The Study of CMS CSC Spatial Resolution and Operation in Extreme Radiation & High Rate Conditions

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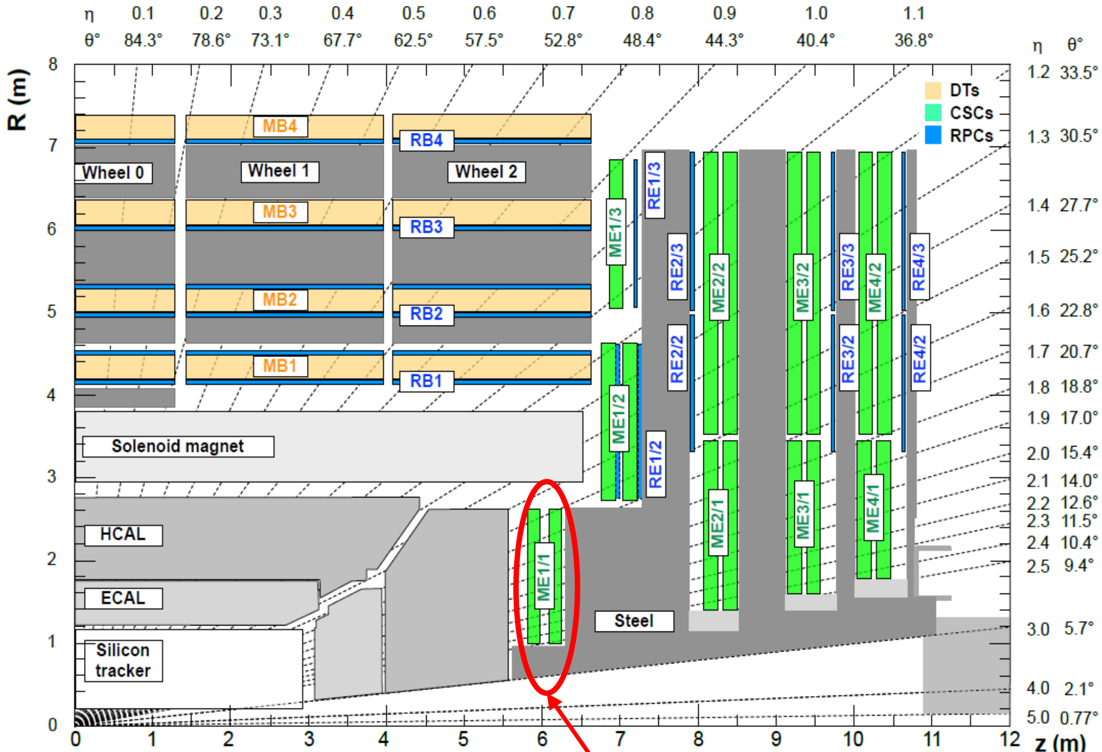
RDMS-2018

CMS Muon System

CMS R-z quadrant



The very forward sub-station ME1/1* was designed and produced at JINR

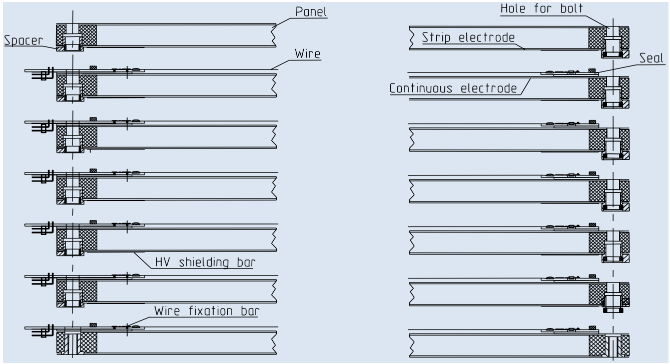
Cathode Strip Chambers compose CMS Endcap muon system (CSC, green color):

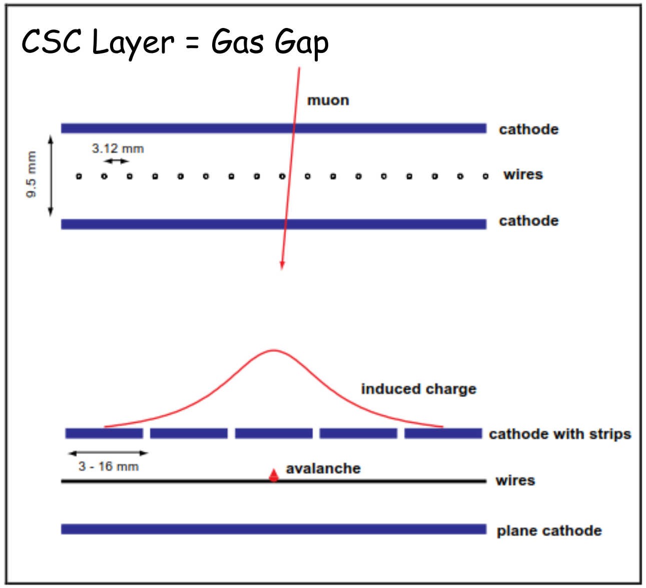
- 4 muon stations;
- 540 6-layer chambers
- Cover 0.9 < |η| < 2.4
- 7000 m2 sensitive area
- More than 2.5 M anode wires
- ~ 200 k anode readout channels
- ~ 250 k cathode readout channels

(*) ME1/1 is composed by 2 sub-stations: ME1/1a part covering pseudorapidity range η=[2.1-2.4] and ME1/1b η=[1.6-2.1]

CSC principle of operation and spatial resolution

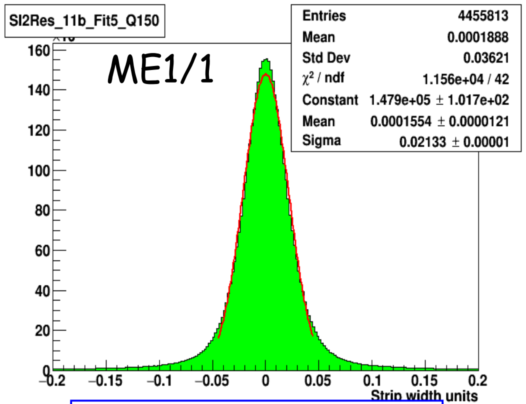
6-layer CSC





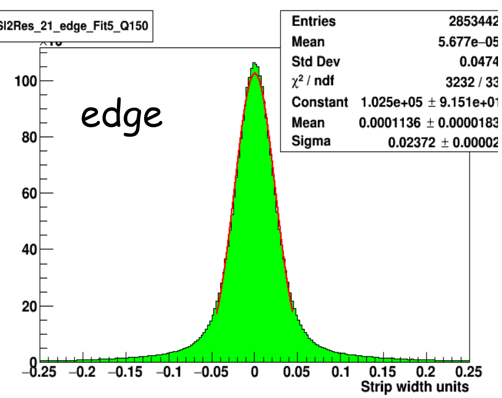
- All 540 CSCs are composed of 6 identical multi-wires proportional chambers with cathode readout.
- The signals from anode groups define the muon's radial coordinate while signals induced on strips give the azimuthal coordinate.
- The Gatti function is used to determine the precise azimuthal coordinate for a CSC Layer.

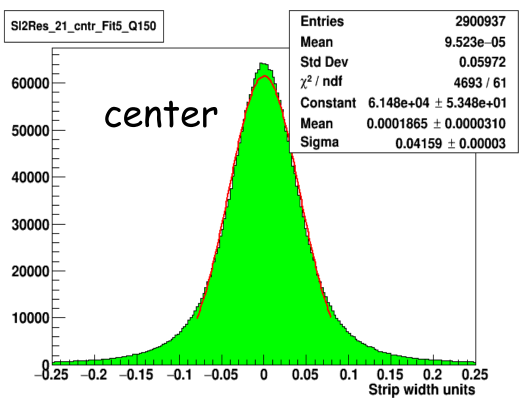
Residuals for CSC Layer



$1/\sigma^2$ (Station) = $6/\sigma^2$

non-ME1/1:

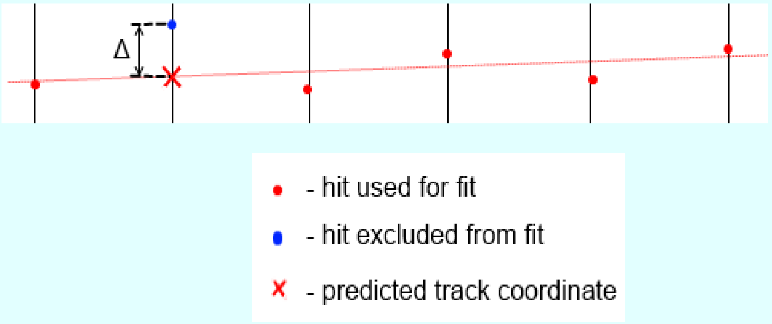




$1/\sigma^2$ (Station) = $3/\sigma_1^2 + 3/\sigma_2^2$

Spatial resolution calculation:

- Only 6 & 5-point segments are considered;
- For each layer with hit a straight line fit is applied excluding the current layer and the residual (Δ) between the measured strip coordinate and the predicted track coordinate from fit is used for resolution calculation.

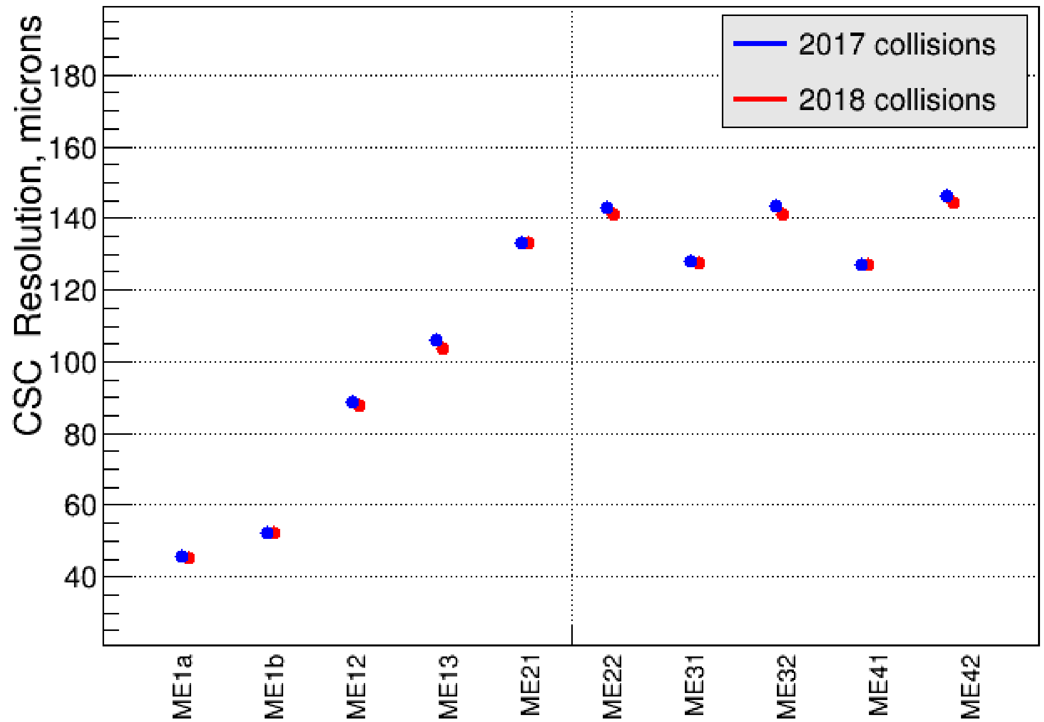


CSC Spatial Resolution 2017-2018 pp collisions

Spatial resolution per station (μm):

Station	Collision dataset	
	Run2	
	2017C,F	2018A
	ZMu	ZMu
ME1/1a	46	45
ME1/1b	53	52
ME1/2	89	88
ME1/3	106	105
ME2/1	133	133
ME2/2	143	141
ME3/1	128	127
ME3/2	143	141
ME4/1	127	127
ME4/2	146	145

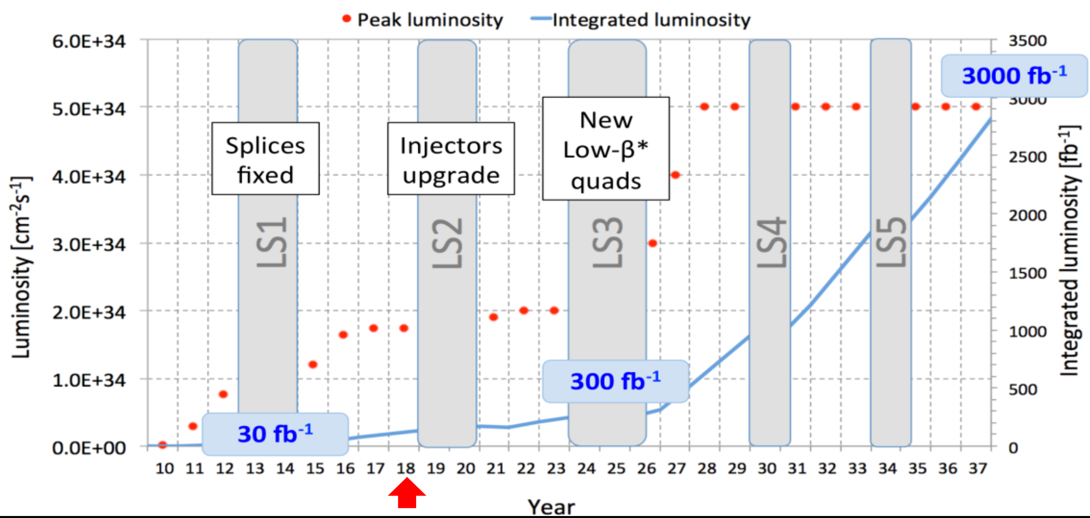
Values are normalized to atm.pressure 965 mbar



For basic CSC gas mixture: Ar+CO2+CF4 (40/50/10%)

Results 2017/2018 are in excellent agreement, and consistent with previous years, thus indicating stability of detector performance

LHC - HL LHC schedule

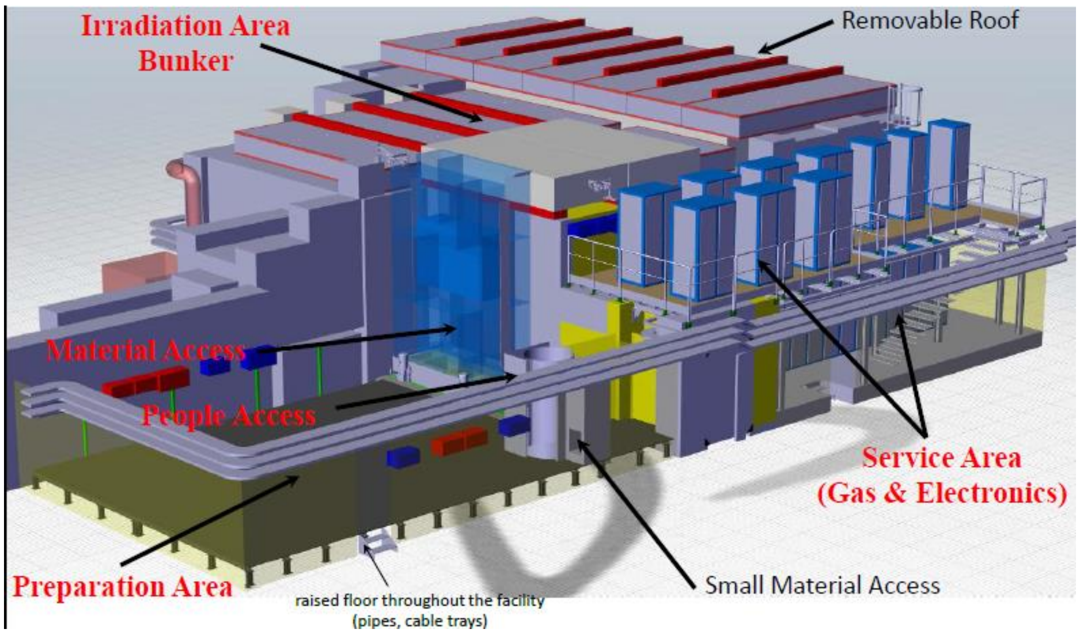


	LHC	HL LHC
Instant. luminosity ($cm^{-2}s^{-1}$)	**10^{34}**	**5×10^{34}**
pileup collisions	**30**	**150**
integrated luminosity (fb^{-1})	**300**	**3000**
CMS L1 trigger rate (KHz)	**100**	**750**

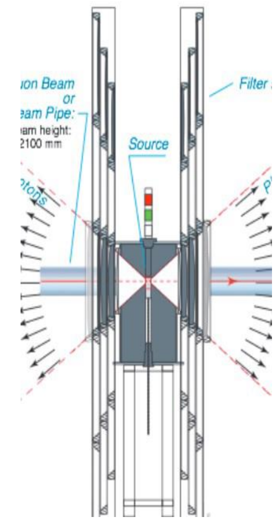
HL-LHC increase in luminosity will produce a particle background in the gas-based muon detectors that is significantly higher than under present conditions at the LHC.
A precise understanding of possible ageing effects of detector materials and gases and chamber’s operation stability with high background rates are of extreme importance.

B. 887 (CERN): GIF++ bunker 3D view

A new Gamma Irradiation Facility (GIF++) was designed and built at the CERN SPS North Area (EHN1, building 887) in 2015.
With this facility, the detectors could simultaneously be exposed to the photons from a 137Cs source and to a high-energy H4 SPS muon beam.



GIF++ Source with filters



Att.Fact. 1÷46.4k

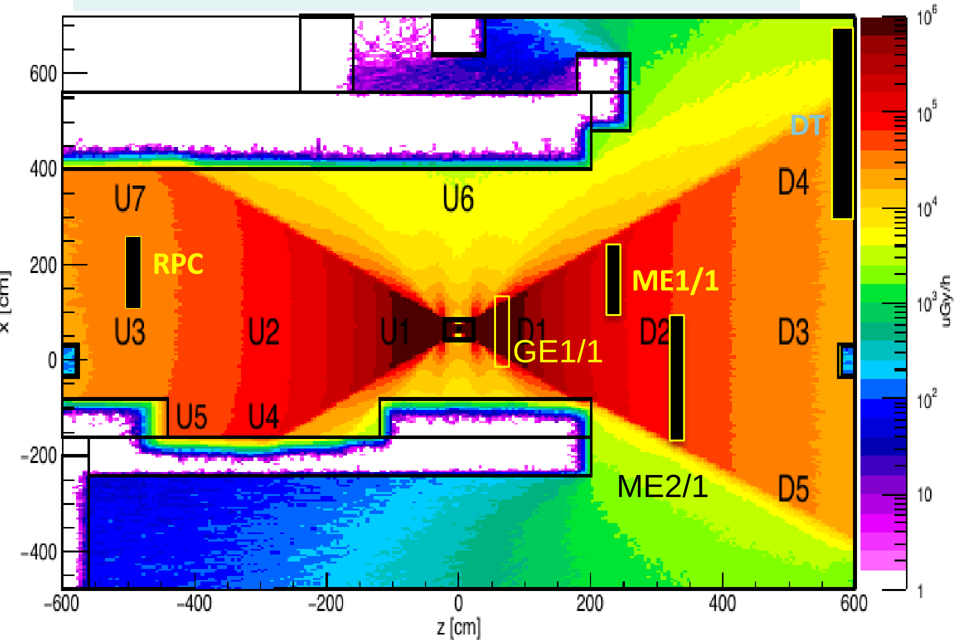
Plane :	A	B	C
Pos. 1	1	1	1
Pos. 2	10	1.47	2.15
Pos. 3	100	100	4.64

- **14 TBq Cs^{137} source (Eγ = 662 keV)**
- **H4 SPS beam line**
- **A set of filters: Attenuation Factor: (1 ÷ 46000)**
- **Upstream + Downstream 100m2 irradiation zone**

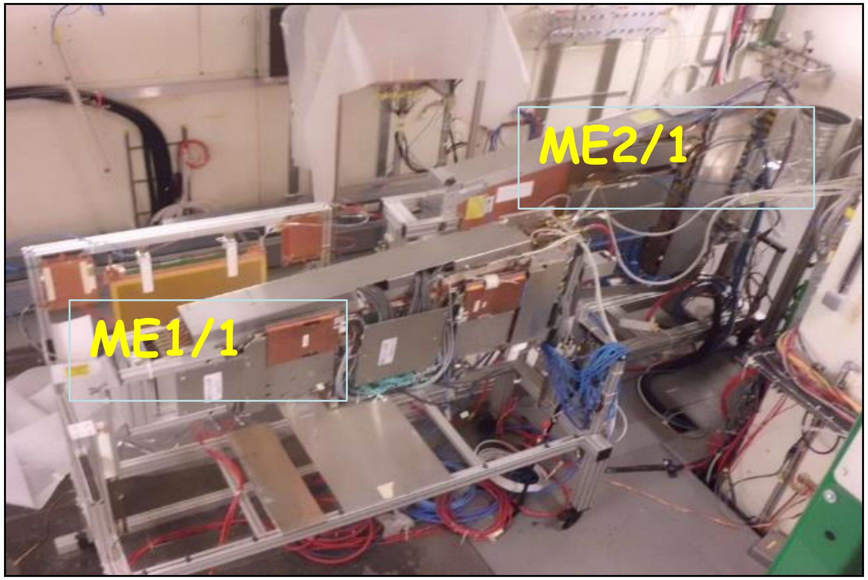
M.R. Jäkel et al.CERN GIF++ : A new irradiation facility to test large-area particle detectors for the high-luminosity LHC program. PoS (TIPP2014) 102

For ageing tests @ GIF++ ME1/1 and ME2/1 CSCs were chosen as operating with highest background in CMS.
During the irradiation 2 outer (reference) CSC gas gaps were off while 4 internal ones were operational.

GIF++ irradiation intensity map



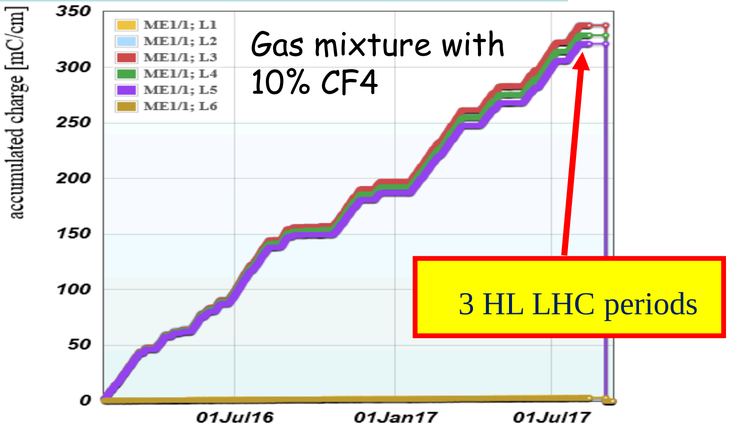
CSCs at GIF++ in irradiating position



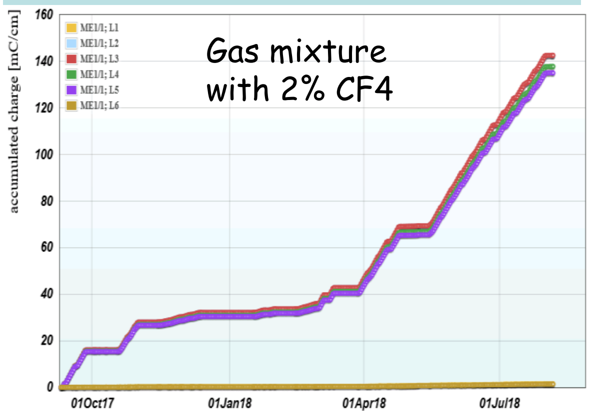
In 2016 we started to test CSCs operation at HL LHC conditions:
- High background rate
- Large accumulated charge

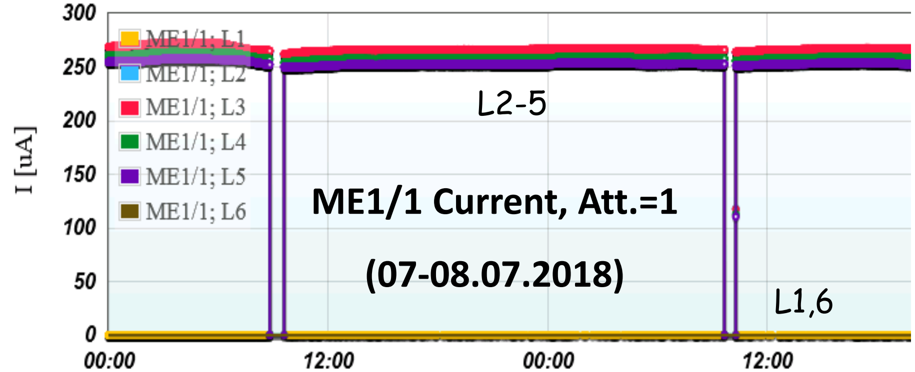
CSCs Accumulated charge

ME1/1 Accum. Charge in 2016-2017



ME1/1 Accum. Charge in 2017-2018

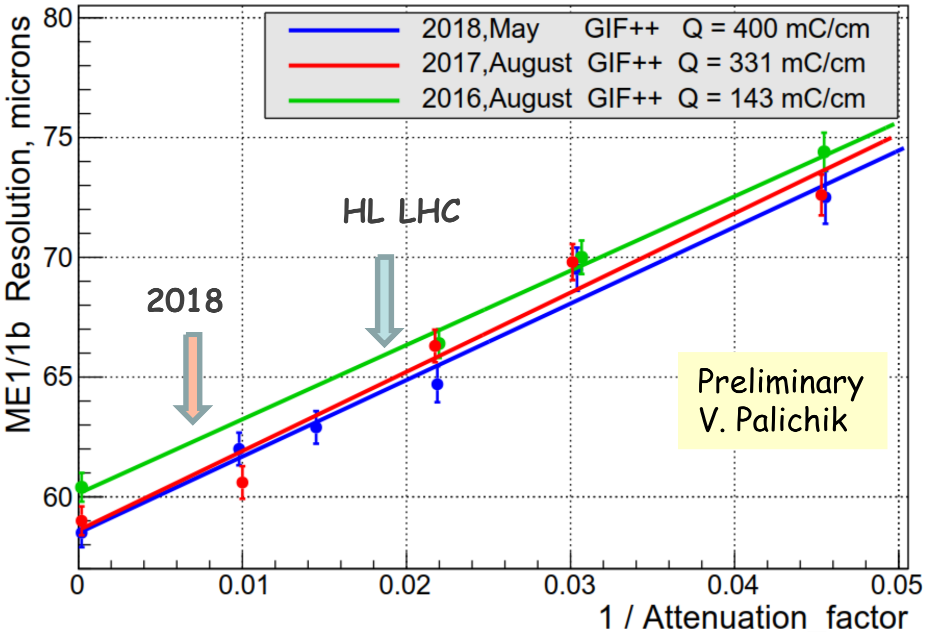


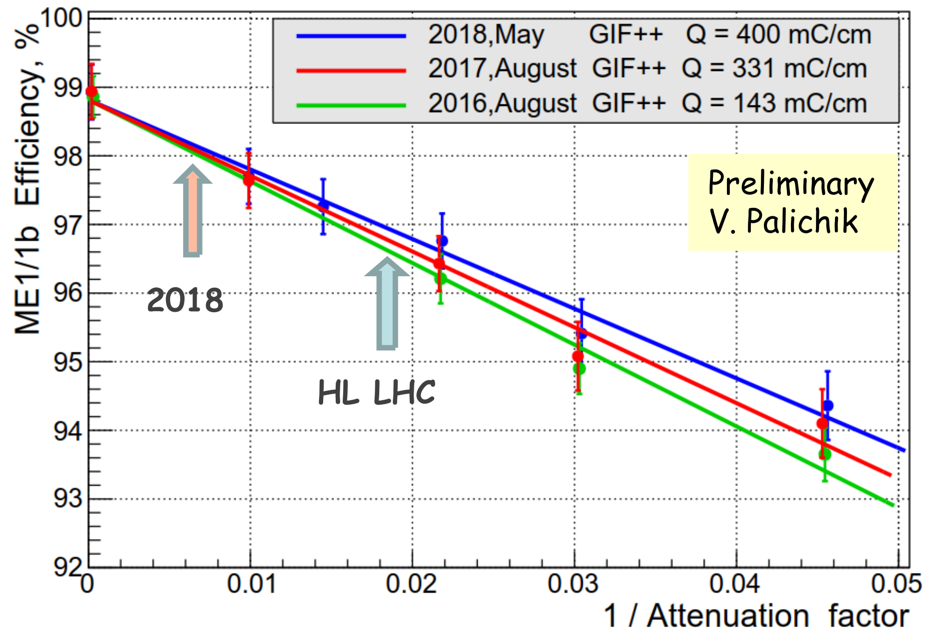


TB	Q(ME1/1) [mC/cm]	<Q(ME2/1s1)> [mC/cm]
Irradiation with Ar+CO2+CF4 (40%+50%+10%)		
June16	83	77
Aug16	146	132
May17	277	260
Jul17	316	299
Aug17	332	314
Irradiation with Ar+CO2+CF4 (40%+58%+2%)		
May18	400	
Aug18	467	

Accumulated charge equivalent to the value of 3 HL LHC periods exposition ~ 9000fb^{-1}

GIF++: ME1/1 Spatial resolution and layer efficiency vs Source intensity





Source irradiation intensity can be varied by interposing attenuation filters

Efficiency per layer (from segments):

Numerator	1	1	1	0	1	0
Segment	x	x	x	o	x	o
Demoninator	1	1	1	1	1	1

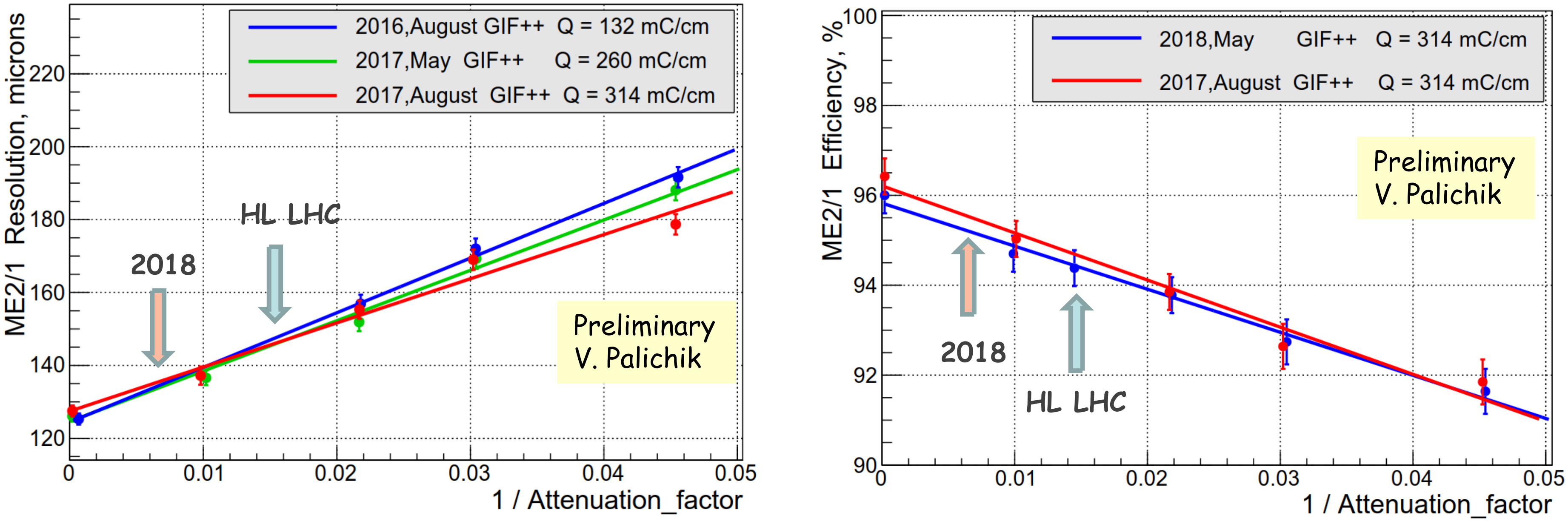
→ Efficiency

ME1/1 Spatial resolution and Efficiency vs Att. factor^{-1} for different values of accumulated charge.

The indicated points correspond to the present (2018) maximum LHC delivered luminosity to CMS (2018) and to the HL-LHC expected luminosity (5e34 Hz/cm^2).

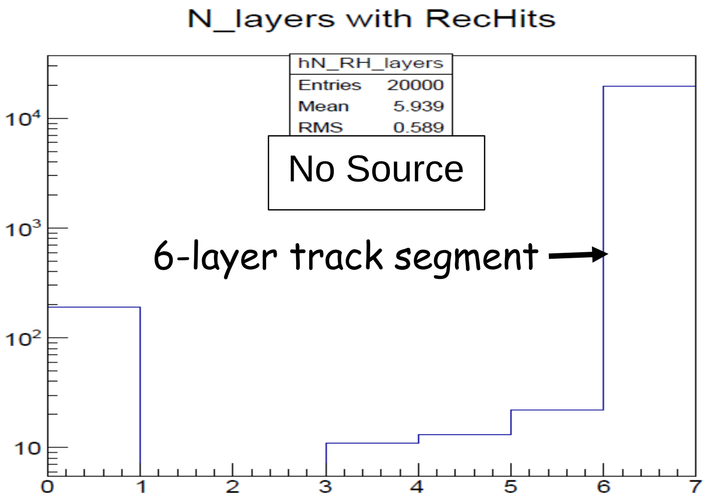
One can expect for HL LHC conditions the spatial resolution degradation of 10% and efficiency degradation of 2%.

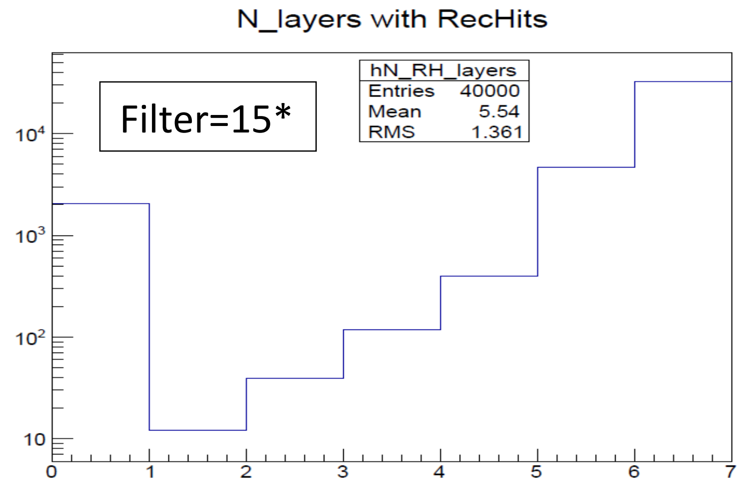
GIF++: ME2/1 Spatial resolution and layer efficiency vs Source intensity



One can expect for HL LHC conditions the spatial resolution degradation for ME2/1 of 16% and efficiency degradation of 1.5%.

Reasons of CSC parameters degradation with B/G increase

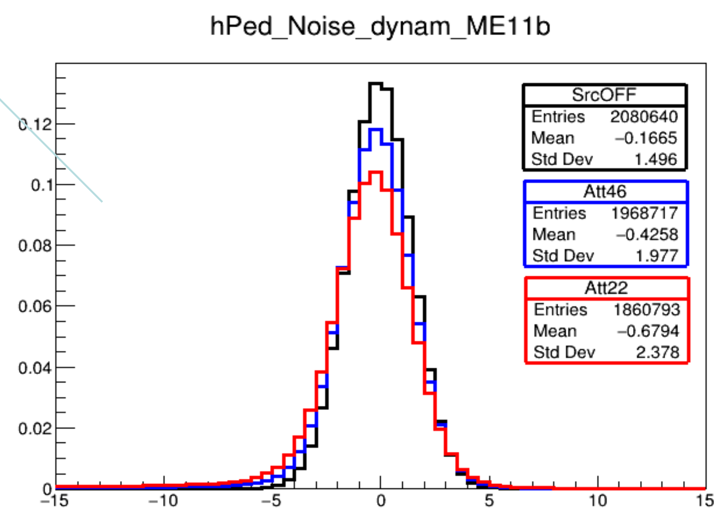




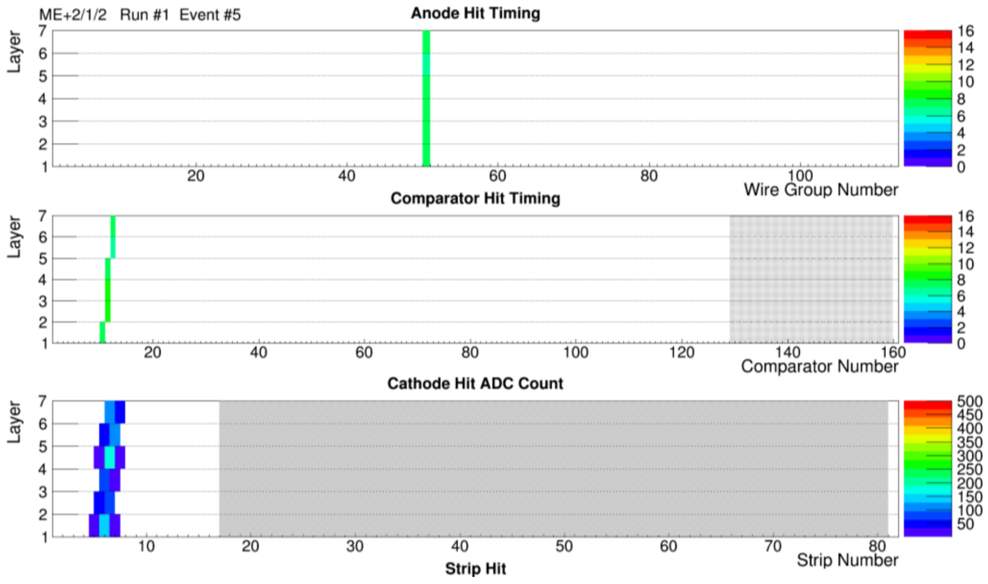
ME2/1 HV0, Test 40, muon beam, hits in Layers per muon trigger w/o Source and with Filter=15* (V. Palichik)

Cluster charge distortion is one the reasons of inefficiency of the CSC layers where the muon hit wasn't found.

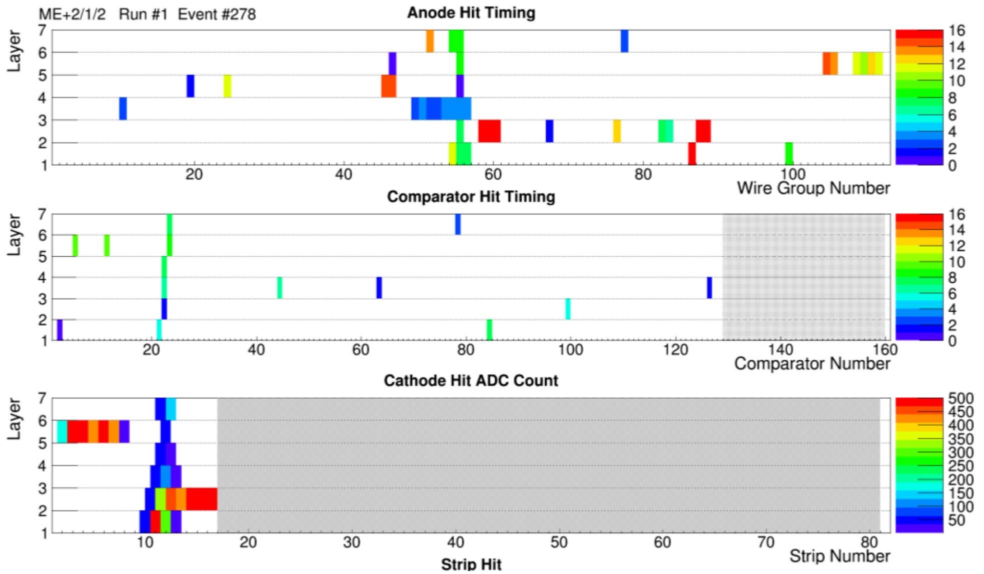
ME1/1b pedestals degradation with B/G Increase Source=off, filters: 46* and 22* (V. Palchik, K. Kuznetsova)



GIF++: ME2/1 event display with Source-off and on



Source=off,
Single muon



Att. Factor=22*:
muon with background

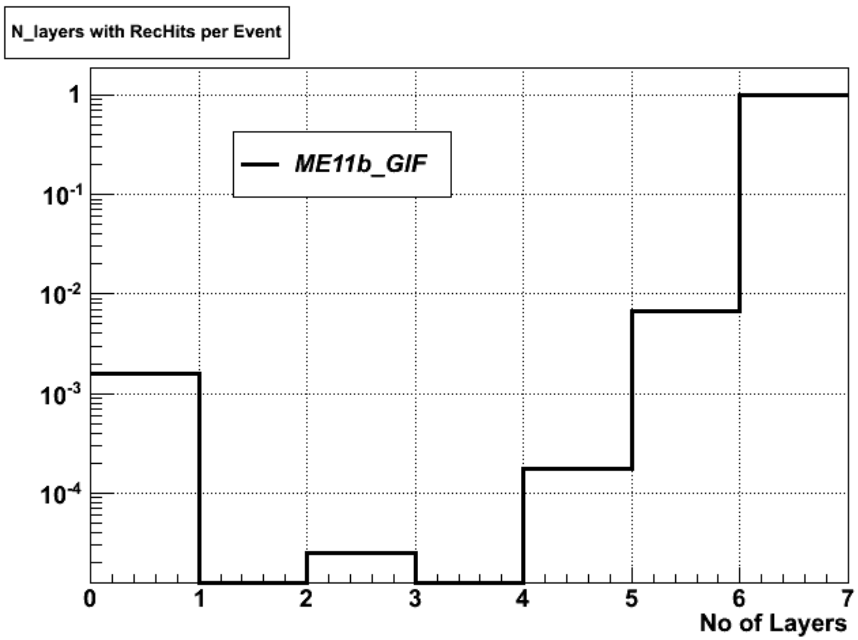
Conclusions

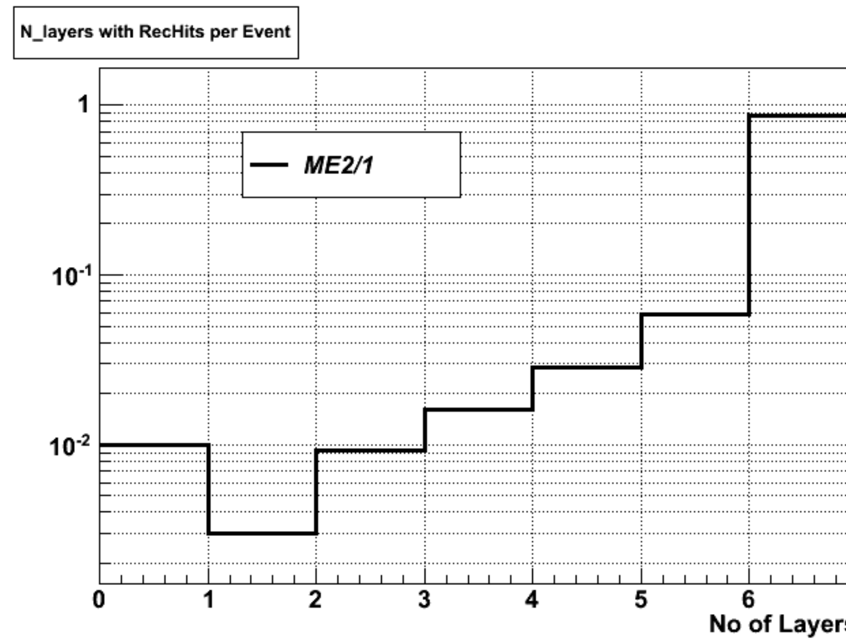
- **CSC spatial resolution in Run2 p-p collisions data is stable.**
- **No ageing effects observed for CSCs at GIF++ with accumulated doses higher than could be expected in operation through 3 HL LHC periods**
- **One can expect for HL LHC conditions the spatial resolution degradation of 10 - 16% and layer efficiency degradation of 1.5 - 2% for the most irradiated CSCs.**

Backup Slides

Number of layers with RecHit per event

Aug17, 10%CF4, Source OFF





CSC Spatial Resolution: selection

Select good quality segment/muon track for spatial resolution measurement:

- segments matched to global muons with P > 10 GeV
- 6 hits on a track segment
- Track-segment χ^2 (2D) criteria
- Cut on large angles dx/dz (local coordinates):

  $|\,dx/dz\,| < 0.25$ for ME11

  $|\,dx/dz\,| < 0.2$ for all other stations
- Track-segment χ^2 (strips) criteria
- Sum of charges for 3 strips and 3 time slices:

  $150 < Q_{3x3} < 4000$ ADCs for ME1/1 station

  $150 < Q_{3x3} < 2000$ ADCs for all other stations

Sofware: CMSSW_10_1_5
Dataset: /SingleMuon/Run2018A-ZMu-PromptReco-v1/RAW-RECO

CMS Runs / Luminosity p-p collisions 2018A

CMS p-p Runs Before MD1 May-2018

2440b-2556b, β*=0.3m, <n> = 59, Lpeak 1.8-2×e34cm-2sec-1

Fill 6642 315721 2018.05.05 04:54 - 09:04 207pb-1

Fill 6643 315741 2018.05.05 11:44 - 12:23 24pb-1

Fill 6645 315764 2018.05.05 15:33 - 17:39 112pb-1

Fill 6646 315770 2018.05.06 02:04 - 04:17 119pb-1

Fill 6648 315784 2018.05.06 10:55 - 12:13 67pb-1

315785 2018.05.06 12:22 - 14:21 103pb-1

315787 2018.05.06 14:57 - 17:57 122pb-1

315790 2018.05.06 18:11 - 00:14 168pb-1 (Linit~1e34cm-2sec-1)

Fill 6650 315800 2018.05.07 06:39 - 10:52 209pb-1

315801 2018.05.07 10:56 - 13:14 95pb-1

Fill 6654 315840 2018.05.07 21:06 - 04:39 344pb-1

Fill 6659 315973 2018.05.08 23:17 - 05:13 275pb-1

Fill 6662 316058 2018.05.09 20:30 - 23:08 133pb-1

316059 2018.05.09 23:09 - 02:50 163pb-1

316060 2018.05.10 02:52 - 08:56 188pb-1

Fill 6663 316082 2018.05.10 12:31 - 15:19 138pb-1

Fill 6666 316110 2018.05.10 21:21 - 22:43 79pb-1

316114 2018.05.10 23:42 - 10:23 351pb-1 (Linit~1.4e34cm-2sec-1)

Fill 6672 316153 2018.05.11 17:02 - 22:07 246pb-1

Fill 6674 316187 2018.05.12 03:17 - 16:45 509pb-1

Fill 6675 316199 2018.05.12 18:41 - 02:27 388pb-1

316201 2018.05.13 02:35 - 05:49 106pb-1 (Linit~1.1e34cm-2sec-1)

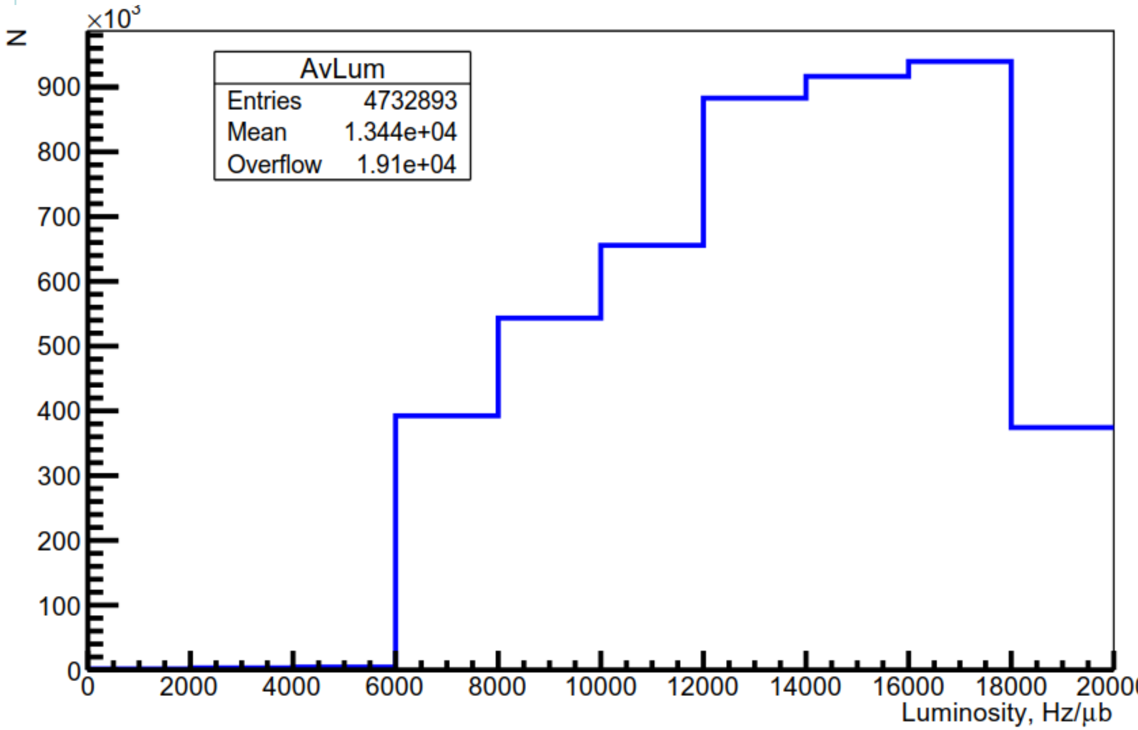
316202 2018.05.13 05:52 - 08:34 74pb-1 (Linit~0.8e34cm-2sec-1)

Fill 6677 316216 2018.05.13 11:47 - 14:56 172pb-1

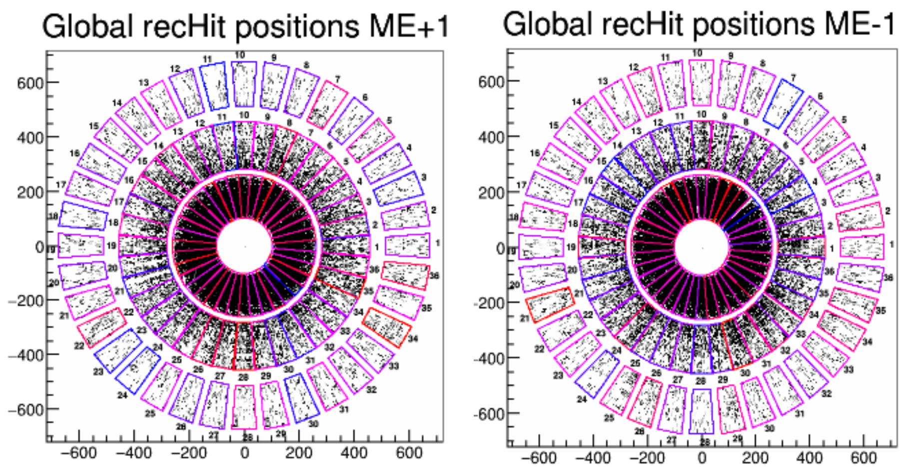
316217 2018.05.13 15:03 - 16:47 85pb-1

316218 2018.05.13 16:51 - 23:30 237pb-1 (Linit~1.3e34cm-2sec-1)

316219 2018.05.13 23:32 - 01:27 48pb-1



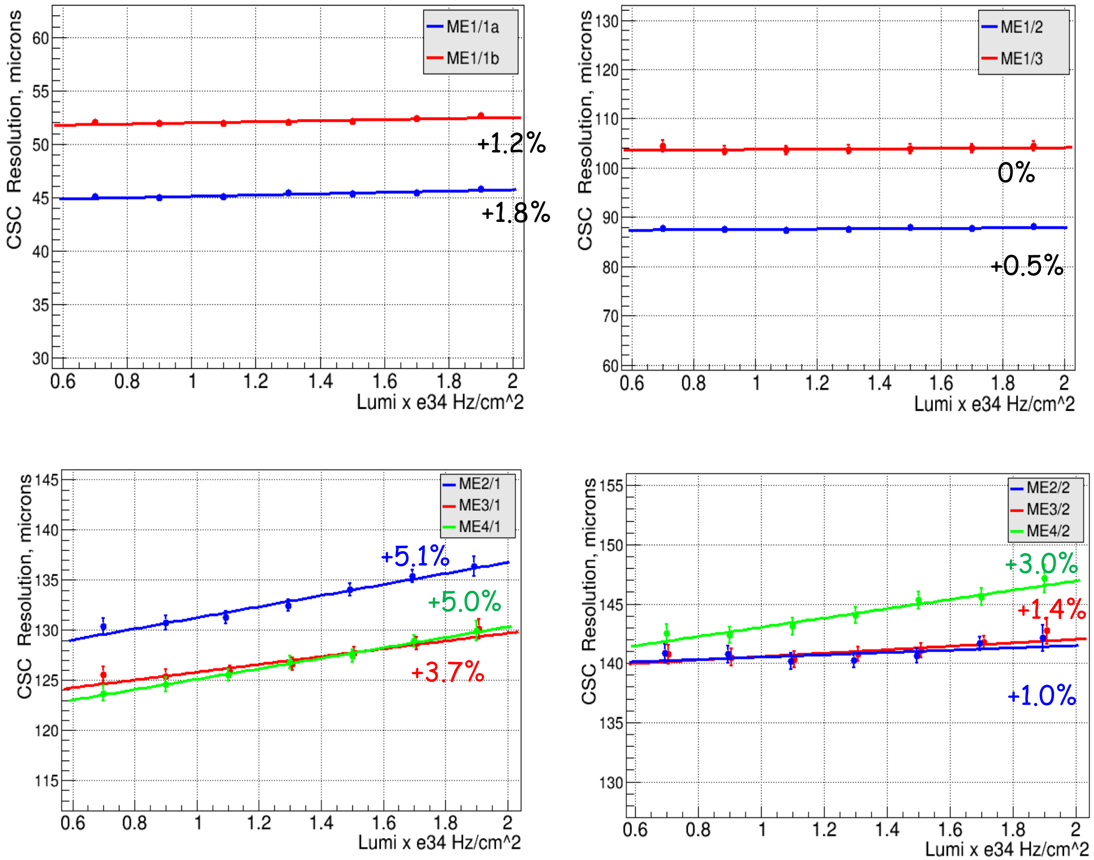
CSC Layer efficiency



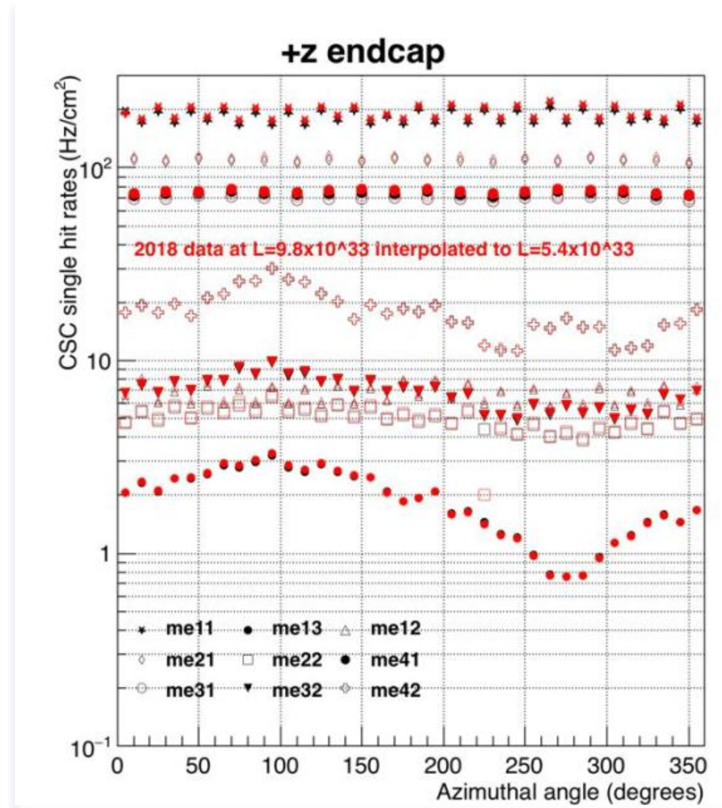
p-p collisions-2018, Run 316994
RecHit position in ME+/-1 stations

CSC Spatial Resolution vs LUMI and background 2018

ME Spatial resolution vs Lumi



ME background rates at L=5.4e34 $cm^{-1}s^{-1}$ (M. Ignatenko)

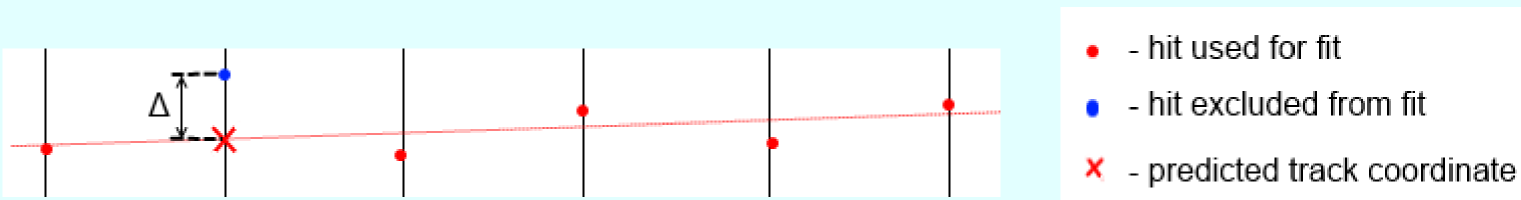


The spatial resolution degradation at high Lumi is observed for the sub-stations having higher background rates (ME1/1- a special case)

Spatial Resolution & Efficiency

Spatial resolution calculation:

- Only 6 & 5-point segments are considered;
- For each layer with hit a straight line fit is applied excluding the current layer and the residual (Δ) between the measured strip coordinate and the predicted track coordinate from fit is used for resolution calculation.

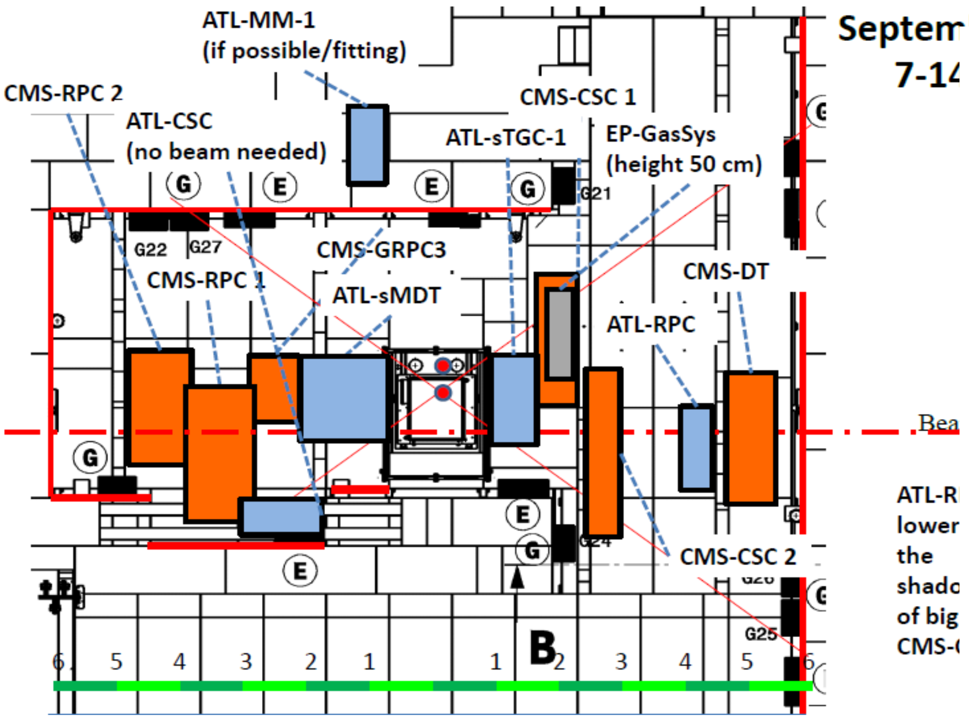


Efficiency per layer (from segments):

Numerator	1	1	1	0	1	0
Segment	x	x	x	o	x	o
Demoninator	1	1	1	1	1	1

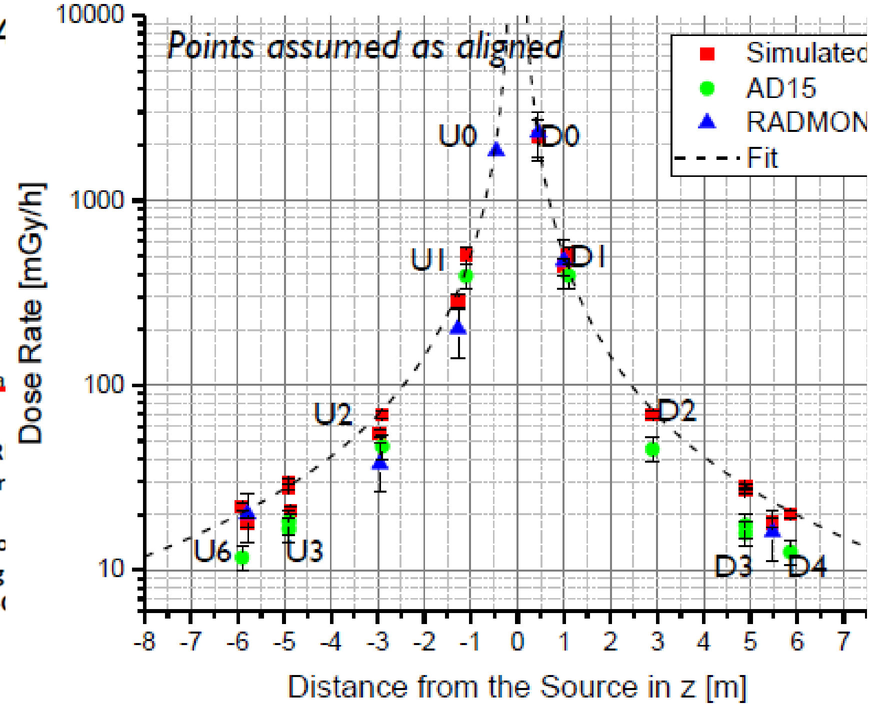
→ Efficiency

Detectors at GIF++



R. Guida. Setups position and schedule for next test beam. https://indico.cern.ch/event/566910/

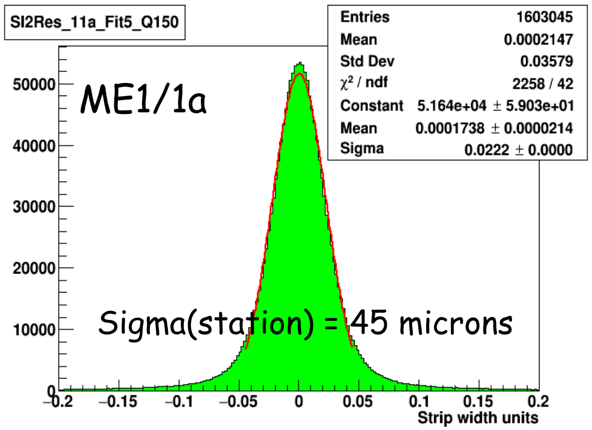
10 permanent GIF++ users, new requests for longevity tests and RadHardness tests are coming



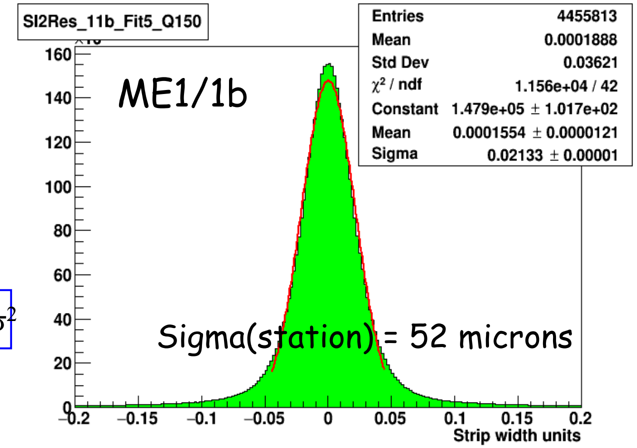
GIF++ radiation measurements Att. Factor=1 (Dose rate vs distance from the Source)

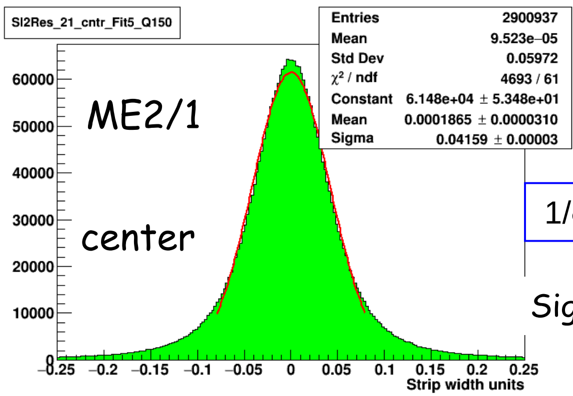
G. Gorine, GIF++ RADIATION ENVIRONMENT https://indico.cern.ch/event/517100

Spatial Resolution: results with 2018A collision data



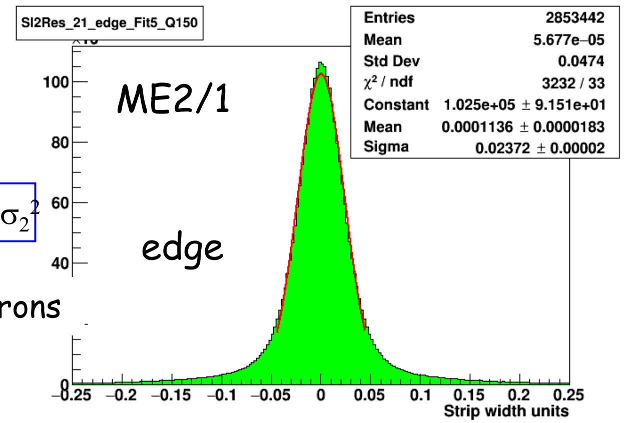
$1/\sigma^2$ (Station) = $6/\sigma^2$

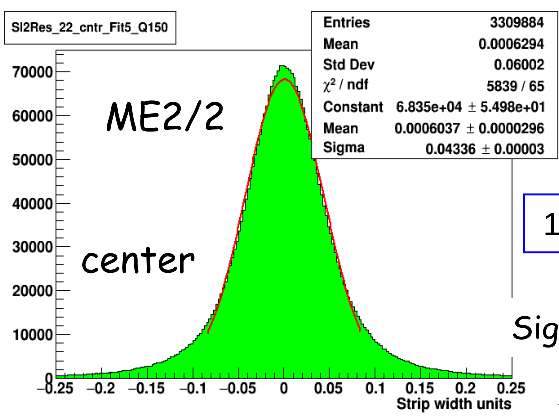




$1/\sigma^2$ (Station) = $3/\sigma_1^2 + 3/\sigma_2^2$

Sigma(station) = 133 microns





$1/\sigma^2$ (Station) = $3/\sigma_1^2 + 3/\sigma_2^2$

Sigma(station) = 141 microns