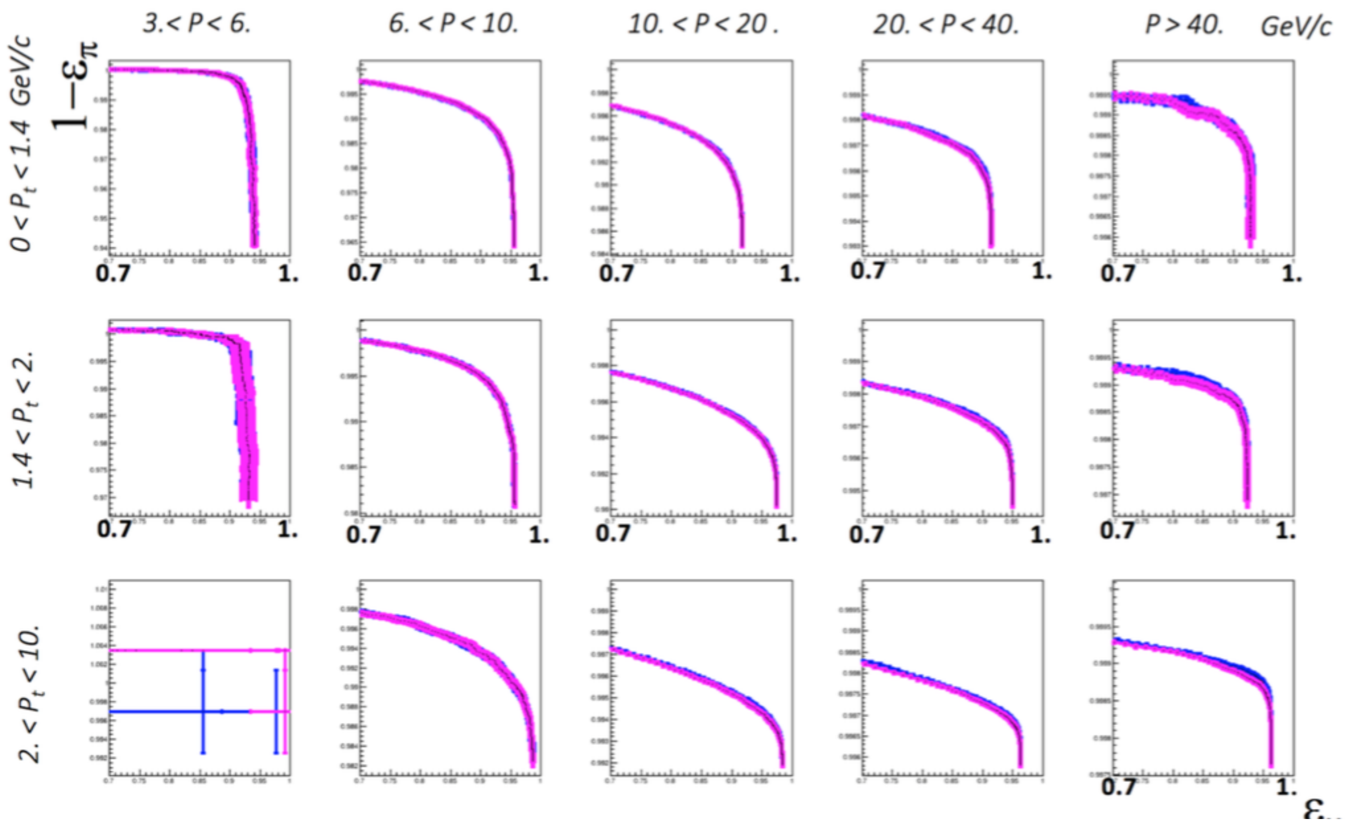


Figure 3: ROC curves of pion misID vs muon efficiency in bins of p and p_T from data control samples for two BDT operators, obtained using informations from MUON+RICH+ECAL+HCAL (blue) and MUON+RICH+ECAL (purple).

P. De Simone

A better usage of muon information seems recovering the loss of PID performance due to HCAL removal

Additional shielding summary and recommendations

The proposed **iron core + concrete-iron sandwich** is reasonably optimised in terms of cost and complexity. On the performance side, a reduction from ~5.6 MHz/cm^2 to ~3.3 MHz/cm^2 in M2R1 is still worth for a detector capable to stand a max rate of ~10 MHz/cm^2. On the other side, further studies are needed to understand if it is possible to improve on bkg rejection

Following the recent discussion at U2PG, the most important recommendations have been summarised in LHCb-INT-2019-011:

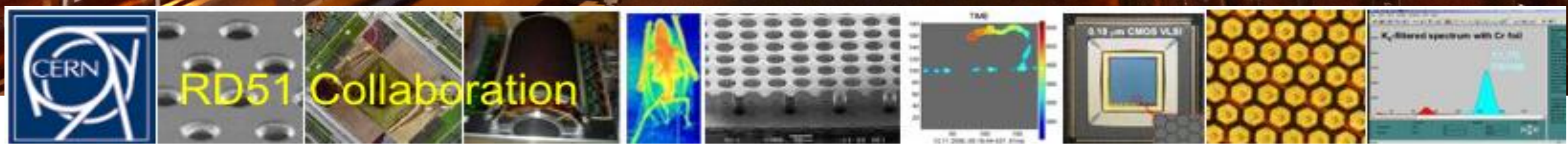
1) The shielding can be introduced inside the envelope of the current HCAL, make good use of the available time during the shutdown and be performed at an affordable cost. The designs utilising a mixture of concrete and iron appear particularly appealing. The panel has no major concerns and encourages the proponents to proceed with their detailed studies.
2) The fact M3 rates are not affected by the wall (or that M2R2 is more affected than M2R1) clearly indicates that bkg originates mostly from the beam pipe: having a full understanding of this may suggest improvements, which could be equally applied to M2 and M3
3) Verify possible backsplashes on ECAL from the additional shielding
4) Verify possible use of HCAL modules for shielding
5) Evaluate expected muon efficiency for Run4 and Run 5 with inclusion of dead time effects
6) Start a discussion within PPG to evaluate if there would be any loss to the physics programme in Run 4, particularly for electroweak analyses, from the removal of HCAL

We thank Pascal Perret and the U2PG for the very constructive discussion

INFN Istituto Nazionale di Fisica Nucleare

The μ-RWELL detector for the Muon System Upgrade II

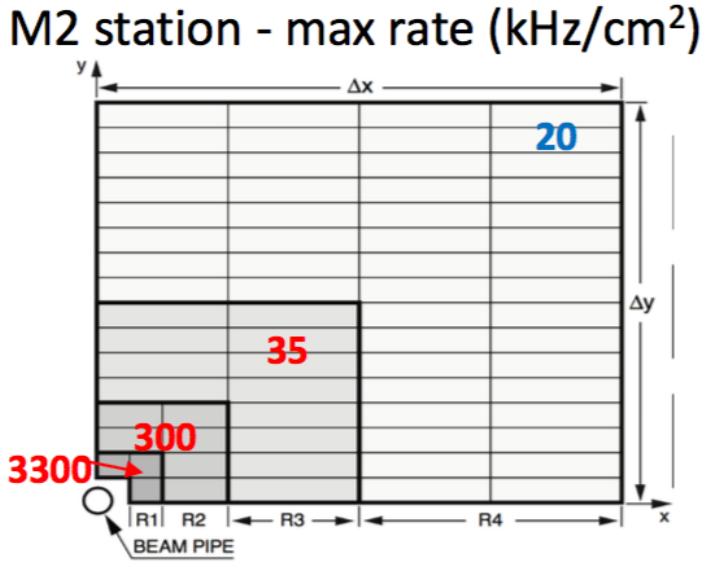
G. Bencivenni, G. Felici, M. Gatta, M. Giovannetti, G. Morello, M. Poli Lener
(Laboratori Nazionali di Frascati)



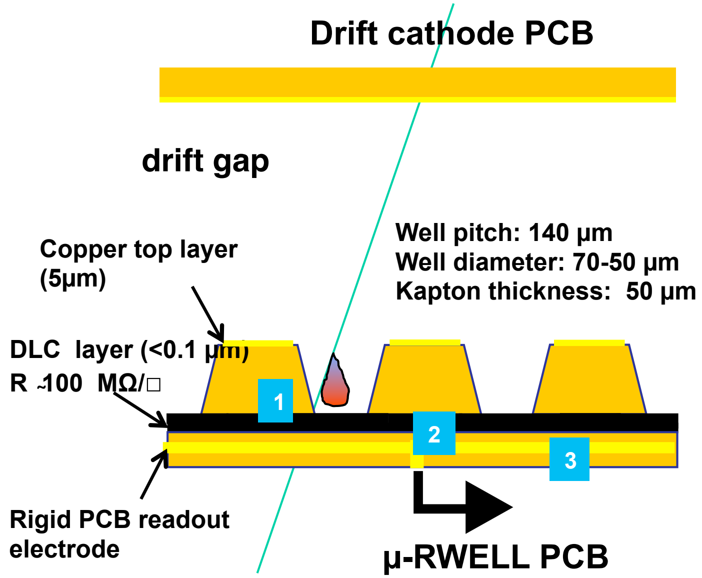
µ-RWELL for LHCb MUON upgrade II

Detector requirements:
- Rate up to 3 MHz/cm^2 on detector
- Rate up to 1 MHz on FEE channel
- Efficiency > 95% within 25 ns per single gap
- Long stability up to 6 C/cm2 acc. charge in 10 y of operation

- Pad cluster size < 1.2



G. Bencivenni et al., 2015_JINST_10_P02008



(*) DLC = Diamond Like Carbon
High mechanical & chemical resistant material

The *µ*-RWELL is composed of only two elements: the ***µ*-RWELL_PCB** and the a **cathode PCB** defining the drift gap

The ***µ*-RWELL_PCB** is realized by coupling:

1) a suitably patterned kapton foil as amplification stage

2) a resistive layer for discharge suppression and current evacuation:

“Single resistive layer” (Low Rate) <100 kHz/cm^2: single resistive layer with surface resistivity ~100 MOhm/□

“Double resistive layer” (High Rate) > 1 MHz/cm^2: more sophisticated resistive scheme must be implemented

3) a standard readout PCB

μ-RWELL for LHCb MUON upgrade II

The main effect of the introduction of the resistive stage is the suppression of sparks, but this needs a careful design in order to keep a high rate capability

- A crucial point is to achieve, in cooperation with printed circuit industry, an effective process for the production of the μ-RWELL_PCB

- An intense R&D is ongoing in Frascati, in cooperation with the CERN PCB workshop, with ELTOS (Italy) and Techtra (Poland) as industrial partners

Low Rate

Large size prototypes (1.2x0.5 m^2) have been realised, and tested up to 40 kHz/cm^2 MIP rate, without loss of gain

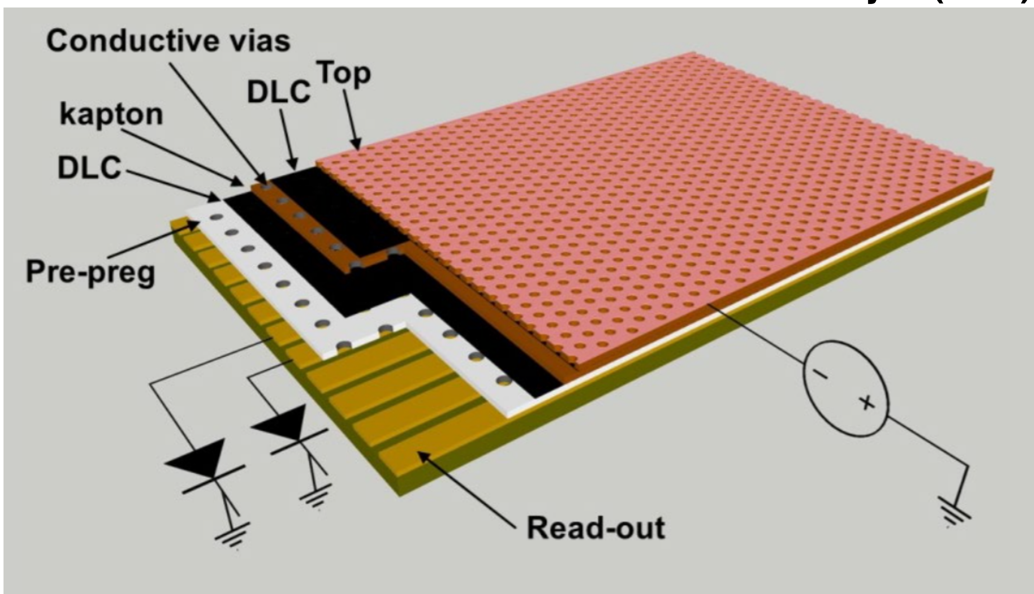
Industrialization process is mature, PCB is produced at ELTOS and sent to CERN for final etching

High Rate

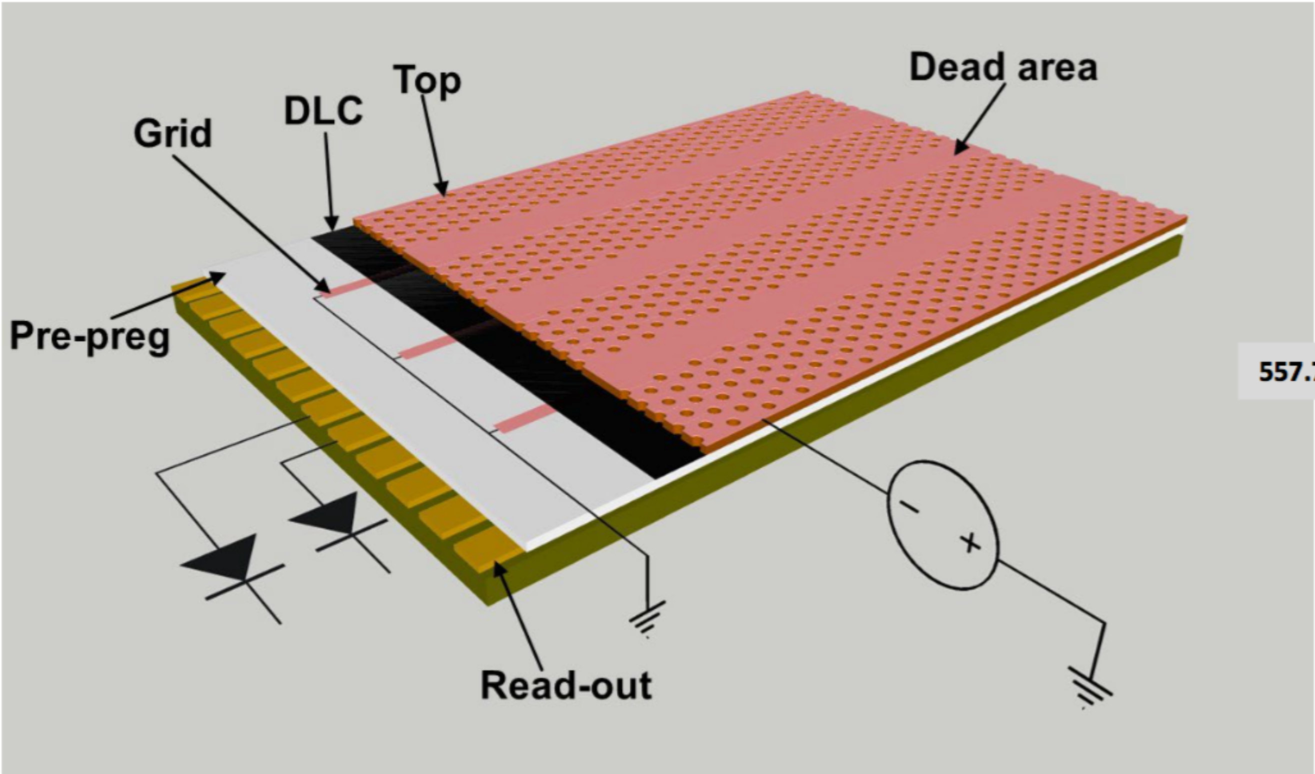
Double resistive layer with conductive vias designed to evacuate the charge is very effective, but is not suited for industrial production

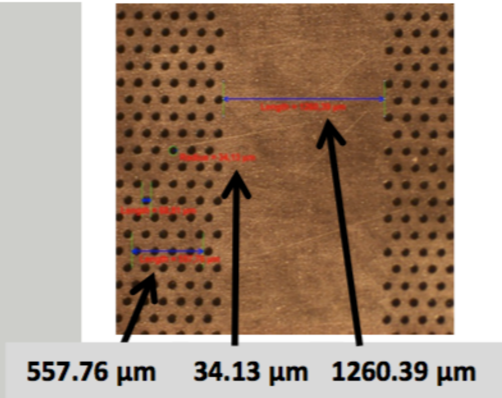
NEW: during the last year simpler layouts have been developed, with silver or resistive grids printed on the bottom of the amplification stage, which can be more easily implemented by industry

The Double Resistive Layer (DLR)



High rate layout: the silver grid

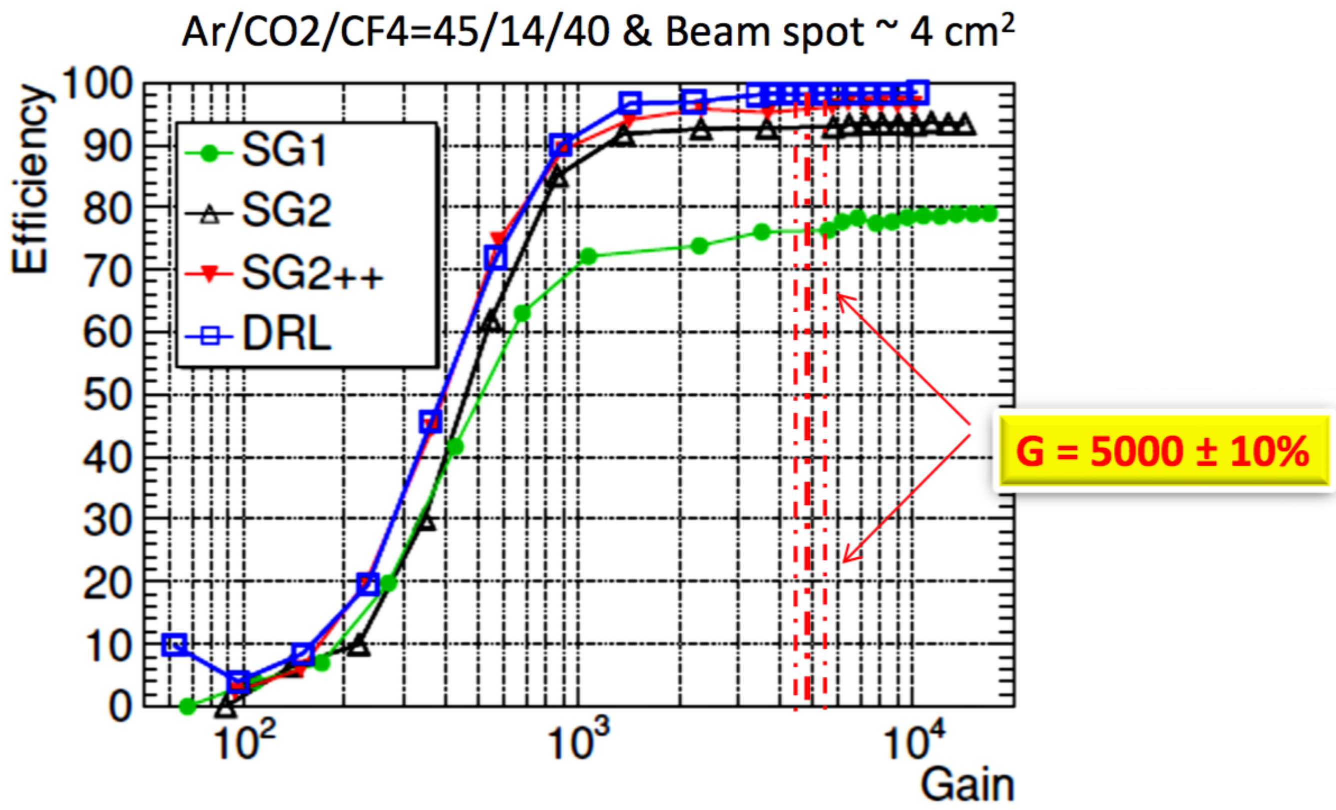




A **simplified high rate scheme based on a single resistive layer** with the implementation of a **2-D grounding** based on **conductive strip lines** realized on the DLC layer.
The **conductive grid** can be screen-printed or better etched by photo-lithography

The conductive grid can induce instabilities due to discharges over the DLC surface, thus requiring for the introduction of a small dead zone on the amplification stage: in the optimised configuration (SG2++), the dead zone is 0.6 mm with a grid pitch of 12 mm → geometric acceptance = 95%

High rate layout efficiency



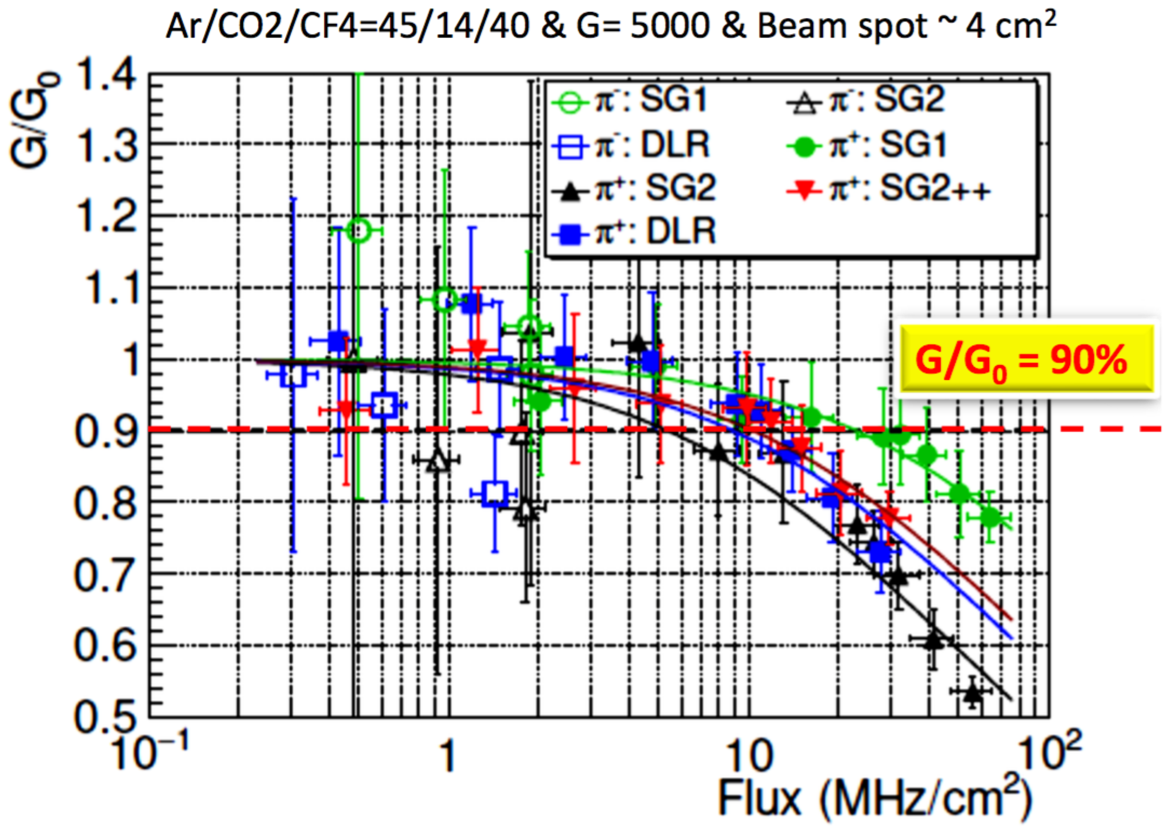
Test beam PSI (october 2018)

The double resistive layer DRL reaches full tracking efficiency , 98% (no dead zone).

The silver grid configurations SG1, SG2 and SG2++ have efficiencies 76% , 93% and 97%, respectively, slightly higher than their geometrical acceptance (66%, 90% , 95% respectively), thanks to the efficient electron collection mechanism that reduce the effective dead zone.

SG2++ seems a good candidate to replace DRL

Rate capability



A rate capability of up to 10 MHz/cm² with a gain drop of ~10% is reached

The gain drop is due to the Ohmic effect on the resistive layer: the current collected on the DLC drift towards the ground "through" an effective average resistance Ω_{eff}, depending on the evacuation scheme geometry and the DLC surface resistivity.

A gain drop of 10 % is largely acceptable since does not affect the detection efficiency

RWELL summary

The µ-RWELL is a single-amplification stage, spark-protected resistive MPGD based on a breakthrough technology suitable for large area planar tracking devices

The detector is being characterized: gas gain ≥ 10^4, rate capability ~10 MHz/cm^2

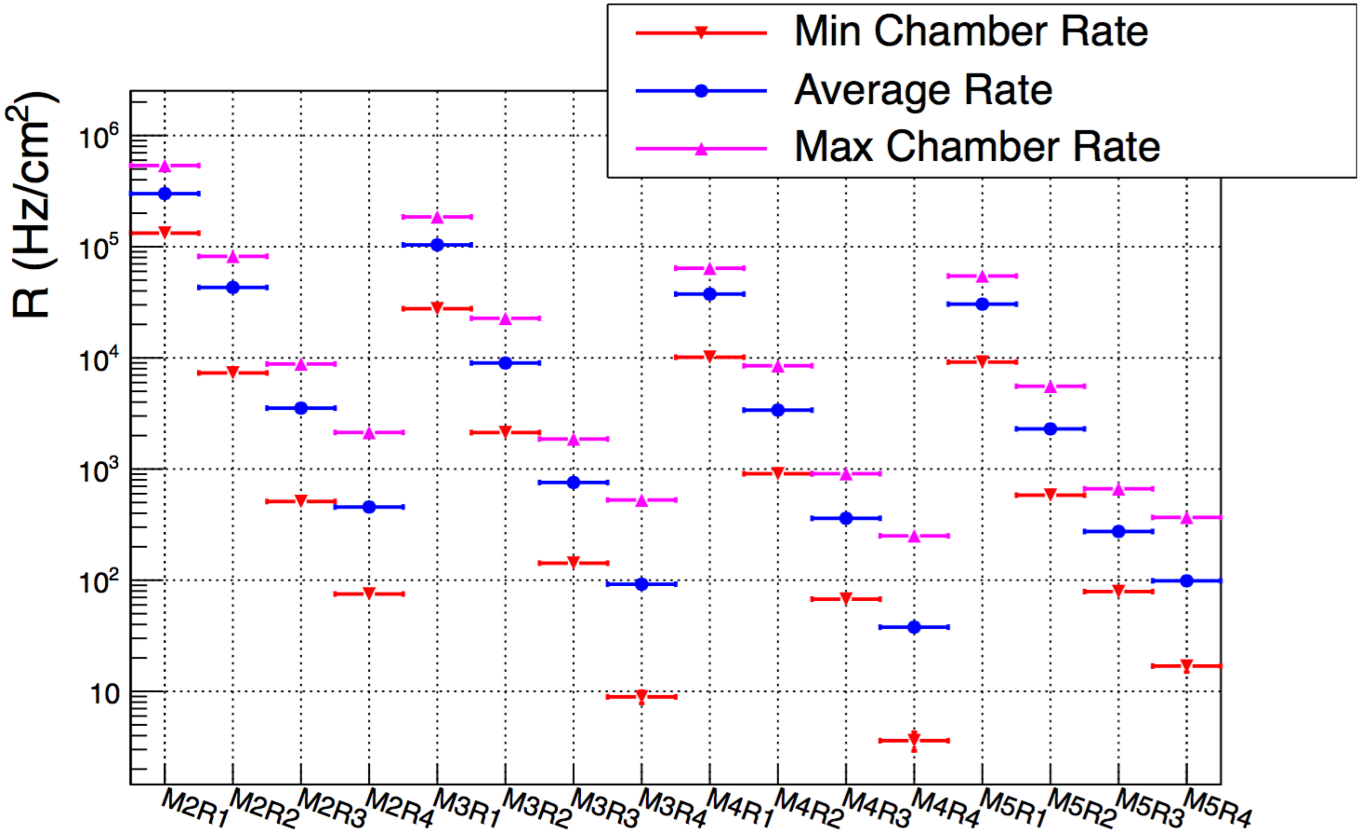
A design for the high rate has been found which is suitable for a simple industrialisation process

Ageing studies ongoing at GIF++ and PSI, a slice test in the cavern could be considered at some point during Run 3

Coupling with electronics is under study: a global optimisation of granularity (and capacitance), rate per channel, cluster size and cost is needed. Target regions to instrument are R1 and R2. Region R3 is to be discussed. Other solutions have to be identified for R4.

SPARES

Next steps on the iron wall simulation

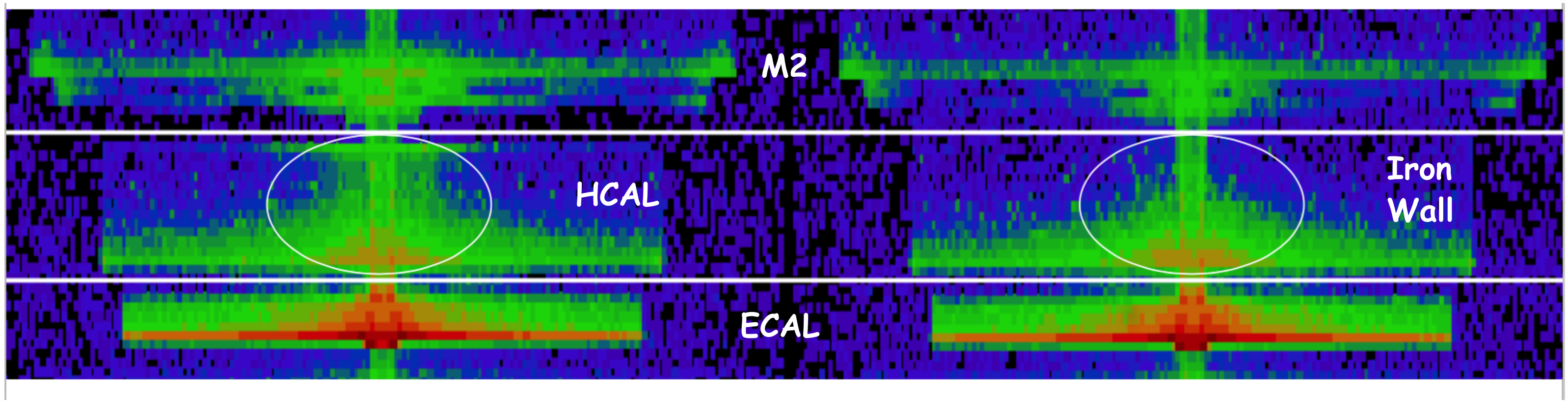


values reduced by 10% wrt TDR in worst regions

G. Graziani, june 2015

Iron wall: simulation results at Elba '17

Started with something simple: HCAL replaced in LHCb simulation (current upgrade configuration) with iron wall, with the same outer dimensions



Average rate scale factors for inner regions

M2R1	M2R2	M3R1	M3R2
0.54	0.23	0.94	0.80

Muon losses

3<p<6 GeV	6<p<10 GeV	p>10 GeV
17%	2,7%	0,6%

2-3% on $B_s \to \mu^+\mu^-$, $B_s \to J/Psi\ \varphi$, $D^0 \to \mu^+\mu^-$

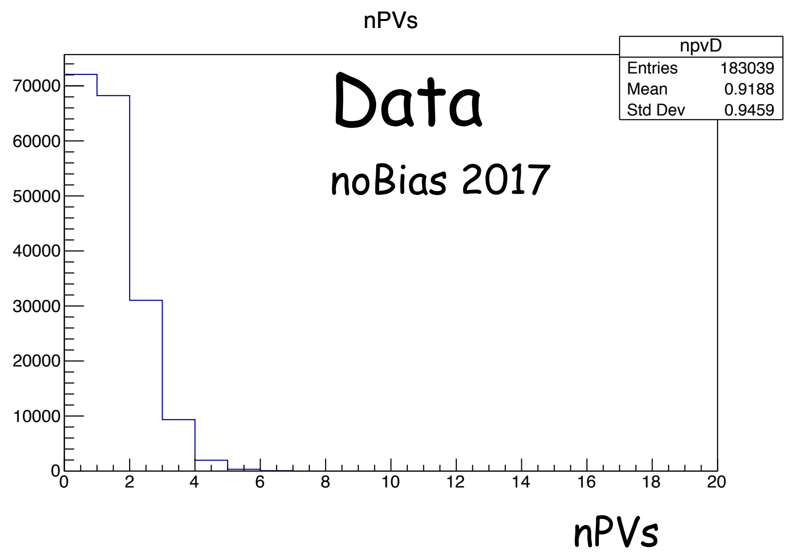
11% on $K_s \to \mu^+\mu^-$, $\tau \to 3\mu$

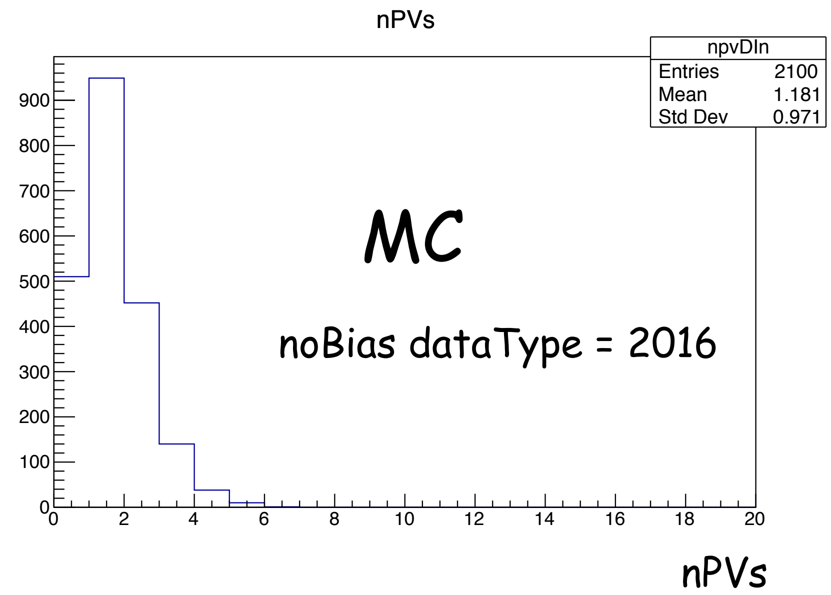
Large room for optimizing the shape of the iron wall

- On the middle plane increase at large X to filter out particles escaping the calorimeter volume
- Away from the middle plane, try to reduce the iron thickness in order to minimise muon losses at low P

Simulation validation

Before starting any optimisation of the wall shape, we decided to carefully check the data/MC comparison using noBias data





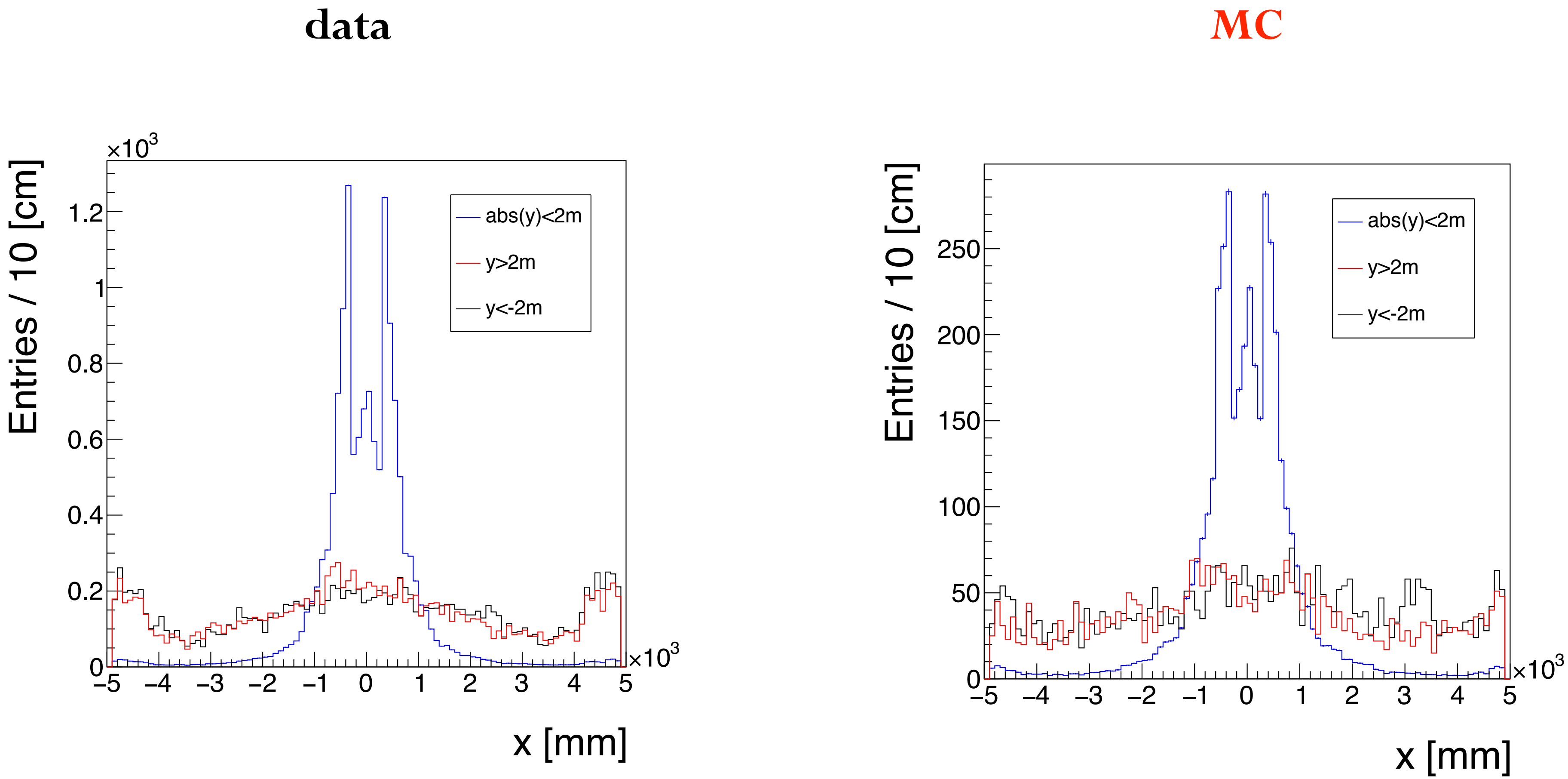
After several attempts we found an optimal MC config:

- low energy thresholds (non standard MC production, only fewx10^3 evts)
- better M1 description (muon-20160511)
- latest additions from Peter on shielding behind M5 + splitter magnet

Details on the MC configs in the backup

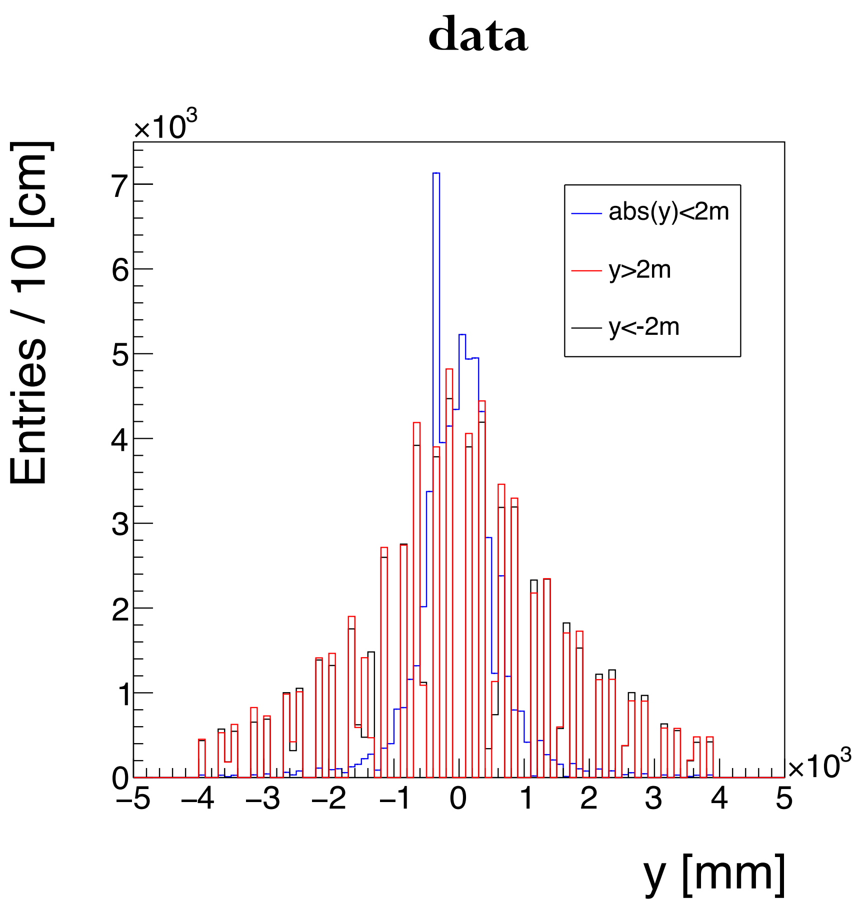
Data and MC occupancies on different stations/regions of muon detector will be compared for nPV=1

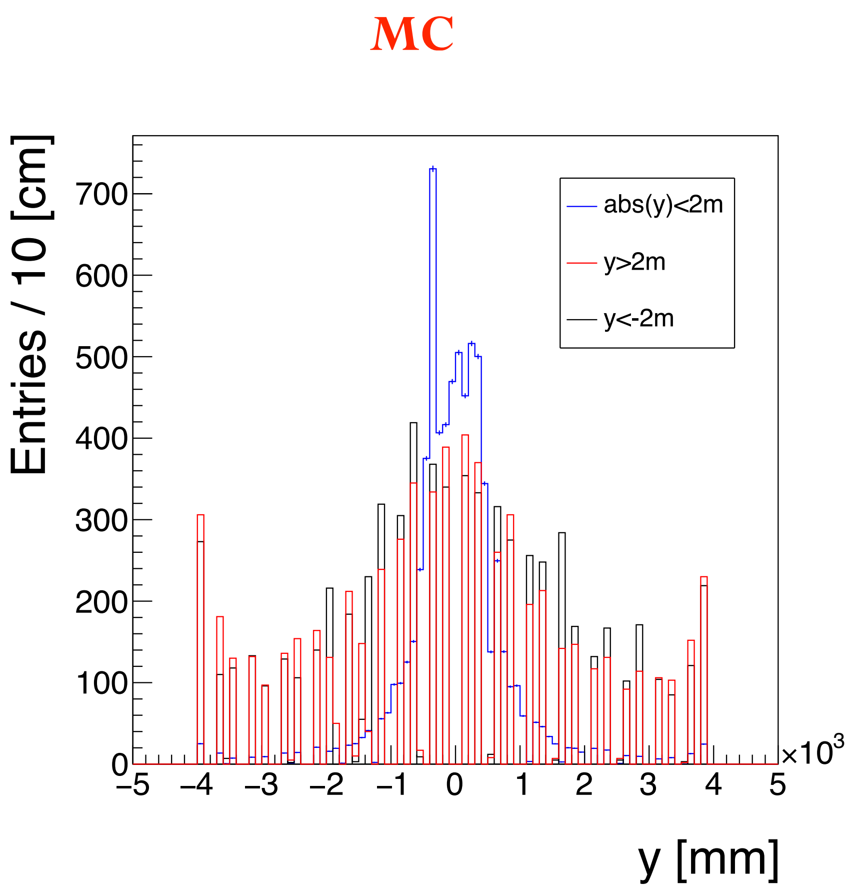
Data and MC X-spectra on M2



Both data and (less) MC show an excess at both sides of the fiducial volume

Data and MC Y-spectra M2





Unlike data, MC shows an excess at top/bottom edges of the fiducial volume (not very relevant for the following discussion)

Upgrade basic configuration

Here and in the following slides, the average multiplicity is computed for each region/station on MC minimum bias events, simulated in upgrade I conditions, all nPVs are considered .

	Present muon	+ new HCAL beam plug (Run 3 config)	
M2 R1	77.2	54.5	×0.71 (*)
M2 R2	48.0	42.1	×0.88
M2 R3	20.1	19.0	
M2 R4	12.6	12.7	
M3 R1	33.9	34.2	
M3 R2	17.3	17.3	
M3 R3	10.7	11.0	
M3 R4	5.8	6.0	
M4 R1	9.1	9.6	
M4 R2	5.1	5.2	
M4 R3	3.1	3.2	
M4 R4	1.2	1.3	
M5 R1	7.3	7.6	
M5 R2	3.5	3.8	
M5 R3	2.1	2.1	
M5 R4	0.8	0.8	

* scale factors wrt 1st column

Simulation with low energy background full simulation shows a 30% bkg reduction from the tungsten shielding + new HCAL beam plug.

A 50% reduction was instead obtained with the standard parametric simulation.

A 30% reduction was conservatively assumed in the rate estimates for upgrade TDR.

Caveat:

- *multiplicity scaling btw MC upgrade and MC run 2 (slide 8) seems incorrect, and needs to be understood; in any case, only the ratio of multiplicities btw different MC configurations is relevant here*
- *the multiplicity is computed from reconstructed hits, so it includes also ghost hits; this is not expected to change dramatically the comparisons we're carrying out here, but nevertheless the computation is to be repeated using MC hits*

MC configuration I

Gauss v51r2

```
Gauss().PhysicsList = {"Em":'NoCuts', "Hadron":'QGSP_BERT_HP', "GeneralPhys":True, "LHCbPhys":True}
```

(FTFP makes little difference)

For Low Ene threshold turn off low energy bkg in Boole v32r2

```
lowEnergy = MuonBackground("MuonLowEnergy")
lowEnergy.BackgroundType = "LowEnergy"
lowEnergy.SafetyFactors = [0.,0.,0.,0.,0.]

flatSpill = MuonBackground("MuonFlatSpillover")
flatSpill.BackgroundType = "FlatSpillover"
flatSpill.SafetyFactors = [0.,0.,0.,0.,0.]
```

```
from Configurables import LHCbApp
LHCbApp().DDDBtag   = "dddb-20170721-3"
LHCbApp().CondDBtag = “sim-20170721-2-vc-md100"
CondDB().LocalTags["DDDB"] = ["rich-20160518","muon-20160511","shielding-20170929"]
```

M1 material tuning

```
from Configurables import Gauss, CondDB
from Configurables import GiGaInputStream

Gauss().DetectorGeo  = { "Detectors": ['PuVeto', 'Velo', 'TT', 'IT', 'OT', 'Rich1', 'Rich2', 'Spd', 'Prs', 'Ecal', 'Hcal', 'Muon', 'Magnet' , 'Infrastructure' ] }
Gauss().DetectorSim  = { "Detectors": ['PuVeto', 'Velo', 'TT', 'IT', 'OT', 'Rich1', 'Rich2', 'Spd', 'Prs', 'Ecal', 'Hcal', 'Muon', 'Magnet' , 'Infrastructure' ] }
Gauss().DetectorMoni = { "Detectors": ['PuVeto', 'Velo', 'TT', 'IT', 'OT', 'Rich1', 'Rich2', 'Spd', 'Prs', 'Ecal', 'Hcal', 'Muon', 'Infrastructure' ] }

Gauss().DataType = "2016"

geo = GiGaInputStream('Geo')
geo.StreamItems     += ["/dd/Structure/Infrastructure"]
```

MC configuration II

Lowered prod cuts wrt default

```
from Gaudi.Configuration import *
from GaudiKernel import SystemOfUnits
from Configurables import (GiGa, GiGaPhysListModular,
     GiGaRunActionSequence, TrCutsRunAction)
from Configurables import GiGaPhysConstructorOp, GiGaPhysConstructorHpd
from Gauss.Configuration import *

giga = GiGa()

def setProductionCuts():

   giga.addTool( GiGaPhysListModular("ModularPL") , name="ModularPL" )
   Gauss().setPhysList(False)
                                          #2005 cuts:
   giga.ModularPL.CutForElectron = 0.1 * SystemOfUnits.mm #0.5mm
   giga.ModularPL.CutForPositron = 0.1 * SystemOfUnits.mm #0.5mm
   giga.ModularPL.CutForGamma    = 0.1 * SystemOfUnits.mm #0.5mm
```

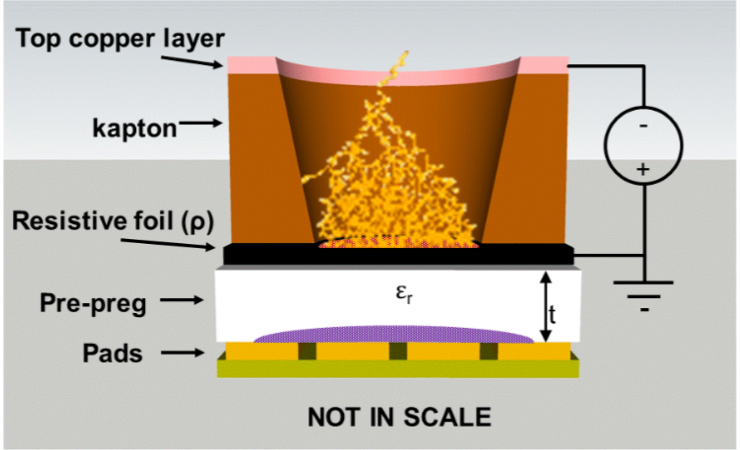
```
def setTrackingCuts():
   giga.addTool( GiGaRunActionSequence("RunSeq") , name="RunSeq" )
   giga.RunSeq.addTool( TrCutsRunAction("TrCuts") , name = "TrCuts" )
                                          #2005 cuts:
   giga.RunSeq.TrCuts.MuonTrCut     = 1.0 * SystemOfUnits.MeV #10.0
   giga.RunSeq.TrCuts.pKpiCut       = 0.1 * SystemOfUnits.MeV #0.1
   giga.RunSeq.TrCuts.NeutrinoTrCut = 0.0 * SystemOfUnits.MeV #0.0
   giga.RunSeq.TrCuts.NeutronTrCut  = 0.0 * SystemOfUnits.MeV #0.0
   giga.RunSeq.TrCuts.GammaTrCut    = 0.03 * SystemOfUnits.MeV #0.03
   giga.RunSeq.TrCuts.ElectronTrCut = 0.03 * SystemOfUnits.MeV #0.03
   giga.RunSeq.TrCuts.OtherTrCut    = 0.0 * SystemOfUnits.MeV #0.0


def muonLowEnergySim():
   from Configurables import SimulationSvc
   SimulationSvc().SimulationDbLocation = "$GAUSSROOT/xml/MuonLowEnergy.xml"

muonLowEnergySim()
appendPostConfigAction(setProductionCuts) #ERROR
appendPostConfigAction(setTrackingCuts)
```

Principle of operation

Applying a suitable voltage between the **top Cu-layer and the DLC** the **"WELL" acts as a multiplication channel** for the ionization produced in the conversion/drift gas gap.



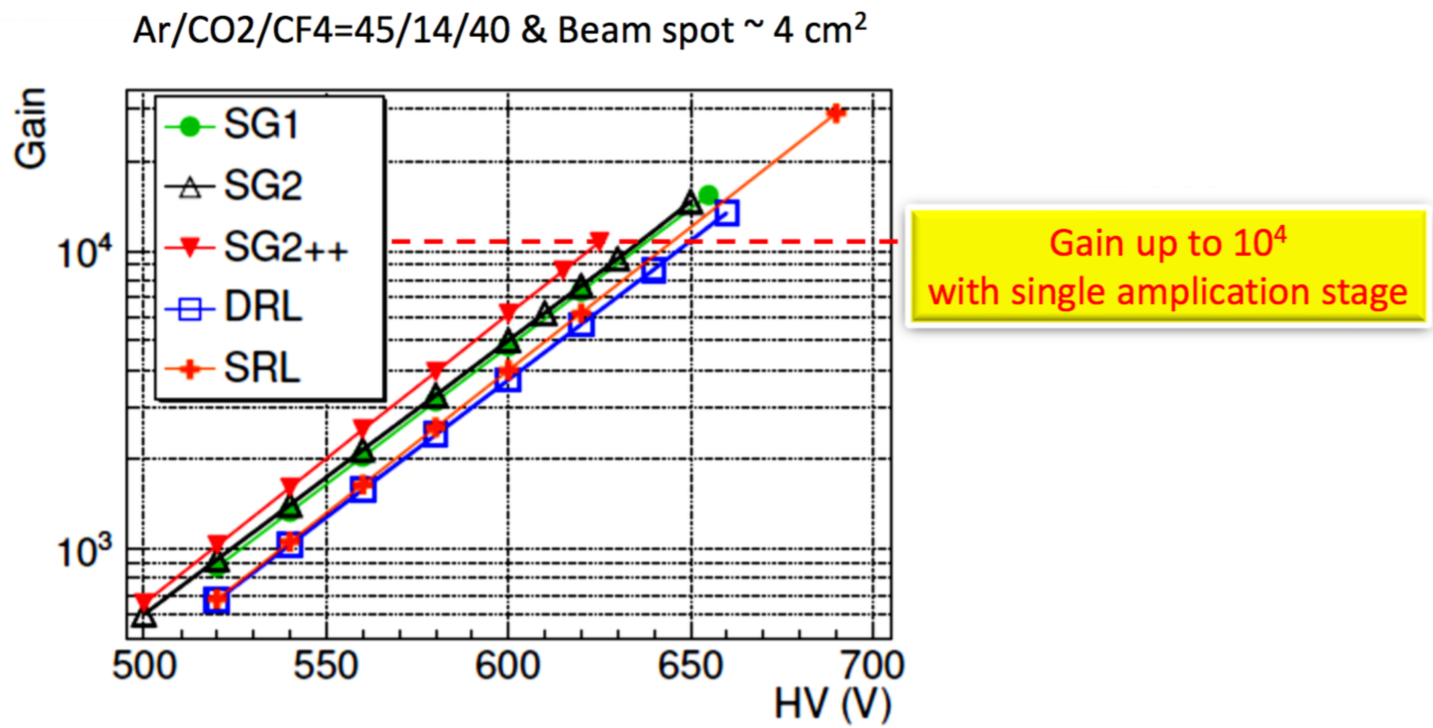
The charge induced on the resistive foil is dispersed with a *time constant*, $\tau \sim \rho \times C$ [*M.S. Dixit et al., NIMA 566 (2006) 281*]:

- the DLC surface resistivity → ρ
- the capacitance per unit area, which depends on the distance between the resistive foil and the pad/strip readout plane → t
- the dielectric constant of the insulating medium → ε_r

$$\boxed{C = \varepsilon_0 \times \varepsilon_r \times \frac{S}{t}}$$

- The main effect of **the introduction of the resistive stage** is the **suppression of the transition from streamer to spark**, with a consequent reduction of the spark-amplitude
- As a drawback, the **capability to stand high particle fluxes is reduced**, but **appropriate grounding schemes** of the resistive layer **solves this problem** (*see High Rate layouts*)

Detector Gain



Gas gain of detectors as measured with a 270 MeV/c π+ beam at PSI with particle fluxes ranging from ~ 320 kHz/cm^2 up to ~ 1.2 MHz/cm^2.

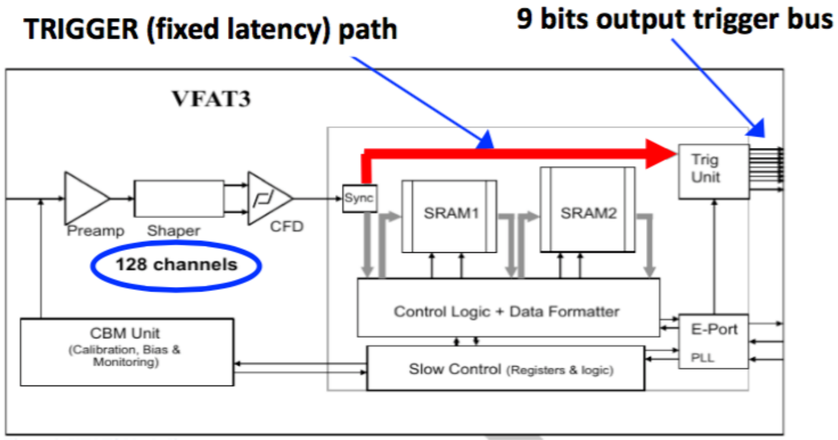
VFAT3 CHIP

VFAT3 front-end chip (128 ch. &130 nm CMOS tech.) is currently under design for the readout of triple-GEM detectors of the CMS phase 1 upgrade ➔
<u>It looks to be an useful starting point on which adjust our needs</u>

VFAT3 features:

1. selectable peaking time

Tpeak [ns]	Delay time Td [ns]
25	**15**
50	29
75	43.4
100	57.8



1. **rate capability = 1 MHz @ T_{PEAK} = 25 ns**
2. time resolution ~ 6 ns @ T_{PEAK} = 25 ns
3. noise $e_{RMS} \leq$ 1000e @ T_{PEAK}= 25 ns, pad capacitance < 100 pF
4. to transfer 128 channels (bits) in 25 ns ➔ 8 bits bus + 640 MHz clock (40 MHz × 16)

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