EP-RD-ET WG2

RD51 mini week

We will skip this (see previous contribution from Christian)

R&D on Experimental Technologies

EP department is launching an R&D programme on **new Detector Technologies**.
This initiative, which spans a **5-years period from 2020 onwards** (with a possible extension by another 5 years), covers detector hardware, electronics and software for new experiments and detector upgrades beyond LHC phase II.
Working groups are formed for the key themes. They are studying the **state of the art**, **limitations and main challenges** in the various domains and **define an ambitious and focused work programme** with milestones, deliverables and resource estimates.
Interested colleagues - no matter if engineer or physicist, staff or user, at CERN or elsewhere - are invited **to contribute to the definition** of the R&D programme. Please inscribe to a mailing list below. There is also a general email list for those, who just want to be informed about progress and events: EP-RDET-General.
Please mark in your agenda the upcoming Workshop 1 where the intermediate status will be presented: 16 March 2018. Register on the indico site.
A second workshop will take place in the autumn of this year, with the aim of preparing a report summarizing the proposed R&D programme before the end of the year.

https://ep-dep.web.cern.ch/rd-experimental-technologies

We will skip this (see previous contribution from Christian)

CERN EP R&D on Experimental Technologies

https://ep-dep.web.cern.ch/rd-experimental-technologies

Working Groups	Convenors	Mailing Lists	WG site *)
Silicon detectors	Heinz Pernegger, Luciano Musa, Petra Riedler, Dominik Dannheim	EP-RDET-WG1-Si	WG1-Si
Gas detectors	Christoph Rembser, Eraldo Oliveri	EP-RDET-WG2-Gas	WG2-Gas
Calorimetry and light based detectors	Martin Aleksa, Carmelo d'Ambrosio	EP-RDET-WG3-Cal-Light	WG3-Cal-Light
Detector Mechanics	Corrado Gargiulo, Antti Onnela	EP-RDET-WG4-Mech	WG4-Mech
IC technologies	Federico Faccio, Michael Campbell	EP-RDET-WG5-IC	WG5-IC
High Speed Links	Paolo Moreira, Francois Vasey	EP-RDET-WG6-Links	WG6-Links
Software	Graeme Stewart, Jakob Blomer	EP-RDET-WG7-Software	WG7-Software
Detector Magnets	Herman Ten Kate, Benoit Cure	EP-RDET-WG8-Magnets	WG8-Magnets

R&D steering committee:

Joram, Cristian (EP-DT-TP)(coordinator)

Farthouat, Philippe (EP-ESE)

Forty, Roger (EP-DI)

Hahn, Ferdinand (EP-DI)

Janot, Patrick (EP-CMG)

Krammer, Manfred (EP)

Linssen, Lucie (EP-LCD)

Mato Vila, Pere (EP-SFT)

Riegler, Werner (EP-AIO)

Schmidt, Burkhard (EP-DT)

WG2 - our scope

- **review state-of-the-art gaseous detectors**, including limitations and main challenges;
- **define the R&D strategy** for gaseous detectors for future experiments (future colliders, fixed target experiments, future LHC experiment upgrades; new (unconventional) ideas are welcome!);
- **identify key technologies (with CERN experience);**

Later…

- define a roadmap with milestones and prototypes to be developed;
- define funding requirements;

WG2 – our “deliverable”

- review state-of-the-art gaseous detectors, including limitatio
- define the R&D strategy for gaseous detectors for future expe fixed target experiments, future LHC experiment upgrades; ne s are welcome!);
- identify key technologies (with CERN experience);
- define a roadmap with milestones and prototypes to be developed;
- define funding requirements;
- prepare a proposal for the organisation of gaseous detector R&D within EP.

The proposal should then result in a ***programme on gaseous detector R&D in the EP*** Department for the period 2020 - 2025 (and maybe 2025-2030).

Proposal enters European Strategy

- First "European Strategy for Particle Physics" in 2006, Strategy Update May 2013.
    - 2013 on R&D: **The success of particle physics experiments, …, relies on innovative instrumentation, state-of-the-art infrastructures and large-scale data-intensive computing.** Detector R&D programs should be supported strongly at CERN, national institutes, laboratories and universities. Infrastructure and engineering capabilities for the R&D program and construction of large detectors, as well as infrastructures for data analysis, …

- Strategy update approval by Council (date fixed, May 2020)
- The strategy update is drafted by the European Strategy Group (ESG)
- The drafting is based on input from the community – collaborations, projects, national institutes, national roadmaps, individuals
- The input is collected by the Physics Preparatory Group (PPG)
- The PPG organizes the Open Symposium to discuss the proposals
- The PPG summarizes the input, the discussions and their conclusions in a Briefing Book
- The Briefing Book constitutes the input for the ESG for drafting the update
- The drafting of the strategy update takes place during a dedicated Drafting Session (the conclave of the EPPSU process)

WG2: proposed schedule

Days	Meeting	Main Goals	Room
09/02	*Preparatory Meeting*	• First inputs	60-6-015 - Room Georges Charpak (Room F)
26/02	*1st WG2 meeting*	• Inputs from community	222-R-001
15/03 (?)	*The "day before" meeting*	Review of the contribution for the *EP-RDET workshop 1*	513-1-024 (8:30-15:30)
16/03	*EP-RD-ET Workshop 1*		
Early Autumn	*EP-RD-ET Workshop* 2	• Detailed Draft and Plans	
November		• Document Release	

now

Not by accident…

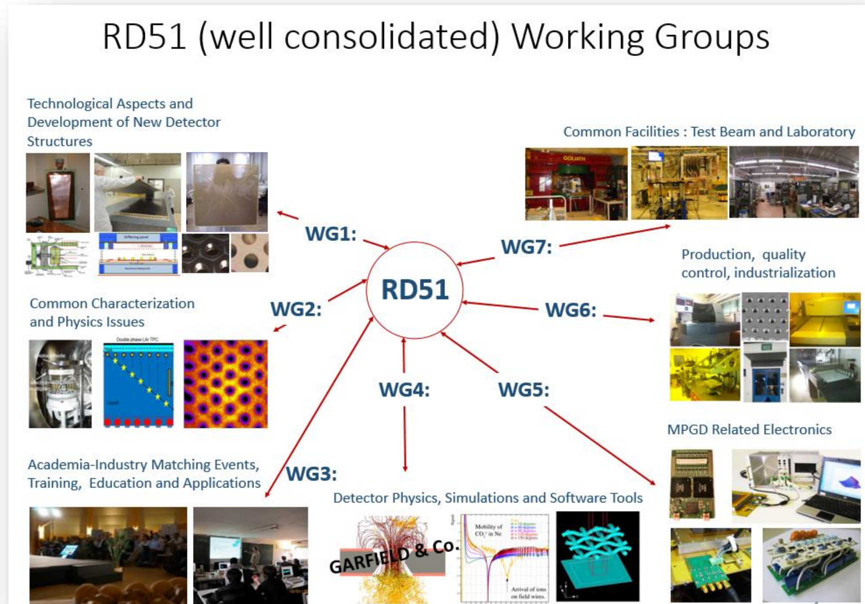
Suggestion: 3-5 days WG2 workshop in April/May:
Giving sufficient time to properly cover all the relevant aspects as topic list, overview on CERN facilities (irradiation & beam), overview on activities/infrastructure of other laboratories/universities

WG2 – Topics

Topics covered by the WG:

- Motivation, Detector Requirements & Physics Challenges;
- Gaseous Detector Technologies
  - MPGD
  - RPC
  - Others
- Detector Simulation and Modelling
- Gas System R&D
- Gaseous Detector Electronics
- Workshops, Infrastructures and Engineering
- New technologies and New materials

Topics based on RD51 working groups structure



WG2 – Preparatory Meeting (9th Feb.)

Preparatory meeting

Friday 9 Feb 2018, 08:30 → 13:00 Europe/Zurich

60-6-015 - Room Georges Charpak (Room F) (CERN)

Description PRELIMINARY TABLE

Videoconference Rooms WG2_preparatory_meeting

08:30 → 09:00 **Introduction**

EP-RD-ET WG2-Prep... EP-RD-ET WG2-Prep...

09:00 → 11:30 **Working Groups**

- Motivation, Detector Requirements & Challenges (Ties)
- Gaseous Detector Technologies
  -MPGD (Leszek)
  -RPC (Roberto, Rinaldo)
  -Others (Anatoli)
  -Novel Technologies and Material Science (All)
- Detector Simulation and Modelling (Heinrich, Rob)
- Gas System R&D (Roberto)
- Gaseous Detector Electronics (Yan, Paul)
- Workshops, Infrastructures and Enginering
  -Micro Pattern Technology workshop (Rui)
  -Thin Film and Glass laboratory (Thomas)
  -Engineering (Andrea)

engineering_RD_ga... engineering_RD_ga... GasSystemR&D.pdf
Preparatory Meetin... Preparatory Meetin... RD51_beyond_201...
simulations_9feb20...

11:30 → 12:30 **Next steps**

- 1st WG2 Meeting (26th February) https://indico.cern.ch/event/702148/
- EP R&D Workshop 1 (16th March) and "day before" meeting
- 3-5 Days WG2 Workshop (dates to be defined)

Process started:
first meeting (9.2.2018) with invited experts to find out
- **what R&D is done at CERN;**
- **what infrastructure/expertise is available;**

Experts invited
Ties Behnke (Motivation, Detector Requirements & Physics Challenges)
Leszek Ropelewski (MPGD)
Roberto Cardarelli (RPC)
Rinaldo Santonico (RPC)
Anatoli Romaniouk (Other Technologies)
Heinrich Schindler (Detector Simulation and Modelling)
Rob Veenhof (Detector Simulation and Modelling)
Roberto Guida (Gas System R&D)
Jan Kaplon (Gaseous Detector Electronics)
Paul Aspell (Gaseous Detector Electronics)
Rui de Oliveira (Micro Pattern Technology workshop)
Thomas Schneider (Thin Film and Glass laboratory)
Andrea Catinaccio (Engineering)

First meeting, 9th February: Brief Summary

- Gas detector R&D: discussion on "how rather than what ™";
- Development and support of electronics and simulation crucial;
- Infrastructure to test new gases / new gas systems crucial;
- Infrastructure to apply new technologies / new techniques vital;
  - Offers exciting possibilities for R&D;
- synergies to other EP R&D WG (detectors, mechanics, software, electronics…) but also with other departments (to be explored).

26th February Meeting (next Monday)

The meeting is meant to:

- *Outline R&D projects (current or future).*
- *Identify key technologies.*
- *Recognize common needs.*
- *Overview existing infrastructures and facilities of other Laboratories and Universities.*

We kindly ask the people that want to give a contribution to cover as many points as they can of the list above. In order to make your contribution effective, *please be conscious that this process is not a funding opportunity to support R&D in your own institute*. What CERN EP asked us is to define a possible R&D program (5 years) that will be carried on in EP at CERN but in close collaboration with you.

Input will be used for the contribution of WG2 to the 1st EP-RD-ET Workshop

In our view…

- Expertise (people and know-how) and R&D facilities (important for our own R&D at CERN and for attracting R&D activities from outside) should have a key role in our proposal.

- Our proposal should look for synergies with other R&D activities in EP and more generally at CERN.

- Ongoing CERN R&D will NOT be replaced NOR resources will be taken away by this initiative. On the contrary: awareness of the importance of R&D will be strengthened

WG2 Soundtrack: [Jumpin' Jack Flash]

But it's all right. I'm Jumpin' Jack Flash
It's a gas, gas, gas

WG2: proposed schedule

now

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backup

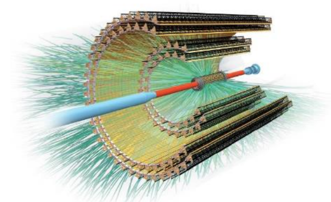
From Kick-Off Meeting… about gaseous detectors

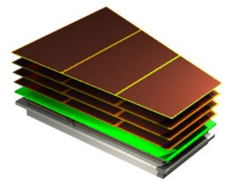
- *Current R&D in LHC experiments*
  - *ALICE*
  - *LHCb*
  - *ATLAS*
  - *CMS*

- *The main challenges beyond HL-LHC*
  - *Hadron machine*
  - *Lepton machine*

Current R&D in the ALICE Experiment

Luciano Musa – CERN/EP





Kickoff Meeting – R&D on experimental technologies
CERN, 20 November 2017

ALICE Upgrades – Layout and key systems

New Inner Tracking System (ITS) *CERN participation*
- CMOS Pixels

→ improved resolution, less material, faster readout

New Muon Forward Tracker (MFT)
- CMOS Pixels

→ vertex tracker at forward rapidity

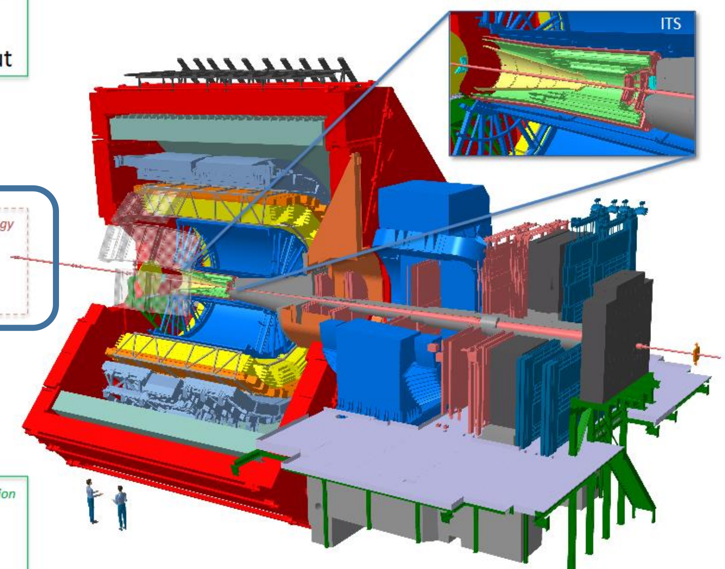
New TPC Readout Planes *CERN technology*
- 4-GEM detectors, new electronics

→ continuous readout

New trigger detectors (FIT, AD)
- Centrality, event plane

Upgrades readout for TOF, TRD, MUON, ZDC, Calor.

Integrated Online-Offline system (O^2) *CERN participation*
- Record minimum-bias Pb-Pb data at > 50kHz (currently ~ 1 kHz)



LHCb upgrades

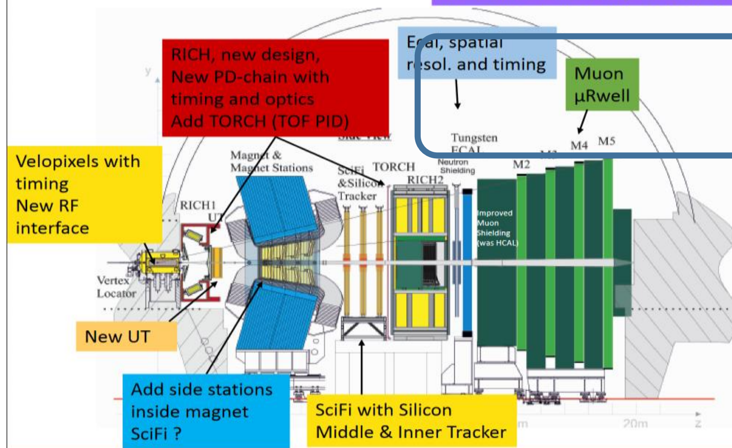
on behalf of CERN-LHCb Team
ie EP-LB*

Where we stand (LS2)
What comes next
Main R&D lines in EP-LB* & Co

EP-LBC	EP-DT
EP-LBD	EP-ESE
EP-LBO	EP-SFT
	…

LHCb LS4 upgrade

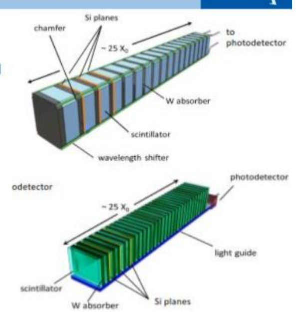
All: 40MHz FE readout, software trigger only



Other R&D

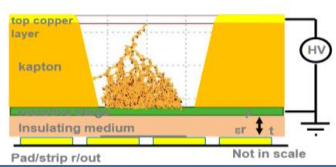
CALO:

- Increased granularity and position resolution
  - Smaller Molière radius => W
  - Now 4x4 (6x6, 12x12), go to ~ 2x2 cm^2
- Radhard lightguides / WLS / crystals
  - up to ~200 Mrad, ~10^{15} n_{eq}
- Use timing as well
  - Silicon pads , 1 cm^2 , 20…50 ps
  - fast/radhard crystals
    - LYSO(Ce), CeF3, GGAG(Ce)



Muons:

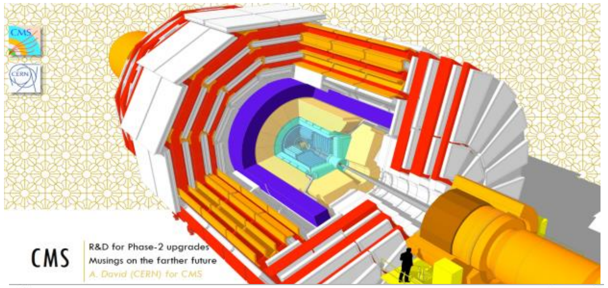
- Challenge: inner region
  - 3 MHz/cm^2 , 6C/cm^2
  - Pad size 6x8 mm^2 => divide by 2…4 ?
- Micro-resistive WELL



CERN Atlas Team's RD towards future detectors and experiments

H. Pernegger / EP-ADE

Current R&D in LHC experiments



CMS

R&D for Phase-2 upgrades
Musings on the farther future
A. David (CERN) for CMS

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CMS PHASE-2 UPGRADES IN A NUTSHELL

Trigger/DAQ (interim TDR submitted)
- Tracker information at 40 MHz.
- 12.5 μs latency.
- HLT input/output at 750/7.5 kHz.
- 7.4 MB/event.

Muon systems (TDR submitted)
- New DT/CSC/RPC FE/BE electronics
- CSC complemented $1.6 < \eta < 2.4$.
- New GEM with coverage to $\eta < 3$.

New tracker (TDR approved*)
- More granular and lighter.
- L1-trigger p_T information.
- Coverage extended to $\eta < 3.8$.

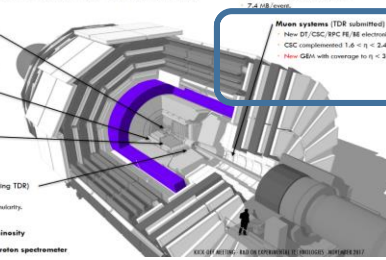
Barrel EM calorimeter (TDR submitted)
- New 160 MHz FE electronics.
- Full granularity L1 trigger.
- Lower running temperature (9C).

New MIP precision-timing layer (Impending TP)
- Barrel: crystals + SiPM.
- Endcap: low-gain avalanche detector.

New Endcap calorimeter (impending TDR)
- Si radiation tolerance.
- High longitudinal and transverse granularity.
- Precise timing of showers.

Beam radiation and luminosity

CMS-TOTEM precision proton spectrometer



a.david@cern.ch for CMS — KICK-OFF MEETING - R&D ON EXPERIMENTAL TECHNOLOGIES - NOVEMBER 2017

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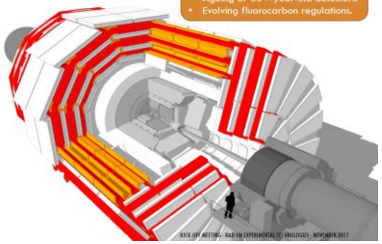
MUON SYSTEMS

RD51

Key challenges:
- Reduce trigger thresholds.
- Ageing of 30+-year-old detectors.
- Evolving fluorocarbon regulations.

DT/CSC/RPC:
- New front-end and back-end electronics.

New detectors:
- LS2:
  - **GE1**: ~50 m², two-layer triple-GEM.
- Between LS2 and LS3:
  - **GE2**: ~100 m², two-layer triple-GEM.
  - **RE3, RE4**: ~90 m², single-layer iRPC.
- LS3:
  - **ME0**: ~60 m², six-layer triple-GEM.



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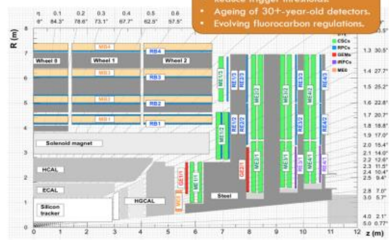

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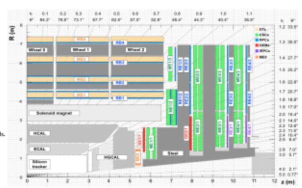
BEYOND 2030 – MUON SYSTEM

>20-year-old systems by 2030:
- DT, RPC, CSC installed 2003-08.
- CF_4 (DT, CSC) and Freon (RPC).

Total surface ~10'000 m².

Foreseen detector upgrades:
- **GE1 to be installed in LS2.**
  - **Followed by GE2 (2022) and ME0 (LS3).**
  - **Mature technology.**
  - **Production across centers worldwide.**
- Improved RPC in 2022-23.
  - Improve robustness and acceptance in cracks.
  - 1.4 mm thinner gap and electrodes, r-measurement through readout at both strip-ends.

GEMs could step in for LS4 replacements, if needed.



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PHASE-2 MUON SYSTEMS

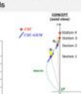
Designed for L1-Trigger, displaced vertices, long-lived particles, increased acceptance

DT, RPC and endcap CSC chambers readout electronics
- Comply with L1-Trigger latency and accept rate, improved spatial/time resolution

GEM stations in endcap
- Reduce L1-trigger rates, enable trigger for displaced vertices, ME0 extend to $\eta \simeq 3.8$
  - 3 GEM foils design

iRPCs in endcaps
- Improve robustness and acceptance in cracks
  - 1.4 mm thinner gap and electrodes, r-measurement through readout at both strip-ends

Muon subsystem / Detector technology	RE3/1 + RE4/1 iRPC	GE1/1 GEM	GE2/1 GEM	ME0 GEM
$\|\eta\|$ range	1.8–2.4	1.6–2.15	1.6–2.4	2.0–2.8
Number of chambers	36 + 36	144	72	216
Number of channels	13 824	442 368	442 368	663 552
Number of layers/station	1	2	2	6
Surface area of all layers	93 m²	54 m²	105 m²	64 m²
spatial resolution	~ 1 cm	200–340 μm	200–410 μm	160–390 μm
time resolution	1.5 ns	8 ns	8 ns	8 ns



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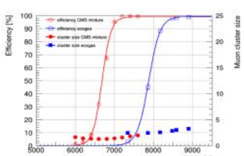
PHASE-2 MUON SYSTEMS

R&D on eco-gas replacement for RPCs.

New signal sampling: from 40 MHz to 640 MHz (1.6 ns).

Improved RPC:
- Reduced gas gap from 2 mm to 1.4 mm.
- Reduced electrode resistivity: about 10^{10} Ωcm.
- New generation of FE electronics: reduce the charge threshold from 150 fC to 50 fC (RPCROC ASIC).
- New readout scheme, reading both end of strip.
- The new FE will include TDC (50-100 ps resolution) to determine the muon position along strip with spatial resolution of 2 cm.



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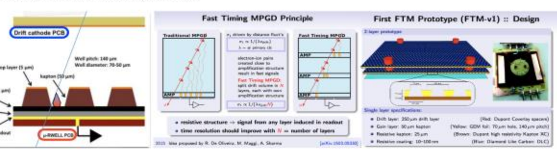
BEYOND 2030 – MUON SYSTEM

New detector technologies and variants can mature over the next decade (i.e., R&D complete and production-ready):
- Fast-timing capability in multi-layer topology.



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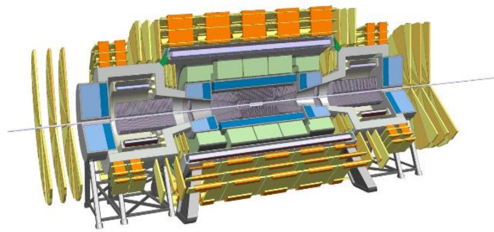
Future Hadron Machines (FCC-hh, HE-LHC

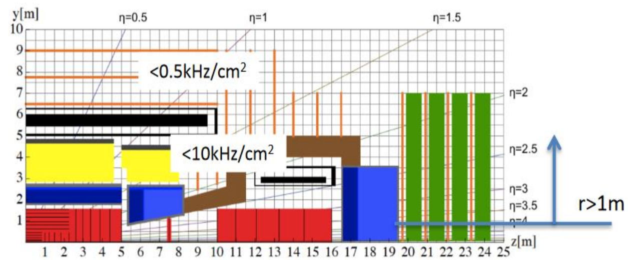
Kick-off meeting for R&D on experimental technologies

Nov. 20th, 2017

W. Riegler

Muon Systems





ATLAS muon system HL-LHC rates (kHz/cm^2):

MDTs barrel:	0.28
MDTs endcap:	0.42
RPCs:	0.35
TGCs:	2
Micromegas und sTGCs:	9-10

Table 4.5: Expected rates on the muon detector when operating at an instantaneous luminosity of 2×10^{33} $cm^{-2}s^{-1}$ at a collision energy of 14 TeV. The values are averages, in kHz/cm^2, over the chamber with the minimum illumination, the whole region and the chamber with maximum illumination. The values are extrapolated from measured rates at 8 TeV.

LHCb

Region	Minimum	Average	Maximum
M2R1	162 ± 28	327 ± 60	590 ± 110
M2R2	15.0 ± 2.6	52 ± 8	97 ± 15
M2R3	0.90 ± 0.17	5.4 ± 0.9	13.4 ± 2.0
M2R4	0.12 ± 0.02	0.63 ± 0.10	2.6 ± 0.4
M3R1	39 ± 6	123 ± 18	216 ± 32
M3R2	3.3 ± 0.5	11.9 ± 1.7	29 ± 4
M3R3	0.17 ± 0.02	1.12 ± 0.16	2.9 ± 0.4
M3R4	0.017 ± 0.002	0.12 ± 0.02	0.63 ± 0.09
M4R1	17.5 ± 2.5	52 ± 8	86 ± 13
M4R2	1.58 ± 0.23	5.5 ± 0.8	12.6 ± 1.8
M4R3	0.096 ± 0.014	0.54 ± 0.08	1.37 ± 0.20
M4R4	0.007 ± 0.001	0.056 ± 0.008	0.31 ± 0.04
M5R1	19.7 ± 2.9	54 ± 8	91 ± 13
M5R2	1.58 ± 0.23	4.8 ± 0.7	10.8 ± 1.6
M5R3	0.29 ± 0.04	0.79 ± 0.11	1.69 ± 0.25
M5R4	0.23 ± 0.03	2.1 ± 0.3	9.0 ± 1.3

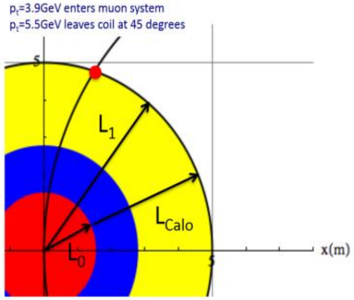
HL-LHC muon system gas detector technology will work for most of the FCC detector area

Muon system performance estimate

Three ways to measure the muon momentum

1) Tracker only with identification in the muon system
2) Muon system only by measuring the muon angle where it exits the coil
3) Tracker combined with the position of the muon where it exists the coil

p_t=3.9GeV enters muon system
p_t=5.5GeV leaves coil at 45 degrees



We assume a constant magnetic field inside the coil radius L_1.

The measurement points in the tracker of radius L_0 are equidistant and have all the same resolution σ_0.

The measurement point at L_1 has a position error σ_1 that is given by the multiple scattering inside the calorimeters (σ_y in the following).

The formula for the momentum resolution is given in the next slide.

Muon Systems

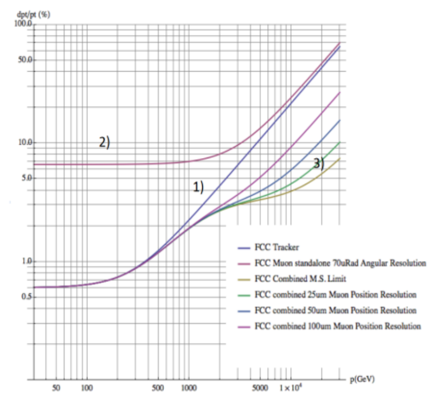
1) Tracker only with identification in the muon system
2) Muon system only by measuring the muon angle where it exits the coil
3) Tracker combined with the position of the muon where it exists the coil

With 50µm position 70µRad angular resolution resolution we find (η=0)

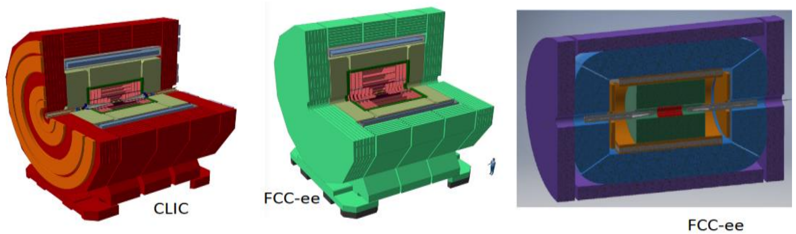
<10% standalone momentum resolution up to 3TeV/c

<10% combined momentum resolution up to 20TeV

All within reach of 'standard' muon system technology



detector requirements for future e^+e^- colliders



Patrick Janot, Lucie Linssen
EP R&D kick-off meeting
November 20th 2017

With many thanks to CLICdp and FCC-ee colleagues for presentation material

FCC-ee tracking accuracy

Precision mostly driven by physics at the Z-peak

Aim:

- Several 10^{-5} to 10^{-6} type of precision measurements
  - $\sin^2 q_W$, to 6×10^{-6}, $a_{QED}(m_Z)$ to 3×10^{-5}, m_Z to 100 keV, Γ_Z to 100 keV
  - (also m_W to 500 keV, …)
- Beam energy spread (0.13% at the Z pole) to be measured with relative precision of a few per mille (using $\mu^+\mu^-$ events).

⇒ **Stringent constraints on the accuracy of the tracker**

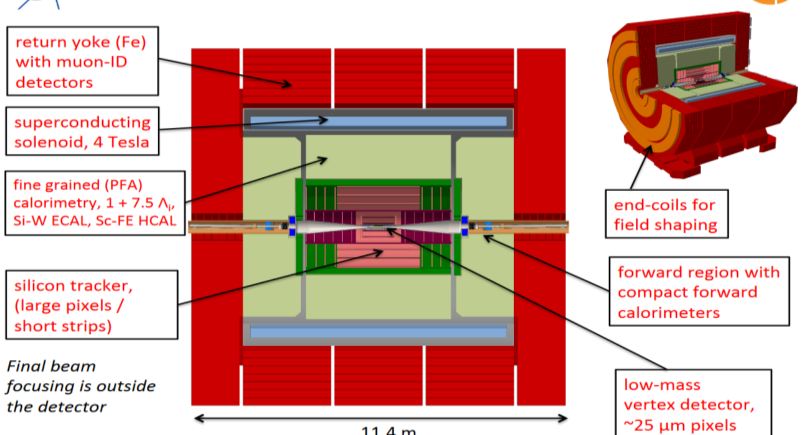
- **Angular resolution $\sigma(\theta)$, $\sigma(\varphi) \leq 0.1$ mrad for 45 GeV muons**
- **Momentum resolution $\sigma(1/p)$ of ~2-3 10^{-5} GeV^{-1}**
- **The tracker needs to be as light as possible**

  (continuous operation impacts on the cooling and thus on material budget)

Options:

- **Silicon technology**
- **Wire Chamber technology**
- ~~TPC not compatible with 20 ns bunch crossing frequency~~

the (new) CLIC detector model

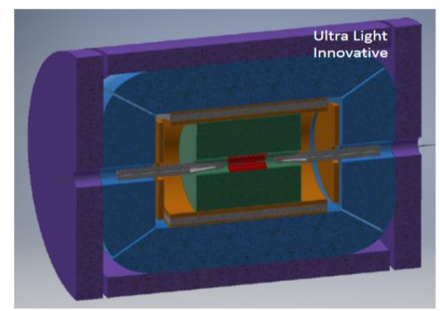


Final beam focusing is outside the detector

CLICdp_Note_2017_001

FCC-ee detector design #2 : IDEA

- **Vertex Si detector**
  With light MAPS technology
  7 layers, up to 35 cm radius
- **Ultra light wire drift chamber**
  4m long, 2 m radius, 0.4% X_0
  112 layers with Particle ID
- **One Si layer for acceptance determination**
  Precise tracking with large lever arm
  barrel and end-caps
- **Ultra-thin 20-30 cm solenoid (2T)**
  Acts as preshower (1 X_0)
  or 1 X_0 Pb if magnet outside calo
- **Two µ-RWell layers**
  Active preshower measurement
- **Dual readout fibre calorimeter**
  2m thick, longitudinal segmentation
- **Instrumented return yoke**



√s = 91 GeV:
Drift chamber may drive
requirements linked to large data flow.

Mandate for Working Group (Co-)convenor(s)

- The WG is formed by the convenors **inviting** specific persons (typically **experts** in a given domain) to contribute to the WG and by interested people joining the WG on their own initiative.
- The convenors shall make sure that the **WG covers all relevant expertise**. Any person can contribute to the WG. There is no restriction on their prof. status (staff, user, …).
- The WG composition shall **reflect the landscape of technologies** and experimental options. If required, the WG shall be organised in sub-groups.
- The convenors shall set up a **work plan** for the period until workshop 1 (WS 1, date 16 March 2018).
- The convenors shall organise meetings to discuss the **scope** of the WG, limitations, upcoming challenges, R&D lines, … If considered useful, a WG meeting can be held on the day before WS 1.
- The convenors shall prepare a **group session in WS 1** (approximately 45 minutes will be available for each WG).
- For WS 2 (in autumn 2018), the convenors shall prepare **a draft chapter of the R&D report**, incl. concrete R&D lines, milestones, deliverables, resource estimates (approximately 10-20 pages per WG). They can **invite members of the WG to contribute to the editing process**.