GenEl

Grant agreement No. 846674

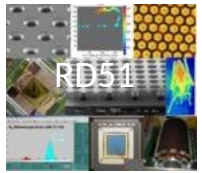
GEM detectors with streaming readout for the AMBER proton radius measurement

Oliver Adam, Lukas Bayer, Karl Jonathan Flöthner Christian Honisch, Virginia Klapper, Michael Lupberger, Jan Paschek, Benjamin Roth, Dimitri Schaab, Emorfili Terzimpasoglou and Bernhard Ketzer

Universität Bonn

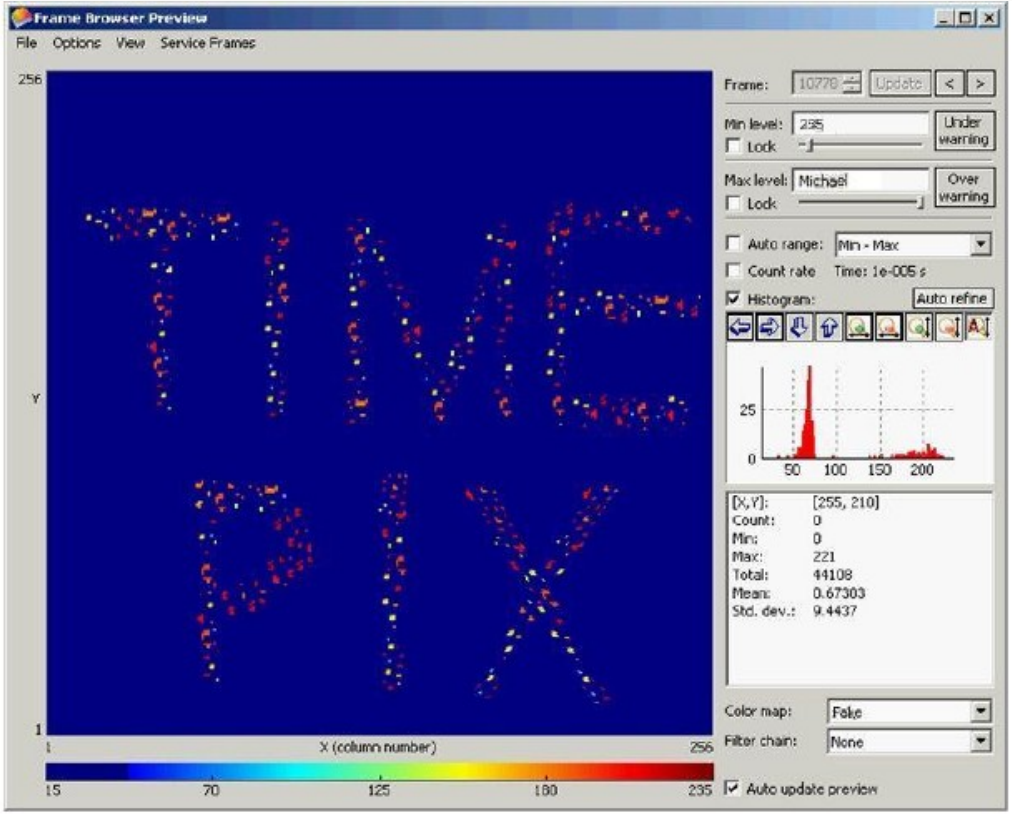
Rencontre du DEDIP, CEA Saclay

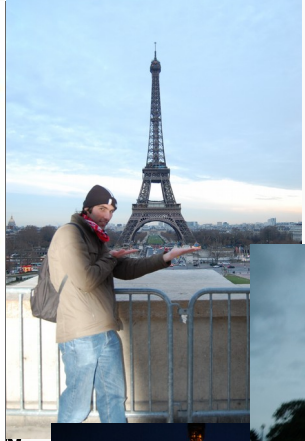
14.06.2022

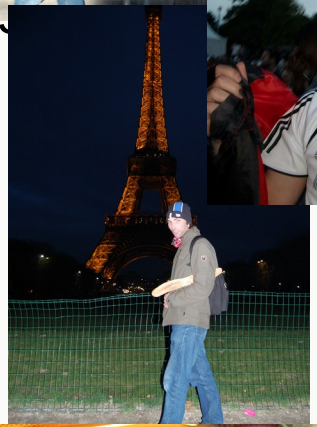


AG Ketzer

Apparatus for Meson and Baryon Experimental Research







Michael Lupberger

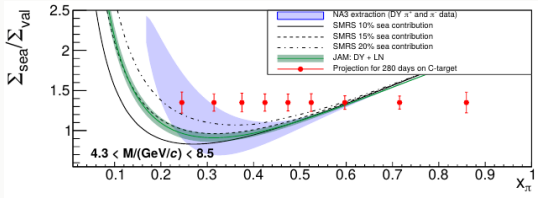
Séminaire Orienté vers une Contribution
au Linéaire à Electron
2009
9 et 10 novembre à l'INSTN (CEA Saclay)

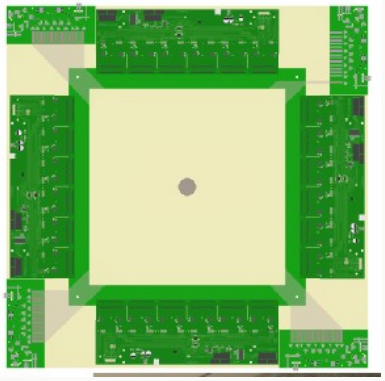
UNIVERSITÄT BONN

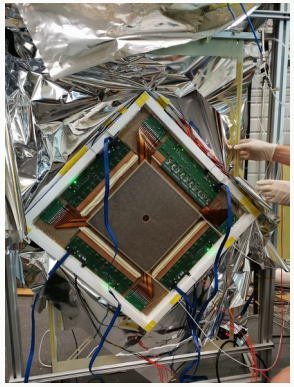
OUTLINE

- What is AMBER?
- Physics at AMBER
- The proton radius measurement
- AMBER GEMs
- Streaming readout

AMBER
Apparatus for Meson and Baryon Experimental Research



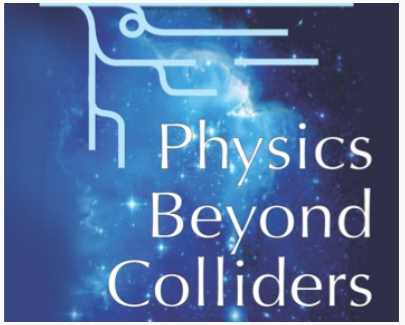


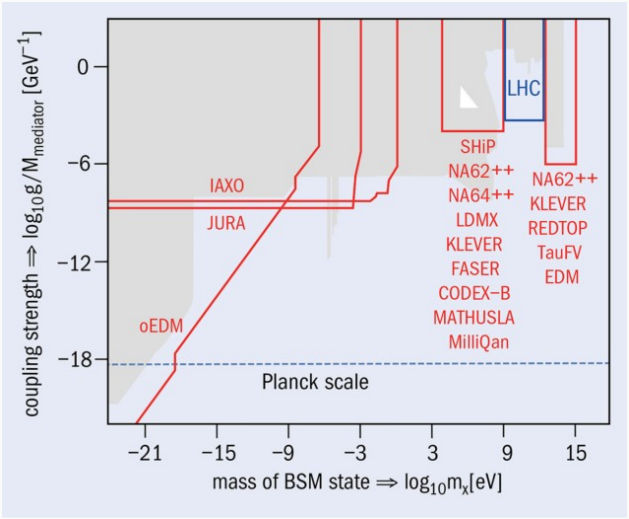


CERN: PHYSICS BEYOND COLLIDER

CERN's *Physics Beyond Collider* initiative:

- Study group launched 2016
- exploiting the full scientific potential of the CERN's accelerator complex and scientific infrastructures
- Complementary to LHC and other future colliders
- CERN impact on physics landscape in next 10-20 years





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Apparatus for Meson and Baryon Experimental Research

Apparatus for Meson and Baryon Experimental Research:

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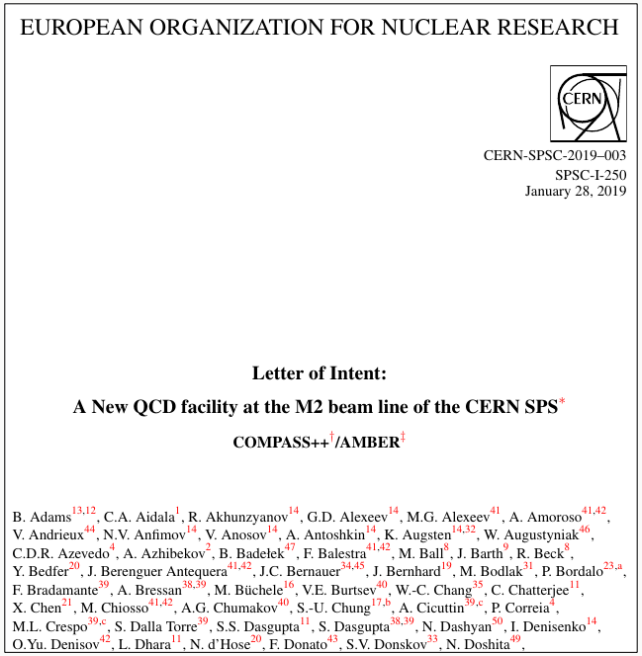
AMBER

Apparatus for Meson and Baryon Experimental Research

Apparatus for Meson and Baryon Experimental Research:

- In the context of CERN's *Physics Beyond Collider* initiative:
  Proposal for a *New QCD facility at the M2 beam line of the CERN SPS*



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN

CERN-SPSC-2019–003
SPSC-I-250
January 28, 2019

Letter of Intent:

A New QCD facility at the M2 beam line of the CERN SPS*

COMPASS++†/AMBER‡

B. Adams[13,12], C.A. Aidala[1], R. Akhunzyanov[14], G.D. Alexeev[14], M.G. Alexeev[41], A. Amoroso[41,42], V. Andrieux[44], N.V. Anfimov[14], V. Anosov[14], A. Antoshkin[14], K. Augsten[14,32], W. Augustyniak[46], C.D.R. Azevedo[4], A. Azhibekov[2], B. Badelek[47], F. Balestra[41,42], M. Ball[8], J. Barth[9], R. Beck[8], Y. Bedfer[20], J. Berenguer Antequera[41,42], J.C. Bernauer[34,45], J. Bernhard[19], M. Bodlak[31], P. Bordalo[23,a], F. Bradamante[39], A. Bressan[38,39], M. Büchele[16], V.E. Burtsev[40], W.-C. Chang[35], C. Chatterjee[11], X. Chen[21], M. Chiosso[41,42], A.G. Chumakov[40], S.-U. Chung[17,b], A. Cicuttin[39,c], P. Correia[1], M.L. Crespo[39,c], S. Dalla Torre[39], S.S. Dasgupta[11], S. Dasgupta[38,39], N. Dashyan[50], I. Denisenko[14], O.Yu. Denisov[42], L. Dhara[11], N. d'Hose[20], F. Donato[43], S.V. Donskov[33], N. Doshita[49],

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AMBER

Apparatus for Meson and Baryon Experimental Research

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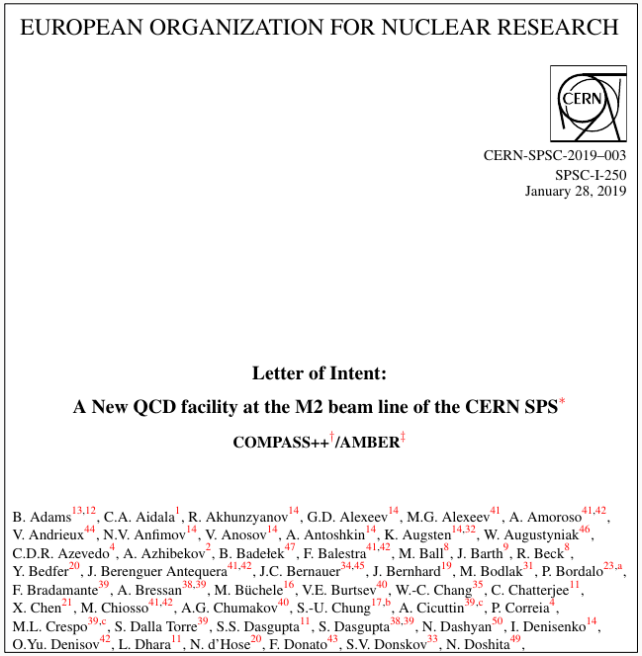

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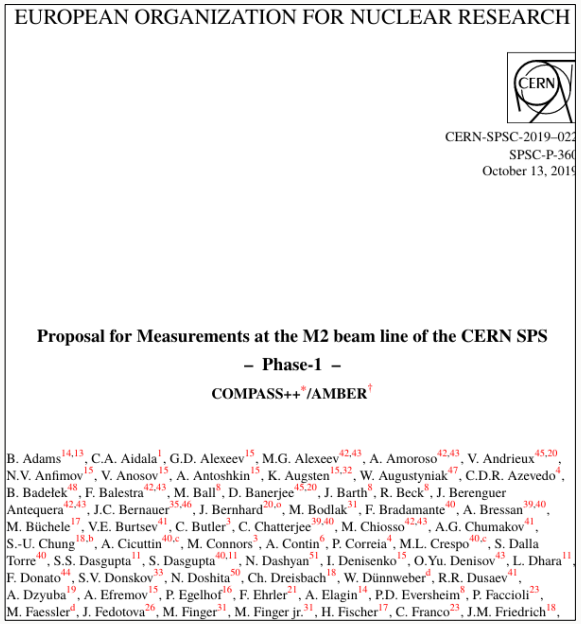
- Proposal for Phase 1 to SPSC: June (update Sept.) 2019



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN

CERN-SPSC-2019-022
SPSC-P-360
October 13, 2019

Proposal for Measurements at the M2 beam line of the CERN SPS

– Phase-1 –

COMPASS++*/AMBER†

B. Adams[14,13], C.A. Aidala[1], G.D. Alexeev[15], M.G. Alexeev[42,43], A. Amoroso[42,43], V. Andrieux[45,20], N.V. Anfimov[15], V. Anosov[15], A. Antoshkin[15], K. Augsten[15,32], W. Augustyniak[47], C.D.R. Azevedo[4], B. Badelek[48], F. Balestra[42,43], M. Ball[8], D. Banerjee[45,20], J. Barth[9], R. Beck[8], J. Berenguer Antequera[42,43], J.C. Bernauer[35,46], J. Bernhard[20,o], M. Bodlak[31], F. Bradamante[40], A. Bressan[39,40], M. Büchele[17], V.E. Burtsev[41], C. Butler[3], C. Chatterjee[39,40], M. Chiosso[42,43], A.G. Chumakov[41], S.-U. Chung[18,b], A. Cicuttin[40,c], M. Connors[3], A. Contin[6], P. Correia[8], M.L. Crespo[40,c], S. Dalla Torre[40], S.S. Dasgupta[11], S. Dasgupta[40,11], N. Dashyan[51], I. Denisenko[15], O.Yu. Denisov[43], L. Dhara[11], F. Donato[44], S.V. Donskov[33], N. Doshita[50], Ch. Dreisbach[18], W. Dünnweber[d], R.R. Dusaev[41], A. Dzyuba[19], A. Efremov[15], P. Egelhof[16], F. Ehrler[21], A. Elagin[14], P.D. Eversheim[8], P. Faccioli[23], M. Faessler[4], J. Fedotova[26], M. Finger[31], M. Finger jr.[31], H. Fischer[17], C. Franco[23], J.M. Friedrich[18],

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- Proposal for Phase 1 to SPSC: June (update Sept.) 2019
- Physics program recommended by SPSC: October 2020

SPSC 139, Oct. 2020

The Committee **recommends** approval of the proposal SPSC-P-360 by the AMBER Proto-Collaboration to use the M2 beam-line before LS3 to perform measurements related to:

(i) Drell-Yan and J/Psi production using the conventional M2 hadron beam;
(ii) proton-induced antiproton production cross sections for dark matter searches;
(iii) the proton charge radius using muon-proton elastic scattering.

The proton-radius program is contingent on a successful pilot run previously approved for the first year of SPS operation after the Long Shutdown LS2.

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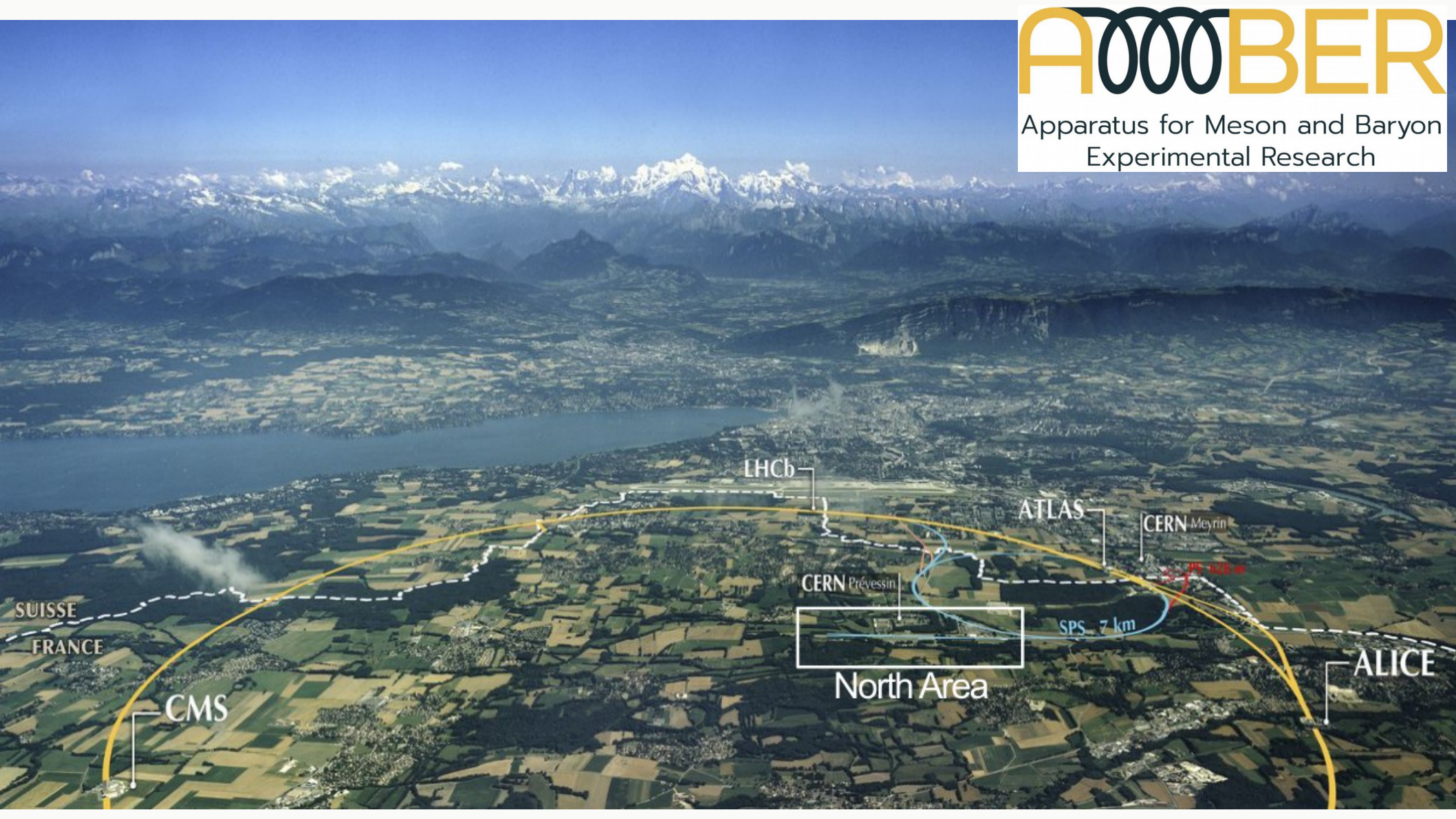
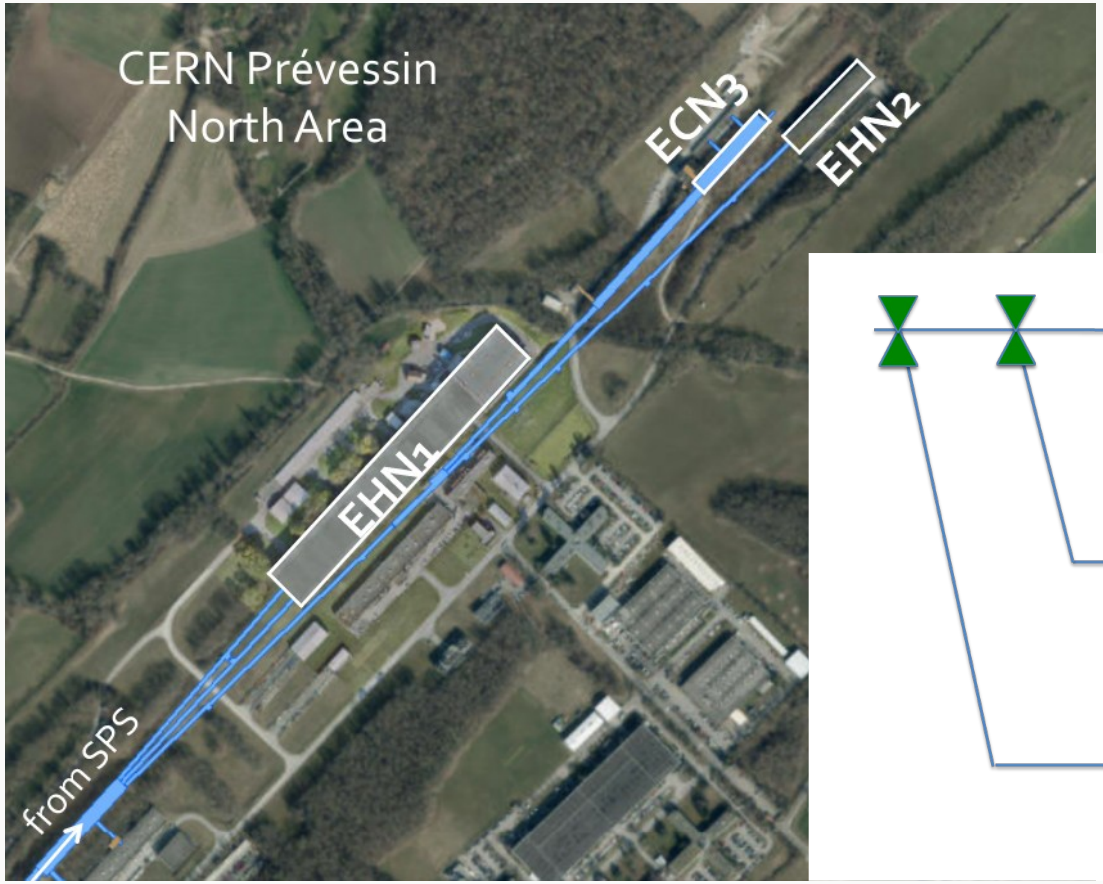
- Physics program recommended by SPSC: October 2020
- Approved as NA66 by the CERN Research Board: Dec. 2020

proposals that are requesting beam there, NA64-mu and MUonE. **The Research Board approved AMBER for its Phase-1 measurements until LS3, with the beam allocation being subject to the optimisation of the overall schedule at the SPSC. The experiment will have reference number NA66.**


AMBER
Apparatus for Meson and Baryon Experimental Research
LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SUISSE
FRANCE
SPS 7 km
North Area
CMS
ALICE

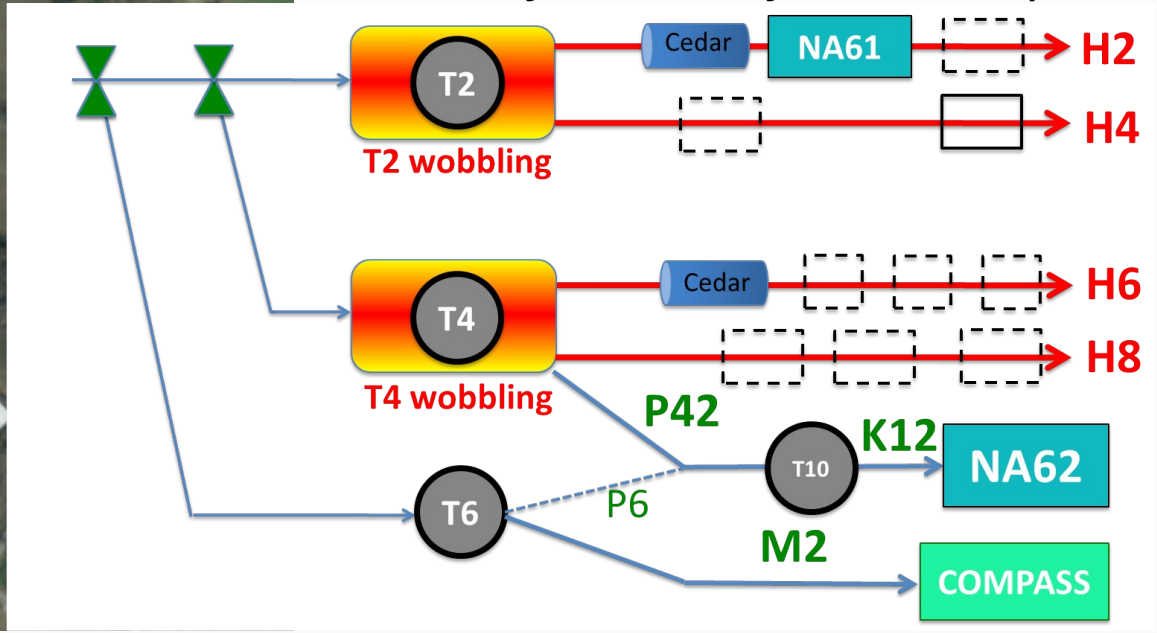
AMBER – WHERE?

Apparatus for Meson and Baryon Experimental Research



M2 beamline (EHN2):

- most versatile beamline at CERN
- high-intensity beams of $\mu^{\pm}$, $\pi^{\pm}$, p
- intensity limited by radiation protection



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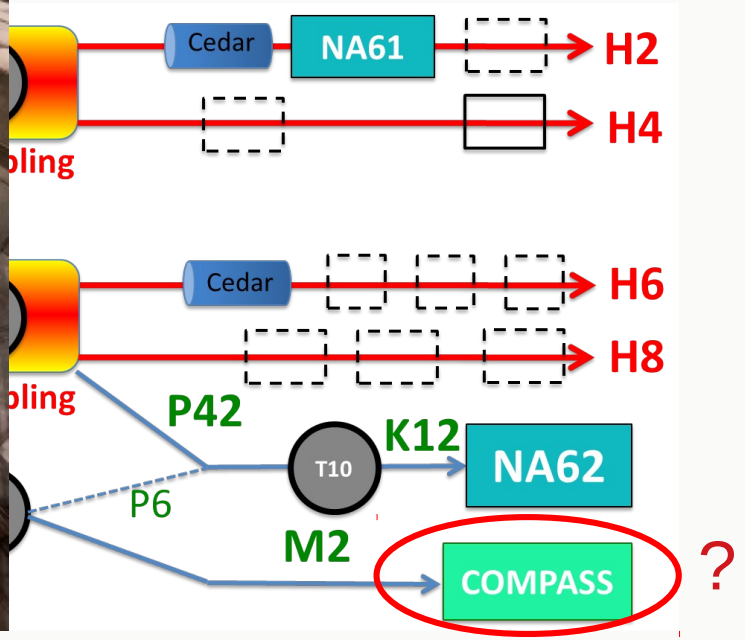
AMBER – M2 BEAMLINE?

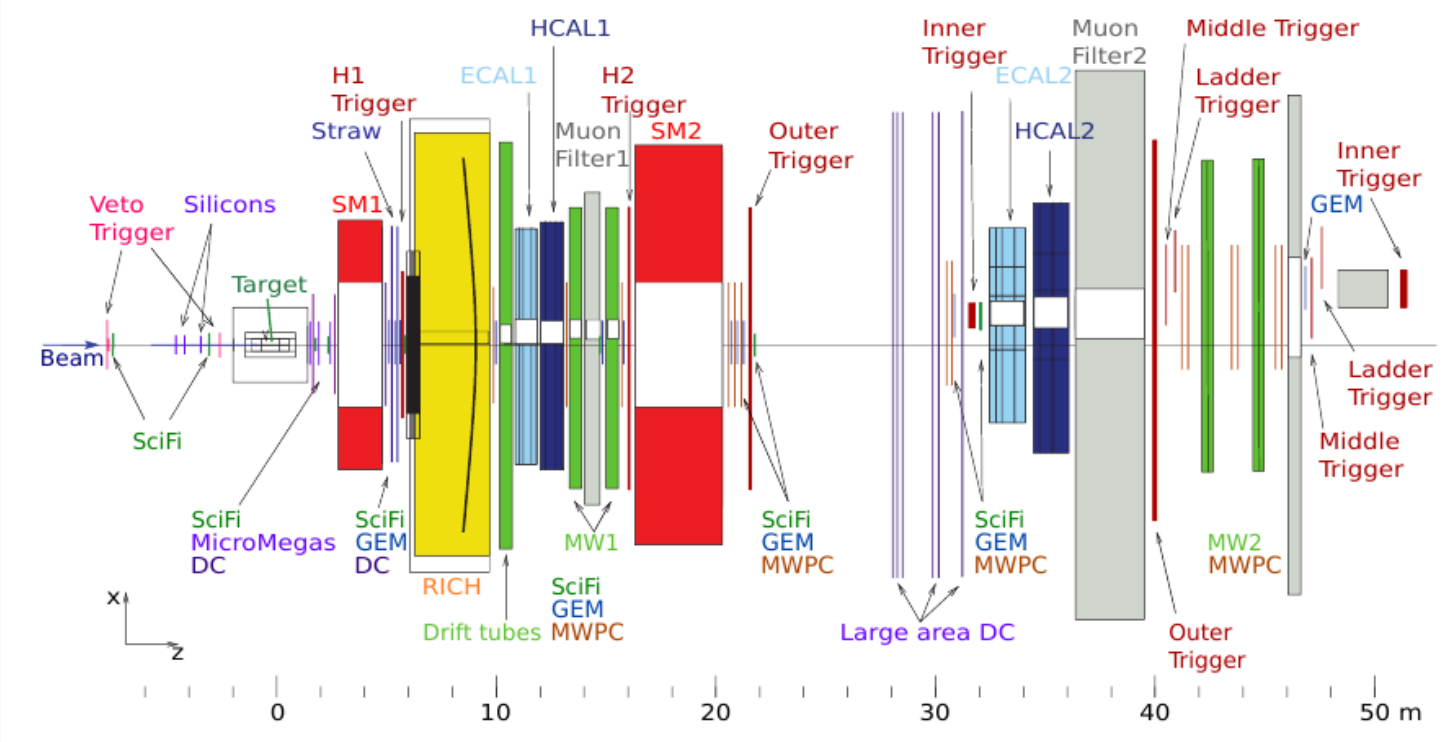
AMBER
Apparatus for Meson and Baryon Experimental Research



COMPASS

Hadron structure and hadron spectroscopy with high intensity muon and hadron beam

- Approved 1997
- Installed 1999-2000
- 2022: Final run on semi-inclusive deep inelastic scattering off transversely polarised deuterons



AMBER – PHYSICS

Apparatus for Meson and Baryon Experimental Research

Approved Phase-1:

1) Drell-Yan and charmonium production using conventional hadron beams
2) Measurement of antiproton production cross sections for dark matter search
3) Proton-radius measurement using elastic muon-proton scattering

NA66

Apparatus for Meson and Baryon Experimental Research

Synonym: AMBER
Research Programme: SPS
Approved: 02-12-2020
Beam:
Status: Preparation

Overview | Teams | Participations

Spokesperson:	DENISOV, Oleg FRIEDRICH, Jan Michael	**Number of Institutes:**	17
Technical Coordinator:	LEVORATO, Stefano	**Number of Countries:**	9
Resources Coordinator:	DENISOV, Oleg	**Number of Participants:**	32
Experimental Safety Officer (EXSO):	DENISOV, Oleg	**Number of Authors:**	23
Experiment secretariat e-mail:	anne.lissajoux@cern.ch	**Status History**	

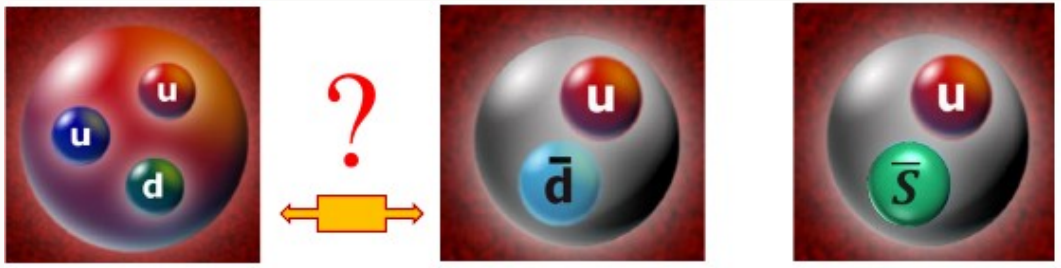
Albert Ludwigs Universitaet Freiburg	Freiburg	Germany	(TL) FISCHER, HORST
Czech Technical University in Prague	Prague	Czech Republic	(TL) NOVY, JOSEF (DTL) VIRIUS, MIROSLAV
Faculty of Mathematics and Physics	Prague	Czech Republic	(TL) FINGER, MICHAEL (DTL) FINGER, MIROSLAV
Helmholtz-Institut fuer Strahlen- und Kernphysik	Bonn	Germany	(TL) KETZER, BERNHARD FRANZ (DTL) THIEL, ANNIKA
Institut fuer Kernphysik	Mainz	Germany	(TL) OSTRICK, MICHAEL (DTL) KABUSS, EVA-MARIA
Joint Institute for Nuclear Research	Dubna	JINR	(TL) GUSKOV, ALEXEY (DTL) KHRAMOV, EVGENY
LIP Lisboa	Lisbon	Portugal	(TL) MARQUES QUINTANS, CATARINA (DTL) STOLARSKI, MARCIN
Los Alamos National Laboratory	Los Alamos	United States	(TL) LIU, KUN
NRC Kurchatov Institute PNPI	Gatchina	Russia	(TL) DZIUBA, ALEKSEI (DTL) INGLESSI, ALEXANDER
National Centre for Nuclear Research	Warsaw	Poland	(TL) SANDACZ, ANDRZEJ (DTL) KUREK, KRZYSZTOF
Stony Brook University	Stony Brook	United States	(TL) BERNAUER, JAN CHRISTOPHER
Technische Universitaet Muenchen	Garching	Germany	(TL) PAUL, STEPHAN (DTL) FRIEDRICH, JAN MICHAEL
Trento Institute for Fundamental Physics and Applications TIFPA	Trento	Italy	(TL) ZUCCON, PAOLO (DTL) NOZZOLI, FRANCESCO
Universita e INFN Torino	Turin	Italy	(TL) PANZIERI, DANIELE (DTL) CHIOSSO, MICHELA
University of Aveiro	Aveiro	Portugal	(TL) DA ROCHA AZEVEDO, CARLOS DAVIDE (DTL) CALAPEZ DE ALBUQUERQUE V, JOAO FILIPE
University of Michigan	Ann Arbor	United States	(TL) LORENZON, WOLFGANG BENEDIKT
Yamagata University	Yamagata	Japan	(TL) IWATA, TAKAHIRO (DTL) DOSHITA, NORIHIRO

AMBER – PHYSICS 1)

Apparatus for Meson and Baryon Experimental Research

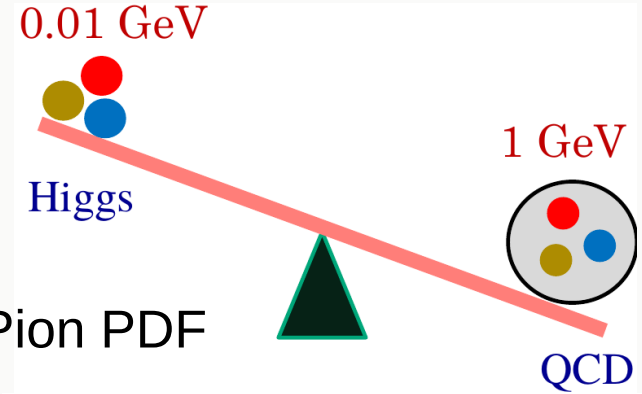
Drell-Yan and charmonium production using conventional hadron beams

Goal: Understanding the emergence of Hadron Mass



938 MeV 135 MeV 493 MeV

⇨ Study Pion PDF



[Chang et al., Chin. Phys. Lett. 38 (2021) 081101]

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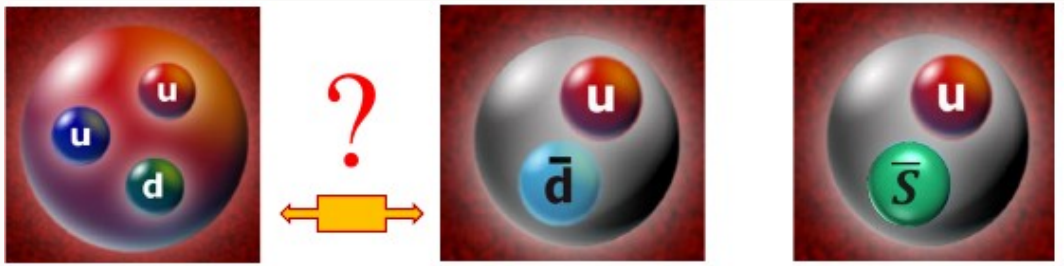

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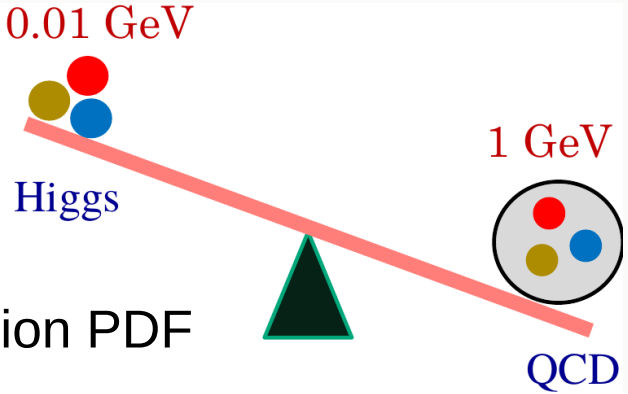

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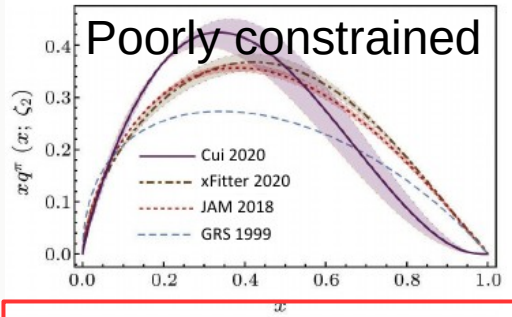
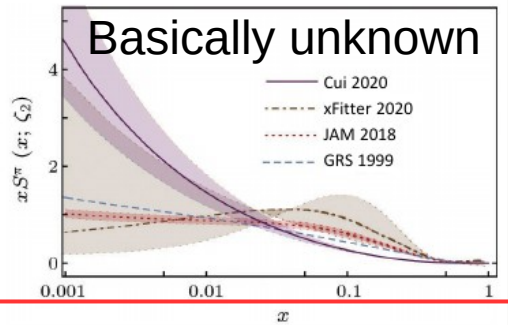
[Chang et al., Chin. Phys. Lett. 38 (2021) 081101]

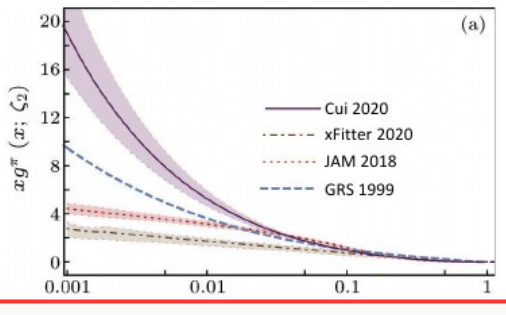
Valence quarks

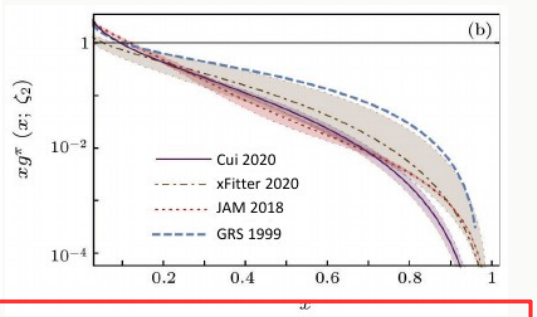


Sea quarks



Gluons





Discrepancies between experiments, old data, mostly heavy nuclear target⇨large nuclear effects

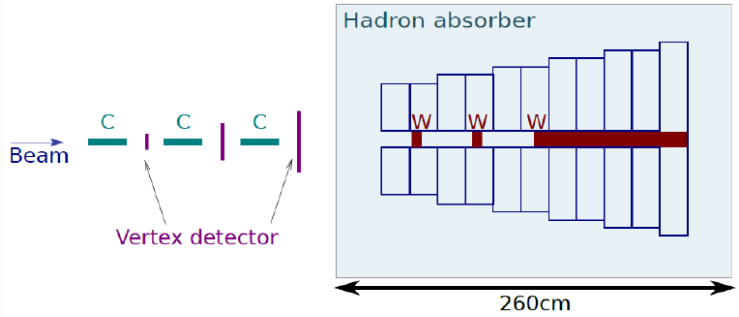
AMBER – PHYSICS 1)

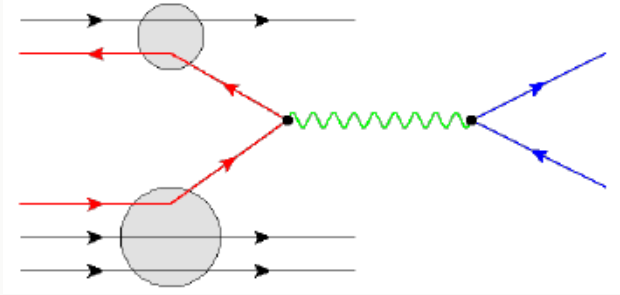
Apparatus for Meson and Baryon Experimental Research

Drell-Yan and charmonium production using conventional hadron beams

Setup:

- 190 GeV $\pi^{\pm}$ beam
- Isoscalar ^{12}C target ⇒ minimize nuclear effects
- Vertex detector
- Hadron absorber
- COMPASS muon spectrometer





Pion-induced Drell-Yan dimuon production

$$\Sigma_{\text{val}} = -\sigma^{\pi^+} + \sigma^{\pi^-} \qquad \text{only valence-valence}$$

$$\Sigma_{\text{sea}} = 4\sigma^{\pi^+} - \sigma^{\pi^-} \qquad \text{sea-valence / valence-sea}$$

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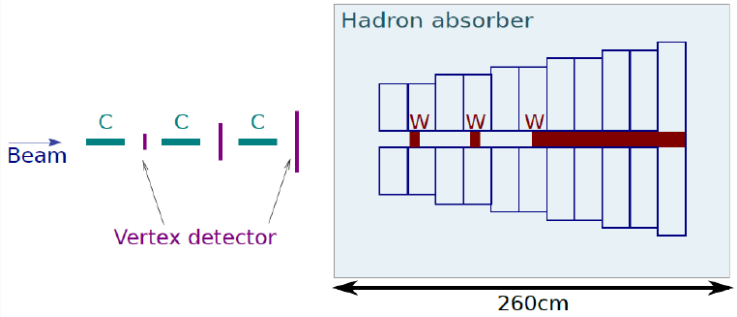
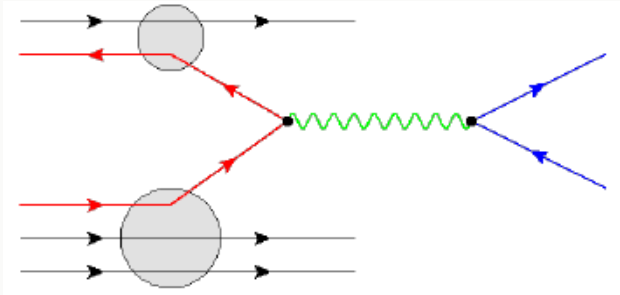
- COMPASS muon spectrometer

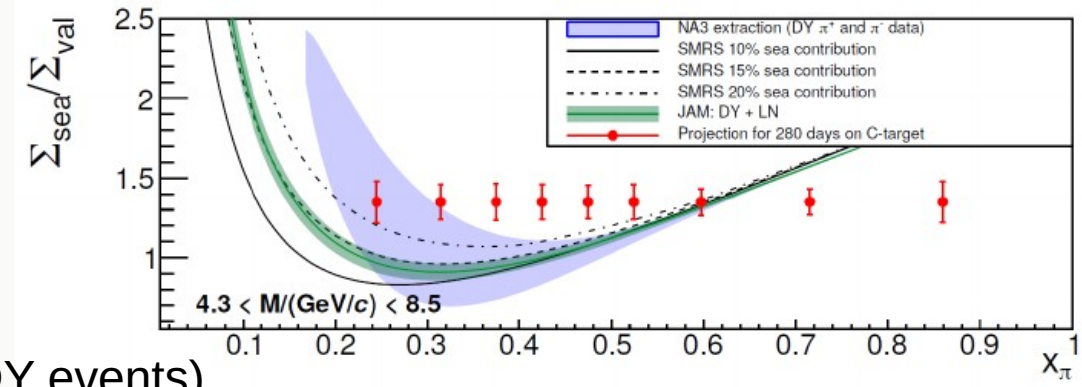




Pion-induced Drell-Yan dimuon production

$$\Sigma_{\text{val}} = -\sigma^{\pi^+} + \sigma^{\pi^-} \quad \text{only valence-valence}$$

$$\Sigma_{\text{sea}} = 4\sigma^{\pi^+} - \sigma^{\pi^-} \quad \text{sea-valence / valence-sea}$$



Goals:

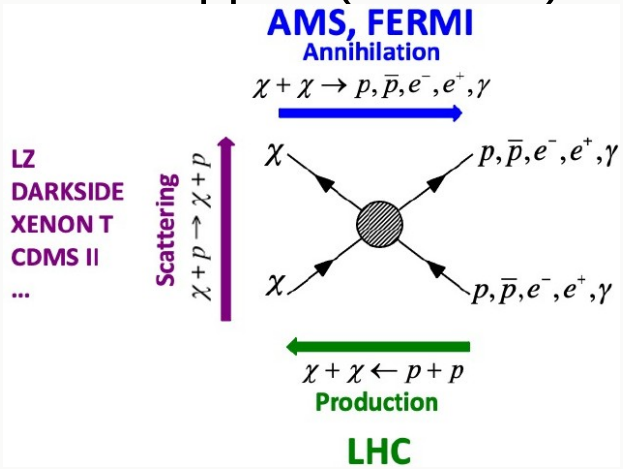
- 10× more data than currently available (25k DY events)
- First precise and direct measurement of the sea quark distribution in the pion:

AMBER – PHYSICS 2)

Apparatus for Meson and Baryon Experimental Research

Measurement of antiproton production cross sections for dark matter search

Goal: support (AMS-02) DM searches in cosmic rays ← DM annihilation



AMBER – PHYSICS 2)

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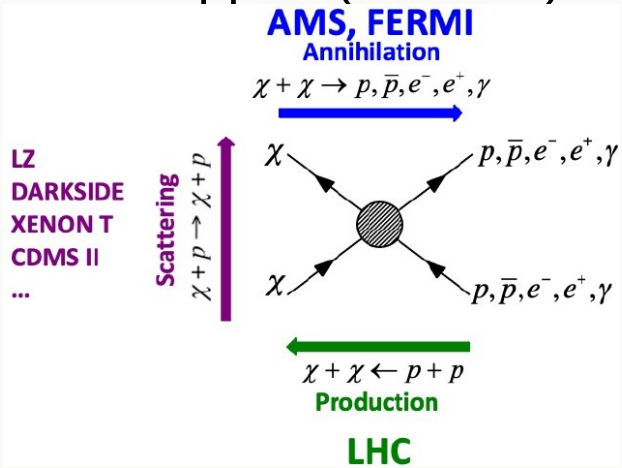
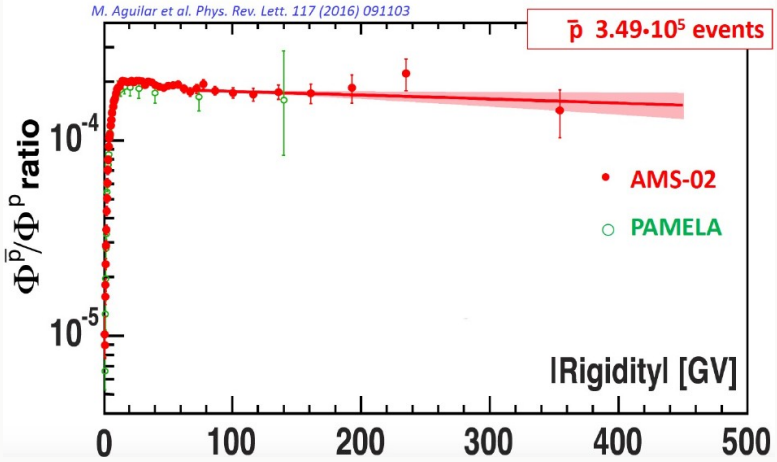
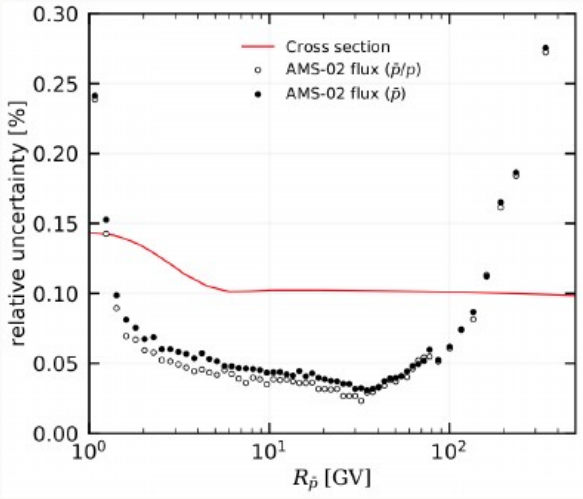






DM signal = Access over SM production

Limiting factor: $\bar{p}$ production cross section from p & He collisions (uncertainties 30-50%)

- $p + p \rightarrow \bar{p} + X$ some measurements (NA49, NA61)
- $p + {}^4He \rightarrow \bar{p} + X$ only LHCb at 4 TeV and 6.5 TeV

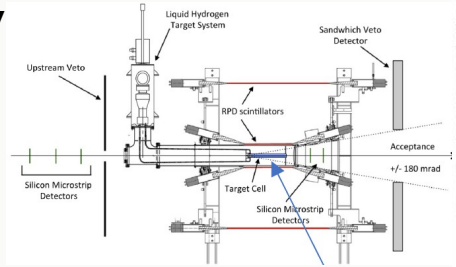
AMBER – PHYSICS 2)

Apparatus for Meson and Baryon Experimental Research

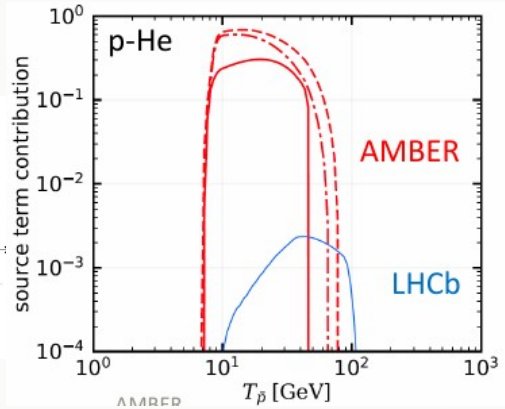
Measurement of antiproton production cross sections for dark matter search

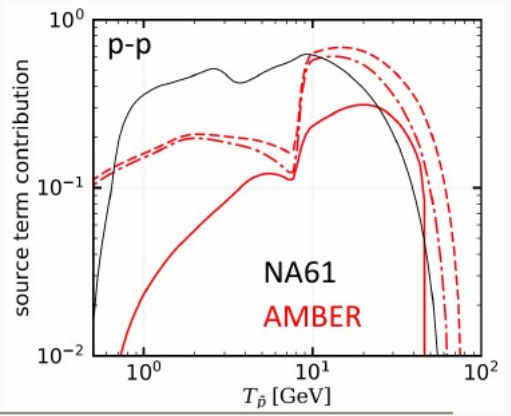
Setup:

- Secondary p beam with 50, 100, 150, 200, 280 GeV
- Minimum bias trigger ⇒ beam intensity of $5 \cdot 10^5$/s
- Liquid H2 and He target
- Proton ID in CEDARs, antiproton ID in RICH
- Measure double-differential cross section in 10 bins in $\bar{p}$ momentum and pseudo- rapidity $2.4<\eta<5.6$
- Statistical uncertainty per data point ≈ 0.5−1%
- Total systematic uncertainty ≈ 5% (efficiencies, dead time)

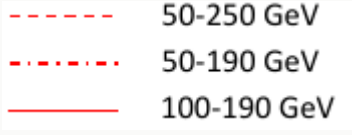


Liquid He target





Plots: impact of measurements on constraining the production of $\bar{p}$ (fraction of total source term constrained by phase space of experiment)



AMBER – PHYSICS 3

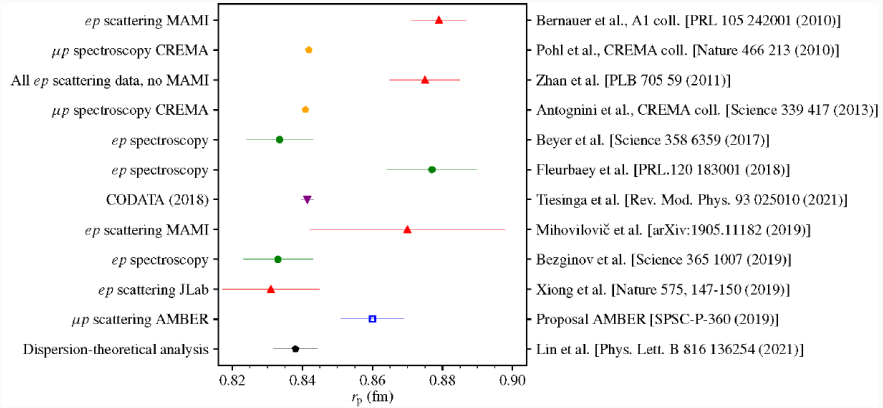
Apparatus for Meson and Baryon Experimental Research

Proton-radius measurement using elastic muon-proton scattering

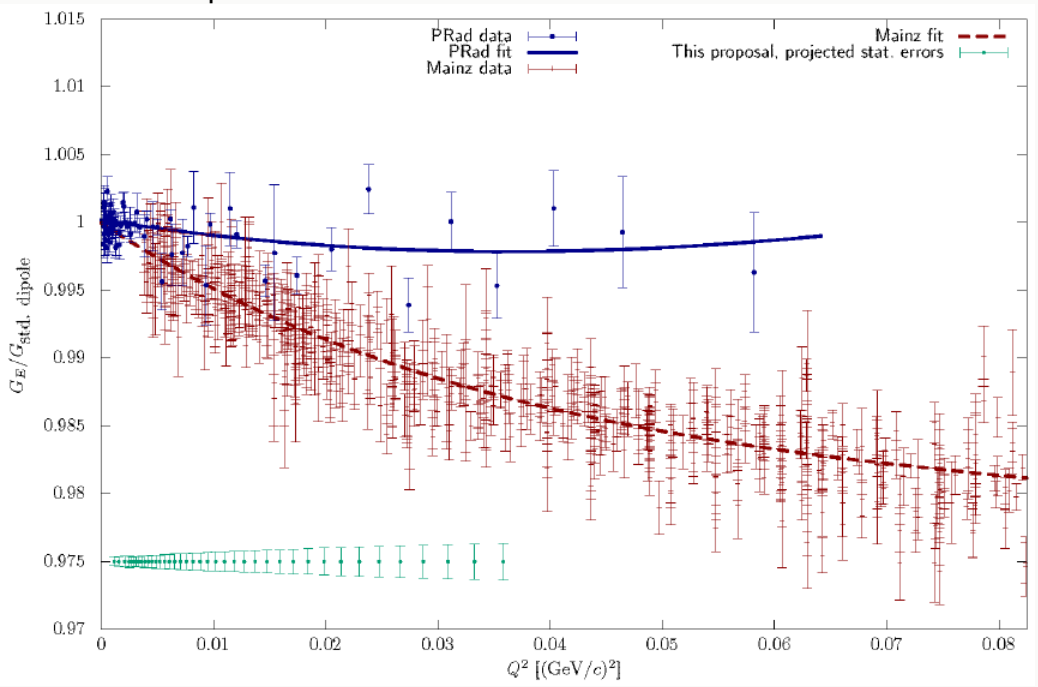
Goal: complement existing experiments to measure r_p with μ, resolve discrepancies

4 ways to measure r_p:

	ep	μp
Scattering	New measurements: • Lower systematics • Lower Q^2	Not measured yet • MUSE @ PSI • AMBER @ CERN
Spectroscopy	New measurements: • Lower systematics • New transitions	Done (CREMA)

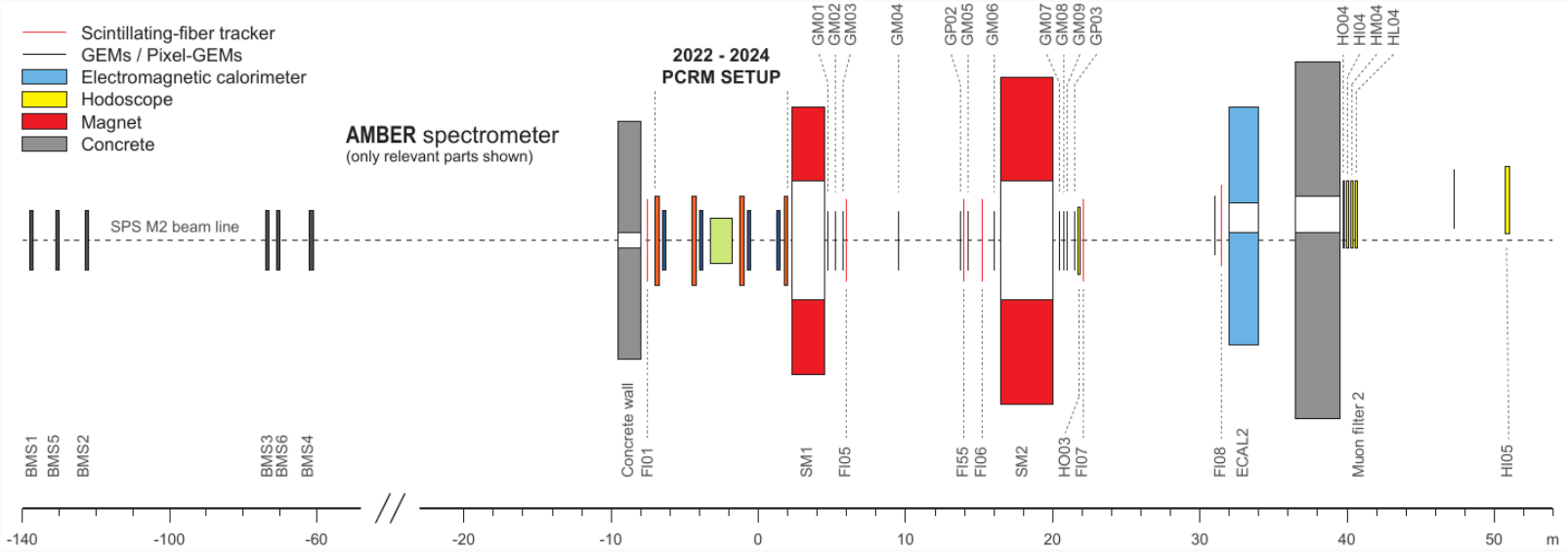


From: B.Ketzer, DPG2022



much smaller radiative corrections than ep

AMBER - PRM

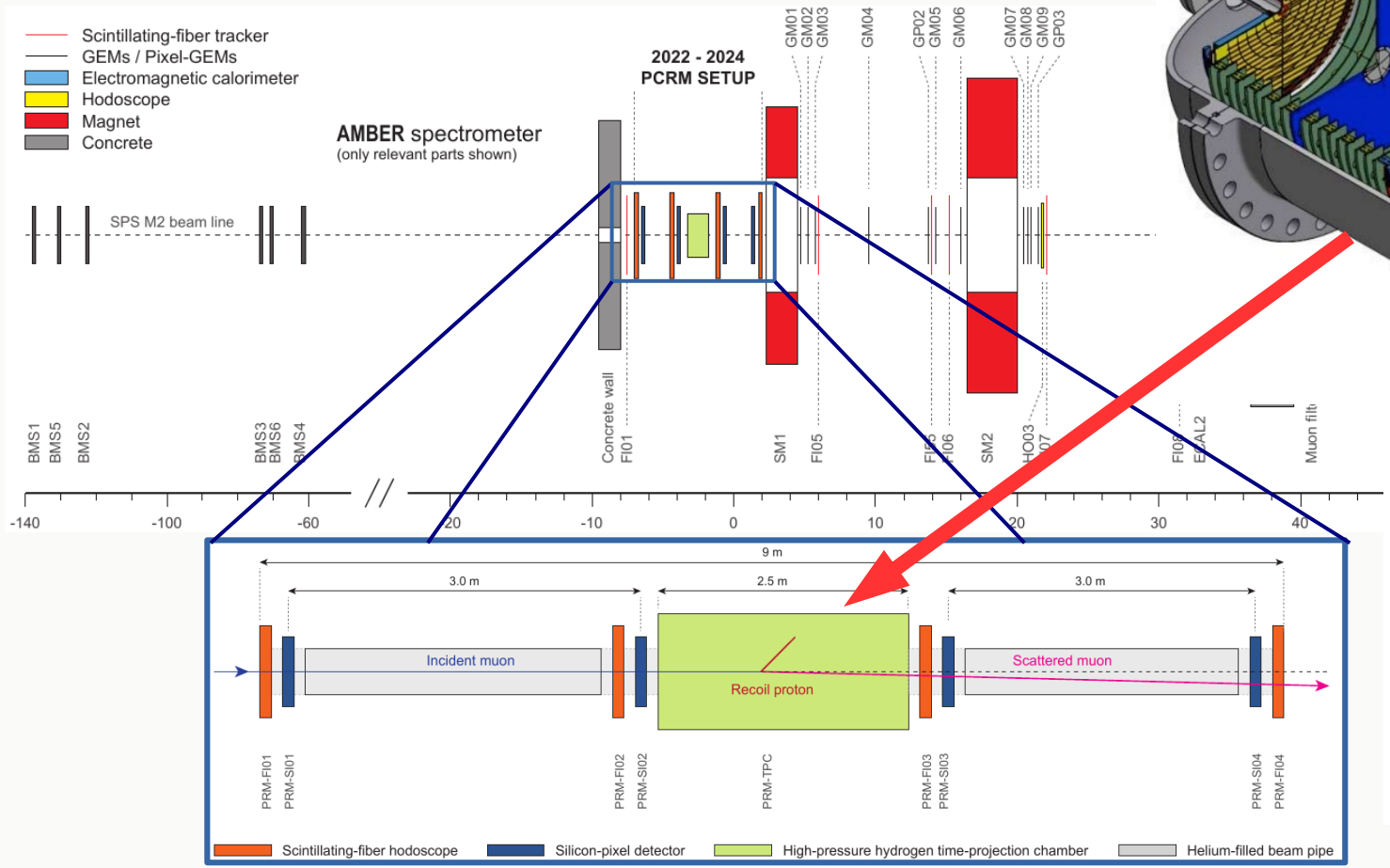


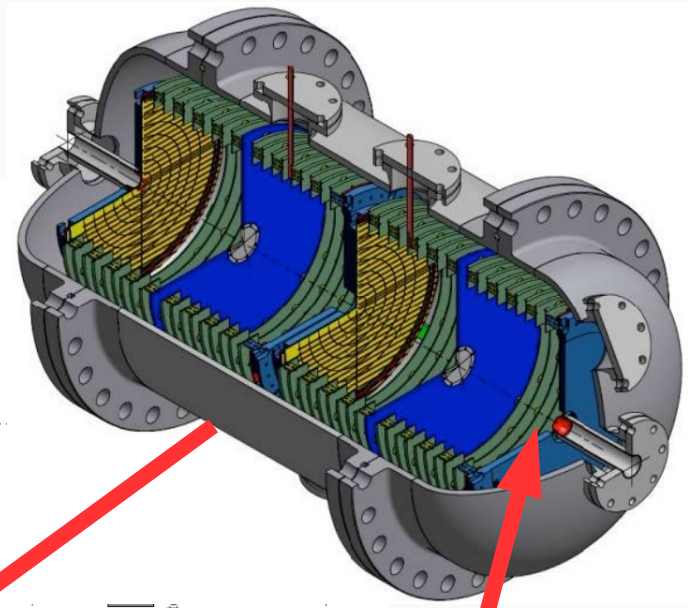
Proton Radius Measurement (PRM) by elastic muon-proton scattering

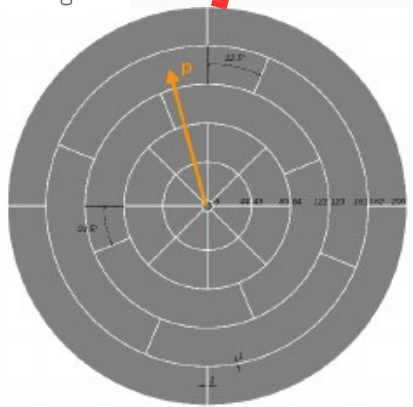
- High-intensity muon beam from SPS
- Hydrogen TPC as active target
- Muon spectrometer

Modified from: B. Adams et. al., COMPASS++/AMBER: Proposal for Measurements at the M2 beam line of the CERN SPS Phase-1: 2022-2024 (2019), CERN-SPSC-2019-022

AMBER - PRM

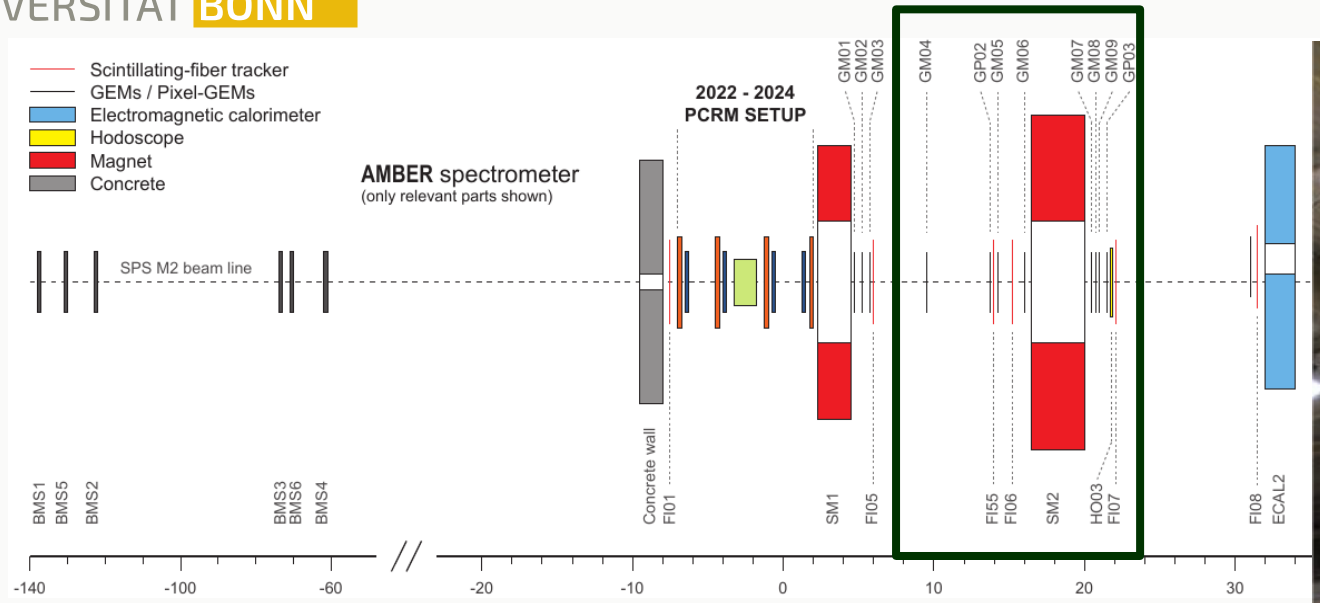


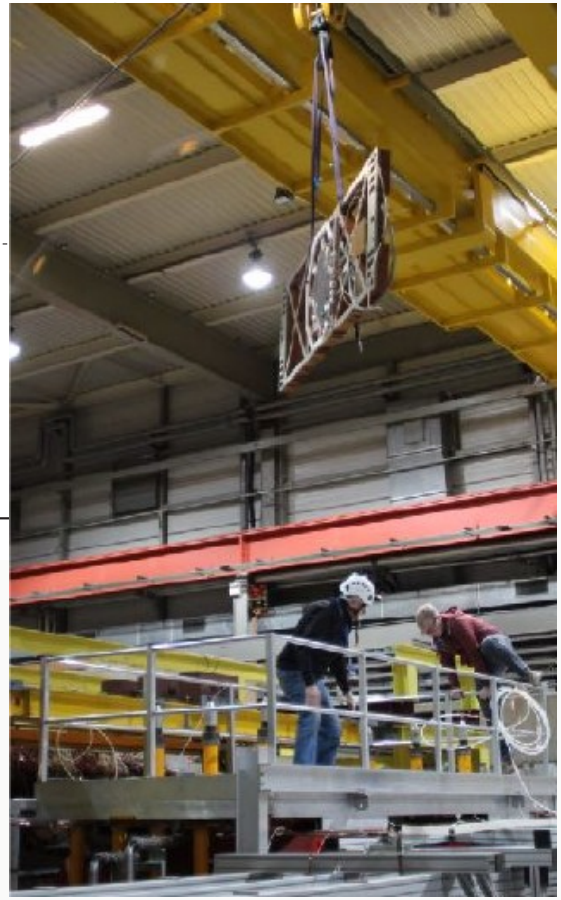




Modified from: B. Adams et. al., COMPASS++/AMBER: Proposal for Measurements at the M2 beam line of the CERN SPS Phase-1: 2022-2024 (2019), CERN-SPSC-2019-022

AMBER - PRM

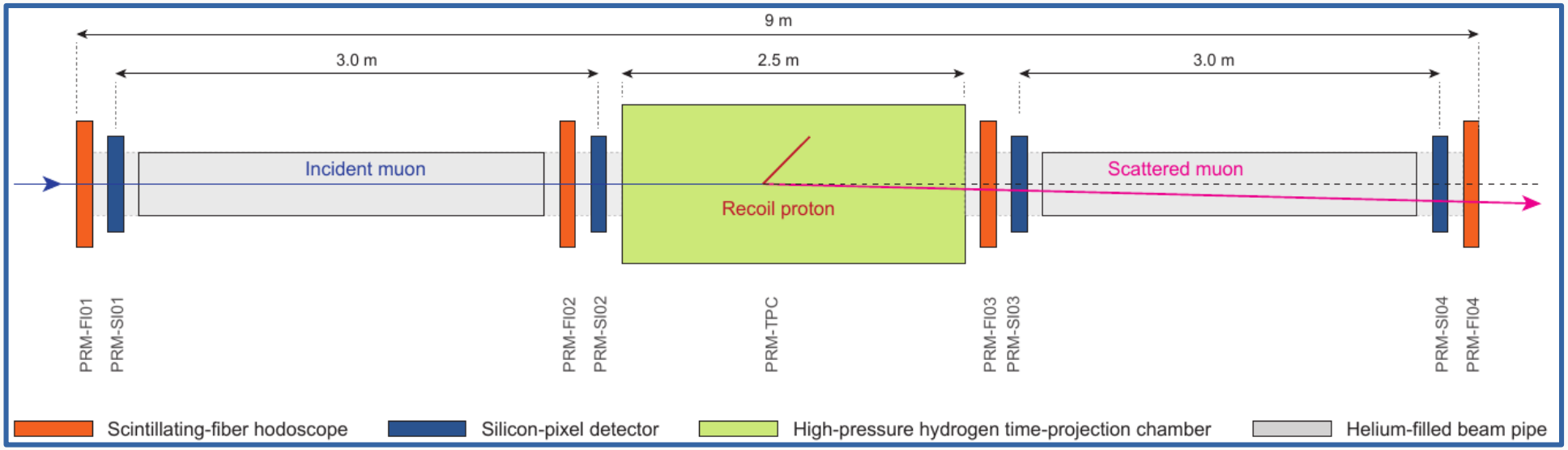




Large-area GEMs

Modified from: B. Adams et. al., COMPASS++/AMBER: Proposal for Measurements at the M2 beam line of the CERN SPS Phase-1: 2022-2024 (2019), CERN-SPSC-2019-022

AMBER - PRM



AMBER PRM readout paradigm

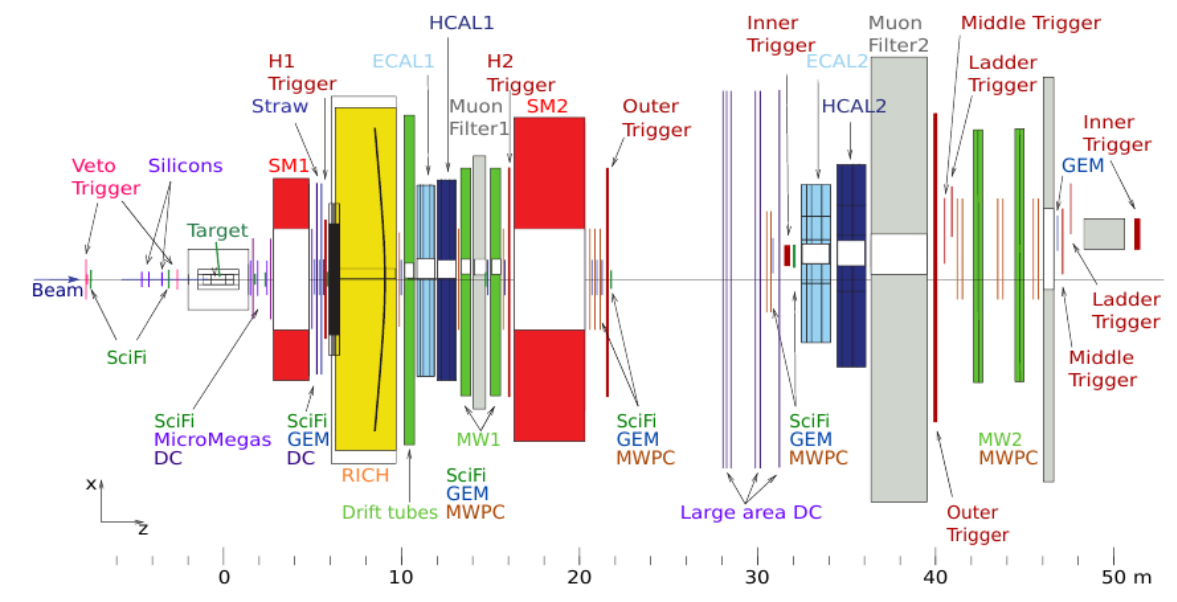
- Incident and scattered muon instantly measured with trackers
- Recoil proton measured in (slow) TPC

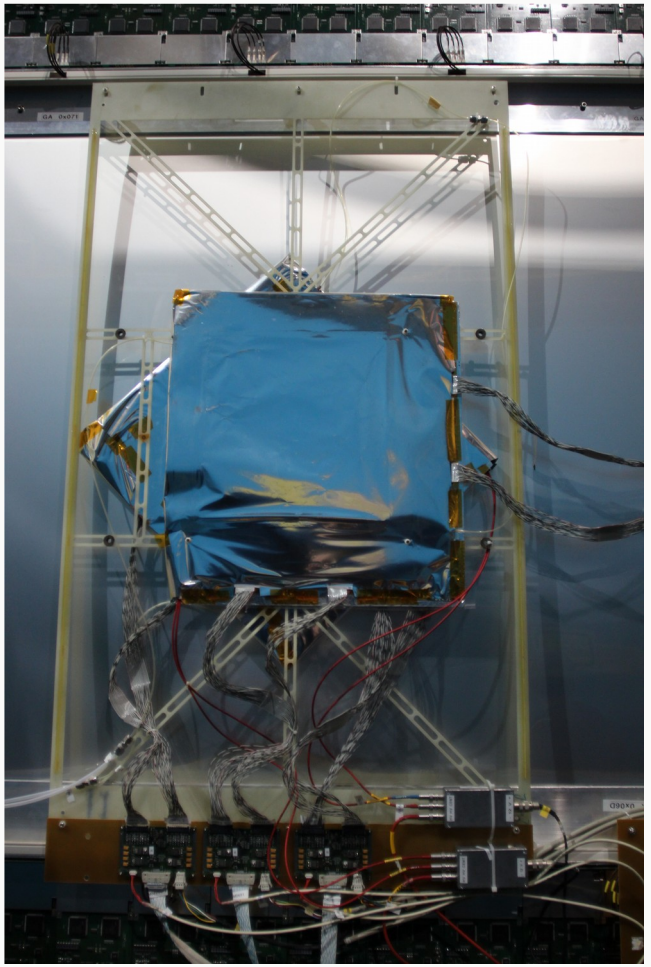
$\Longrightarrow$ Assignment can only be done in high-level trigger

$\Longrightarrow$ Continuous readout and self-triggering required

Modified from: B. Adams et. al., COMPASS++/AMBER: Proposal for Measurements at the M2 beam line of the CERN SPS Phase-1: 2022-2024 (2019), CERN-SPSC-2019-022

COMPASS → AMBER





COMPASS GEM setup:

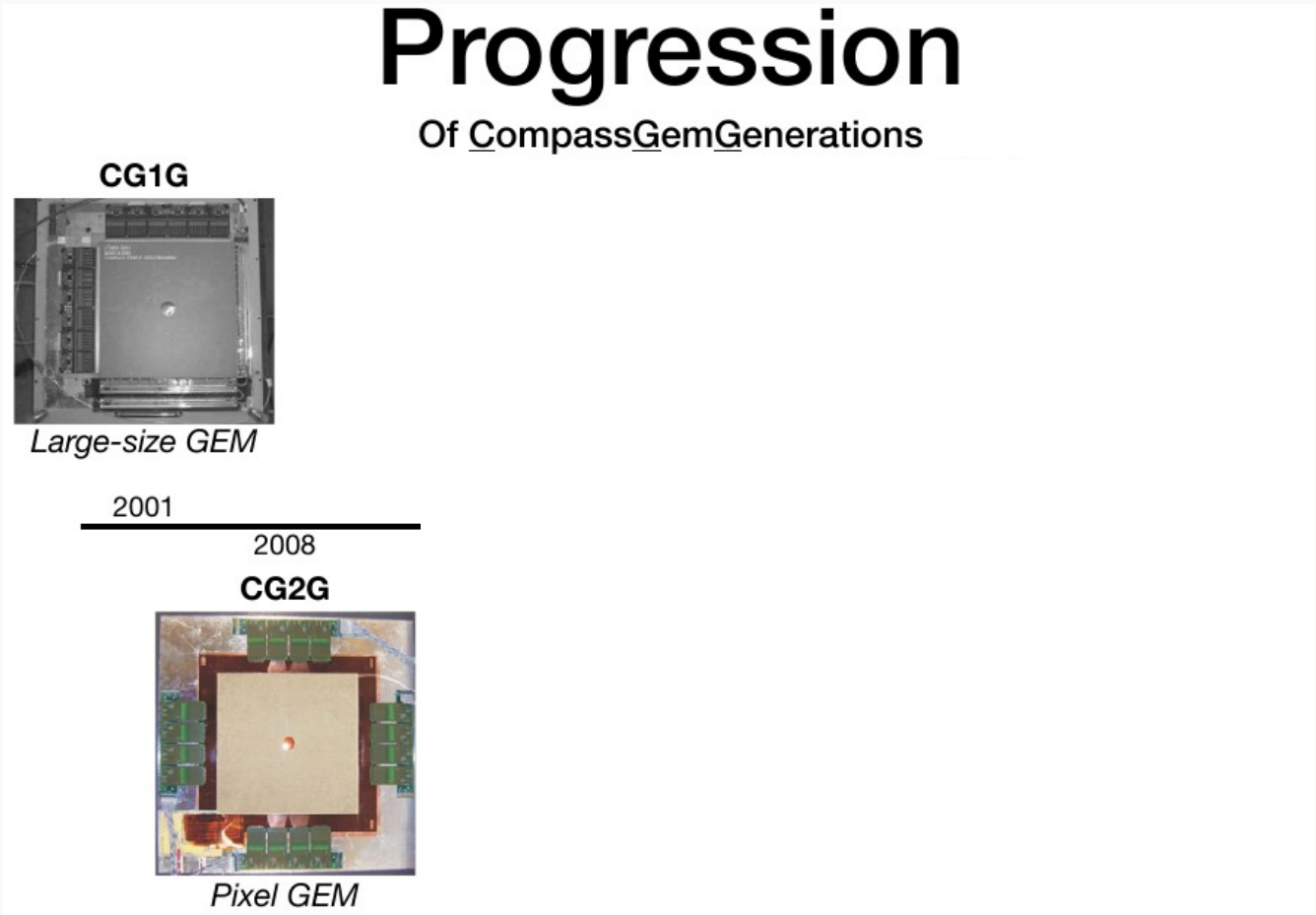
- 22 large-size GEM (30x30 cm²) from 2001
- 5 pixel GEM (10x10 cm²) from 2008
- Readout ASIC: APV25 (only triggered mode possible)

COMPASS GEM UPGRADE

GEMs in COMPASS

- Large size (30×30 cm²) installed 2002
- PixelGEMs (10×10 cm²) With 3×3 cm² pad readout installed 2008

- Main purpose: μ-momentum measurement



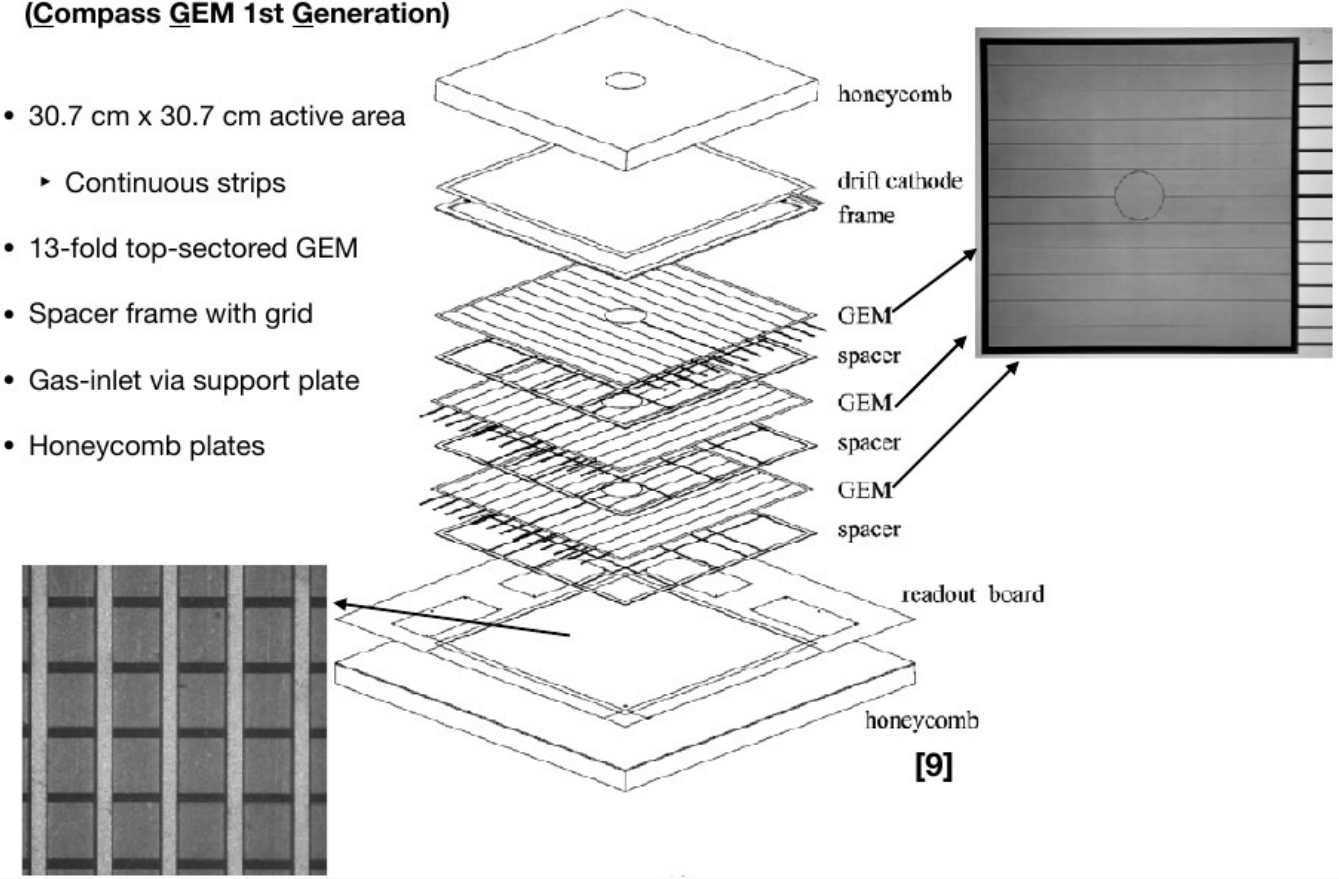
COMPASS GEM UPGRADE

CG1G

- Large area GEM
- From 2001

1st generation large-size GEM
(Compass GEM 1st Generation)

- 30.7 cm x 30.7 cm active area
  - Continuous strips
- 13-fold top-sectored GEM
- Spacer frame with grid
- Gas-inlet via support plate
- Honeycomb plates

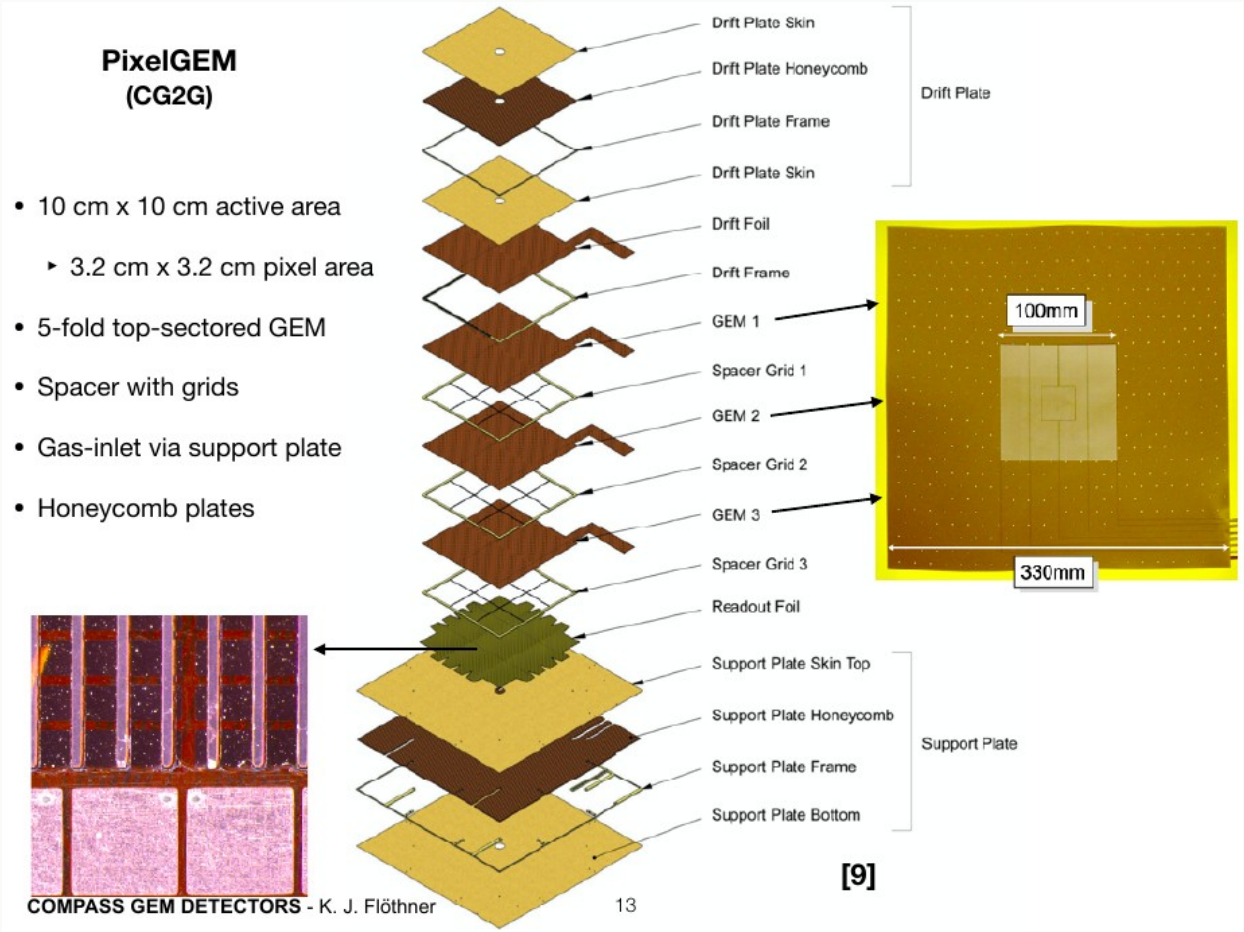


Ketzer, B., et al. "A triple-GEM Detector with pixel readout for high-rate beam tracking in COMPASS." 2007 IEEE Nuclear Science Symposium Conference Record. Vol. 1. IEEE, 2007.

COMPASS GEM UPGRADE

CG2G

- PixelGEM
- From 2008

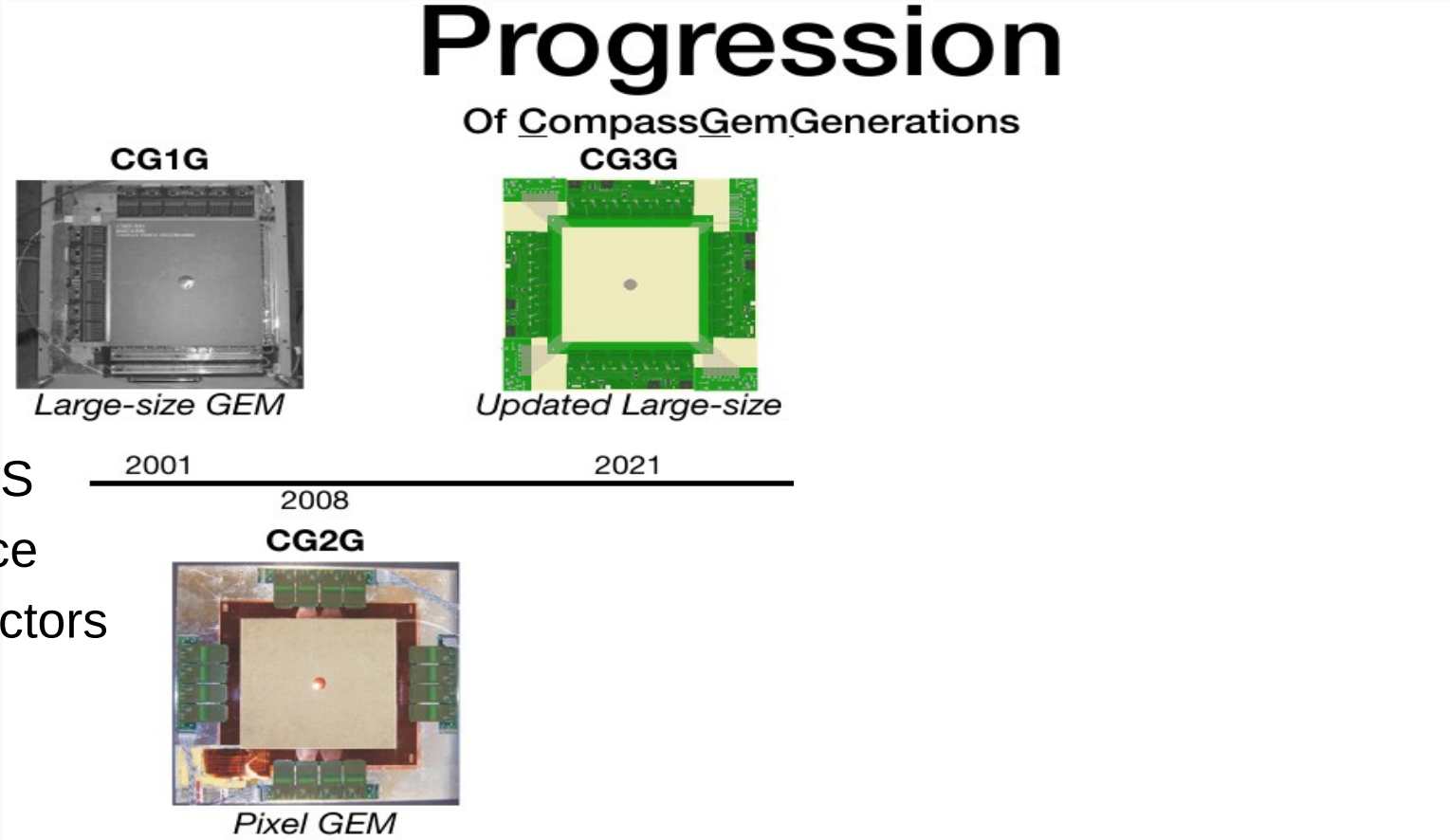


C. Altunbas et al., Construction, test and commissioning of the triple-gem tracking detector for compass, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 490 (2002) 177, issn: 0168-9002, url: http://www.sciencedirect.com/science/article/pii/S0168900202009105

COMPASS GEM UPGRADE

CG3G

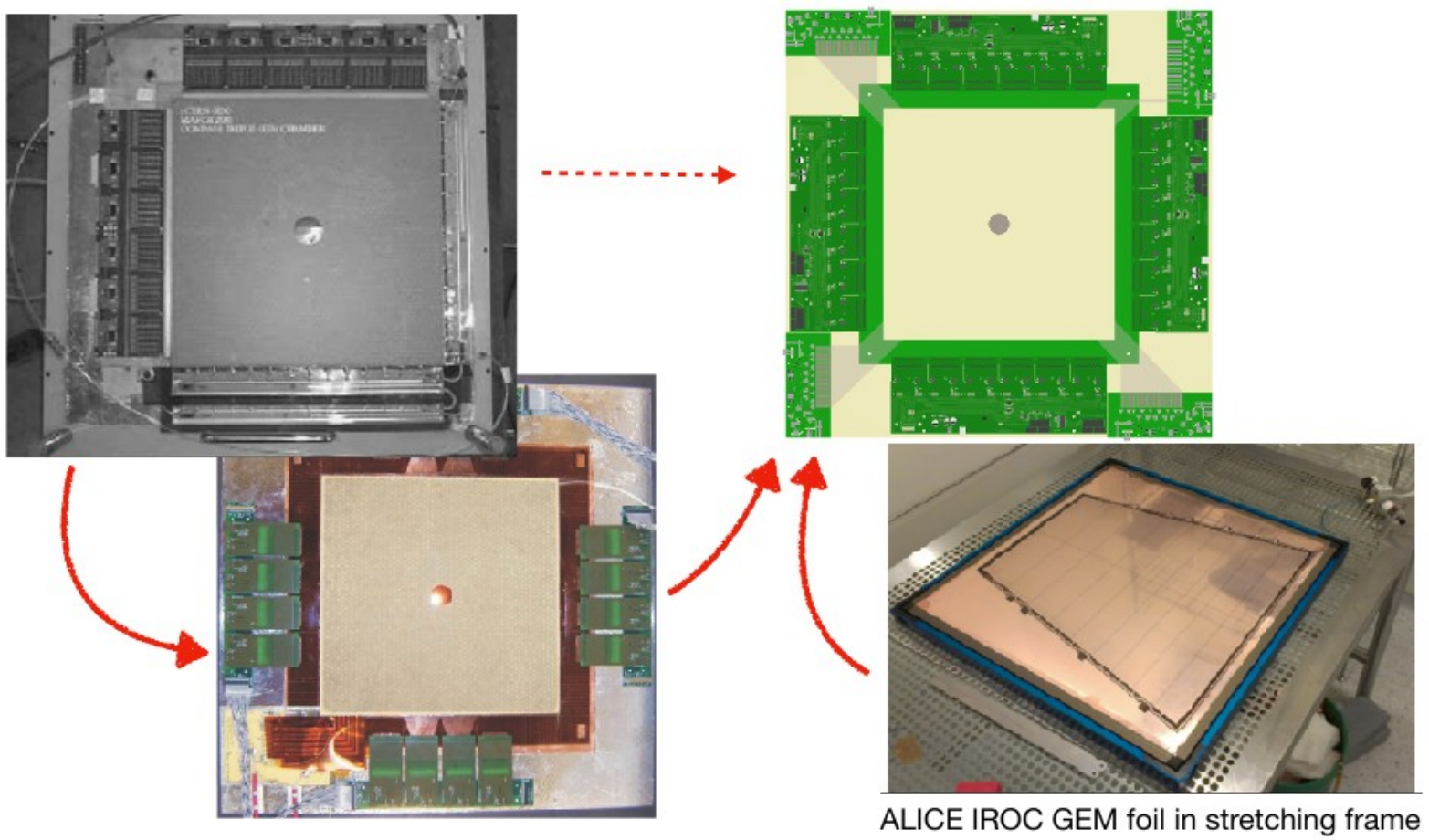
- Large area GEM
- From 2021
- For final COMPASS run: need to replace four old GEM detectors



COMPASS GEM UPGRADE

CG3G

- Large area GEM
- From 2021
- Know-how

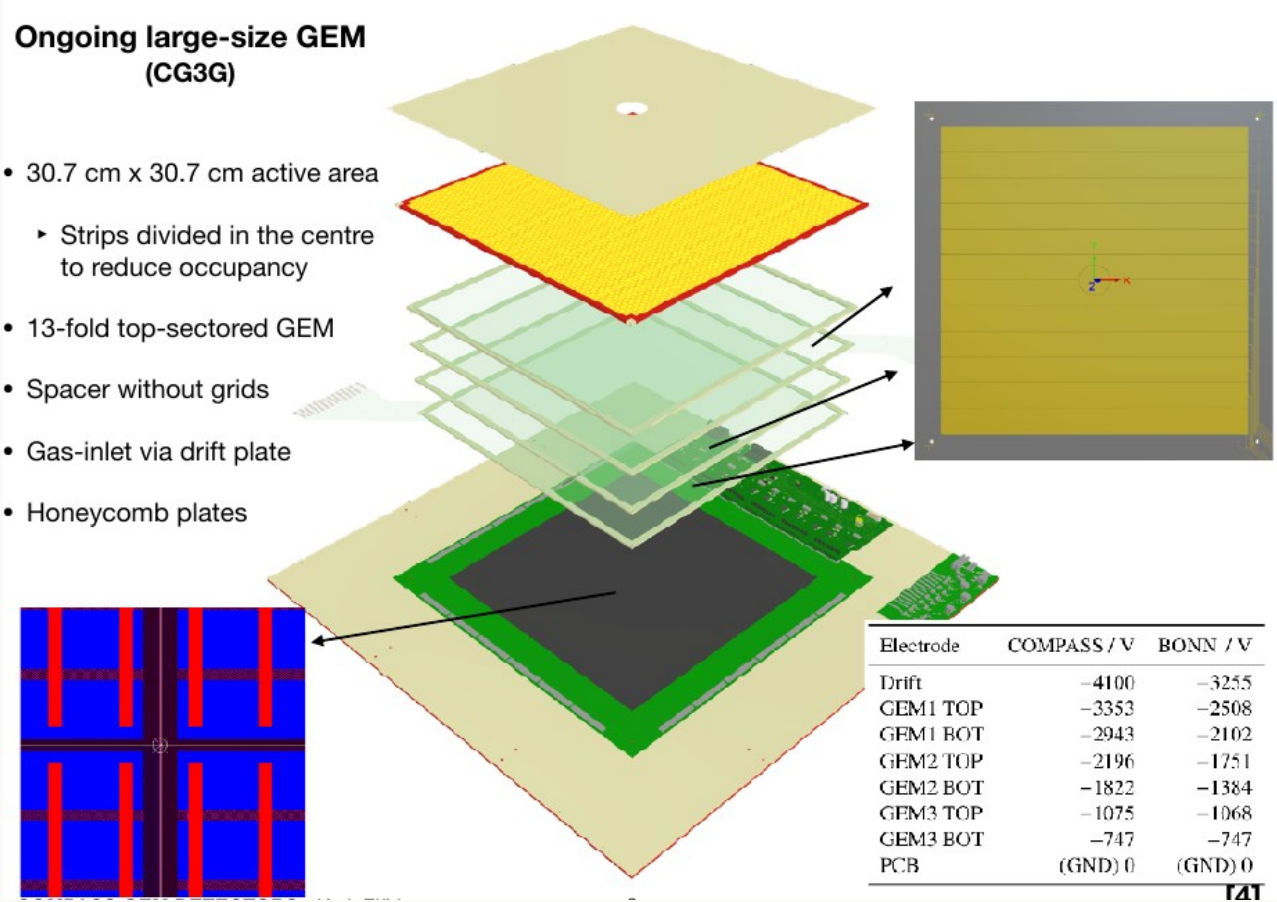


ALICE IROC GEM foil in stretching frame

COMPASS GEM UPGRADE

CG3G

- Large area GEM
- From 2021
- Layout



Electrode	COMPASS / V	BONN / V
Drift	−4100	−3255
GEM1 TOP	−3353	−2508
GEM1 BOT	−2943	−2102
GEM2 TOP	−2196	−1751
GEM2 BOT	−1822	−1384
GEM3 TOP	−1075	−1068
GEM3 BOT	−747	−747
PCB	(GND) 0	(GND) 0

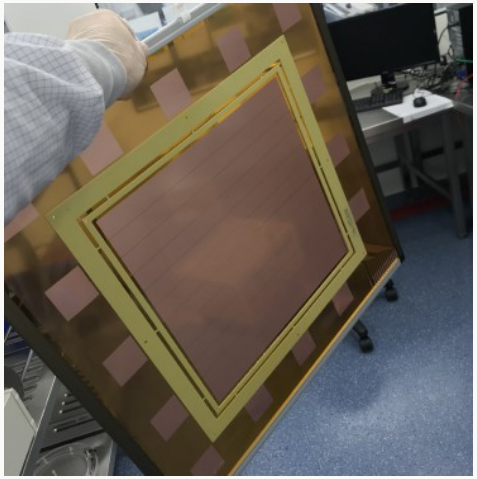
[41]

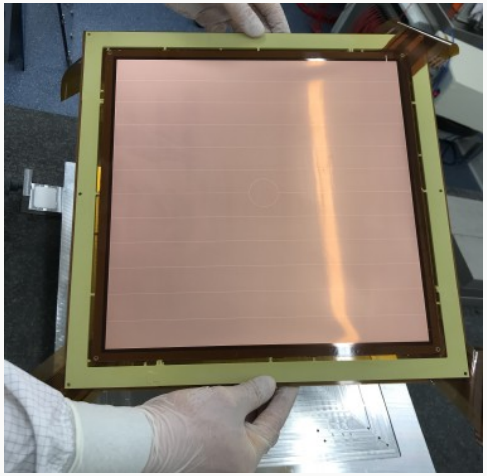
Jonathan Ottnad, Optimierung der GEM-basierten Verstärkungsstufe einer TPC für das CB/TAPS-Experiment, PhD thesis: Rheinische Friedrich-Wilhelms-Universität Bonn, 2020, url: http://hdl.handle.net/20.500.11811/8516

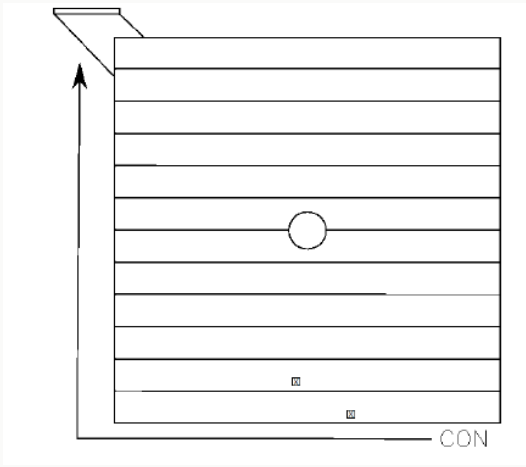
COMPASS GEM UPGRADE

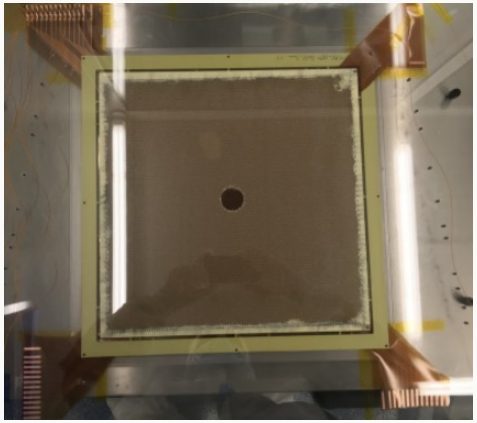
CG3G

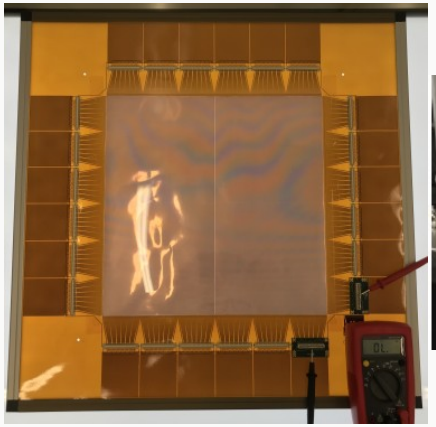
- Large area GEM
- From 2021
- Production

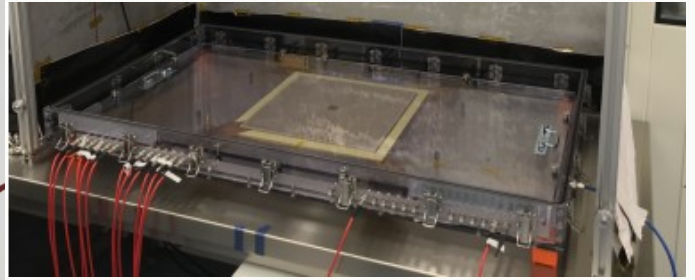










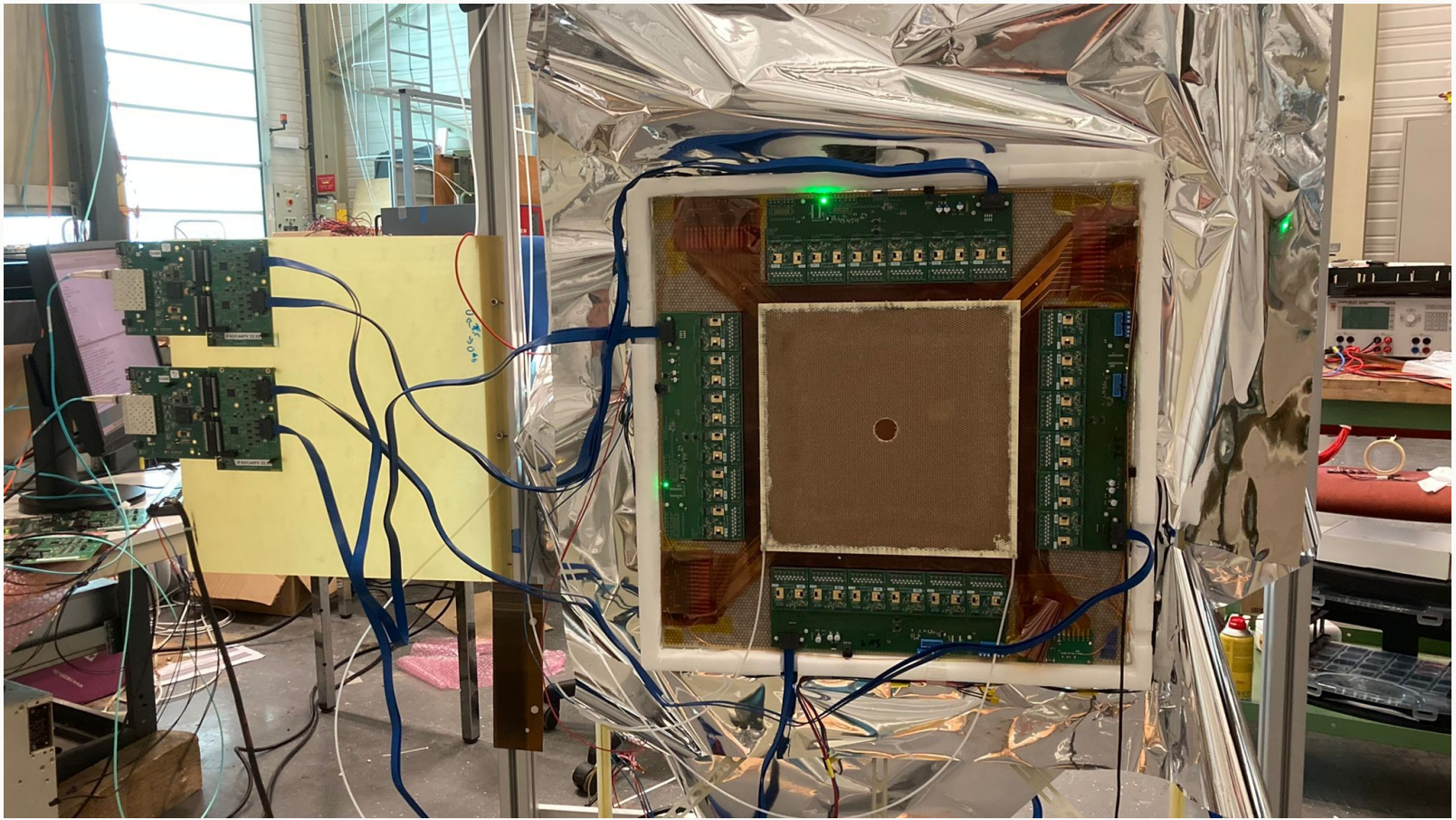


UNIVERSITÄT BONN

COMPASS GEM UPGRADE

CG3G

- Large area GEM
- May 2022
- Final readout test



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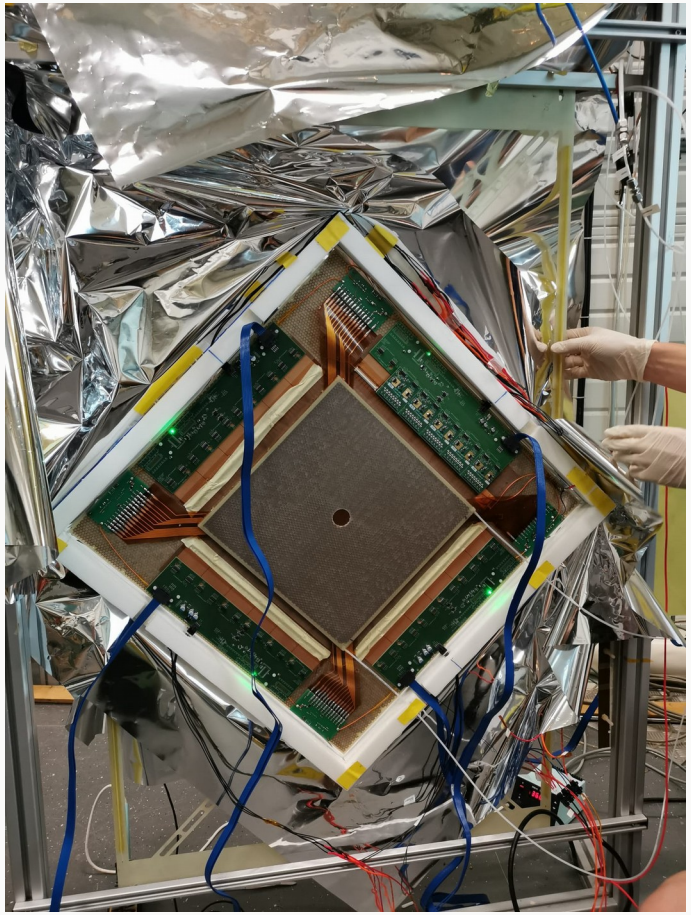
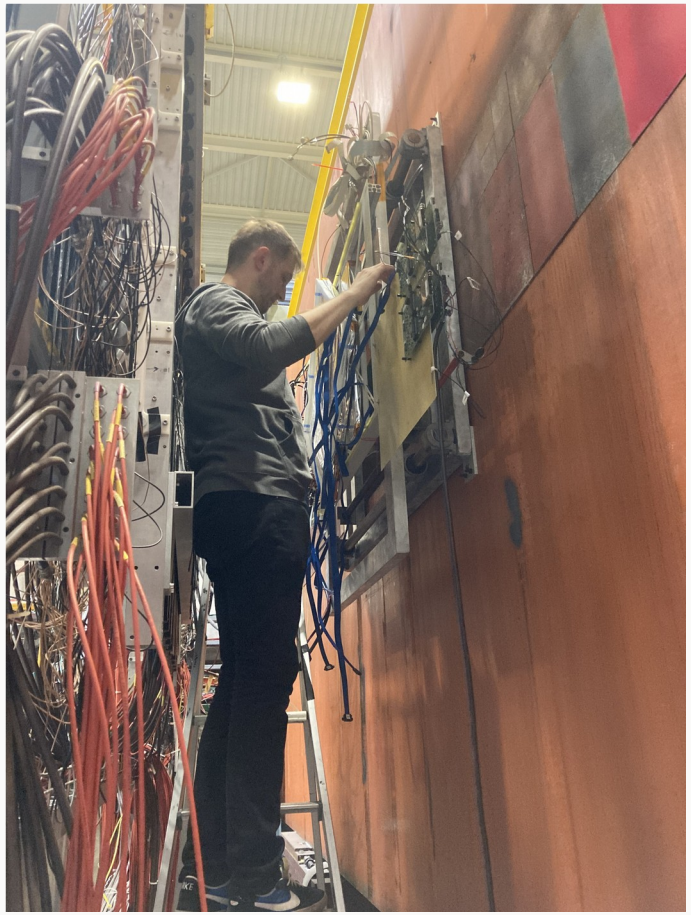
COMPASS GEM UPGRADE

CG3G

- Large area GEM
- May/June 2022
- Cabling
- Shielding
- Installation



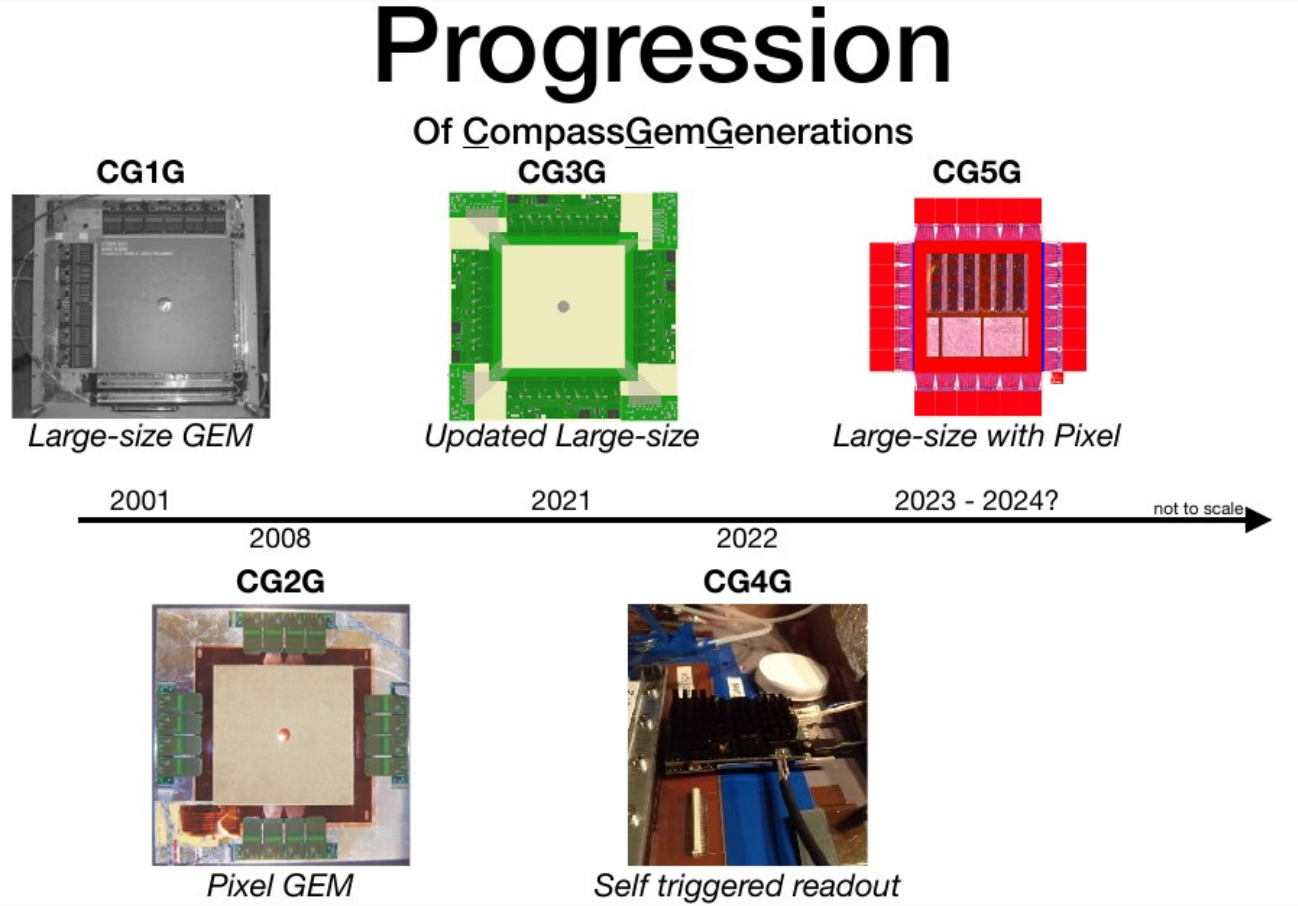


AMBER GEMS

CG3G → CG4G → CG5G

- CG4G: Large area GEM
  as for COMPASS
  with self-triggered readout

- *CG5G: Large are GEM*
  with pads in the centre
  (as PixelGEMs)
  and self-triggered readout



GEM FRONTEND ASIC

Two candidate chips

ASIC	*Developed for*	*Developed by*	*Available Readout System*	*Channels*	*Rate/ch. Output bandwidth*	*Gain Dynamic range*	*Time resolution*	*Power consumption*
TIGER [1]	BES III Cylindrical GEM	INFN Torino [3]	GEMROC (INFN Ferrara & Torino)	64	~100 kHz 1.6 Gb/s	11 mV/fC < 50 fC	~ 1.8 ns	< 12 mW/ch
VMM [2]	ATLAS New Small Wheel	Brookhaven National Laboratory	Scalable Readout System (RD51)	64	~1 MHz 0.8 Gb/s	0.5-16 mV/fC < 2 pC	~ 1 ns	~ 15 mW/ch

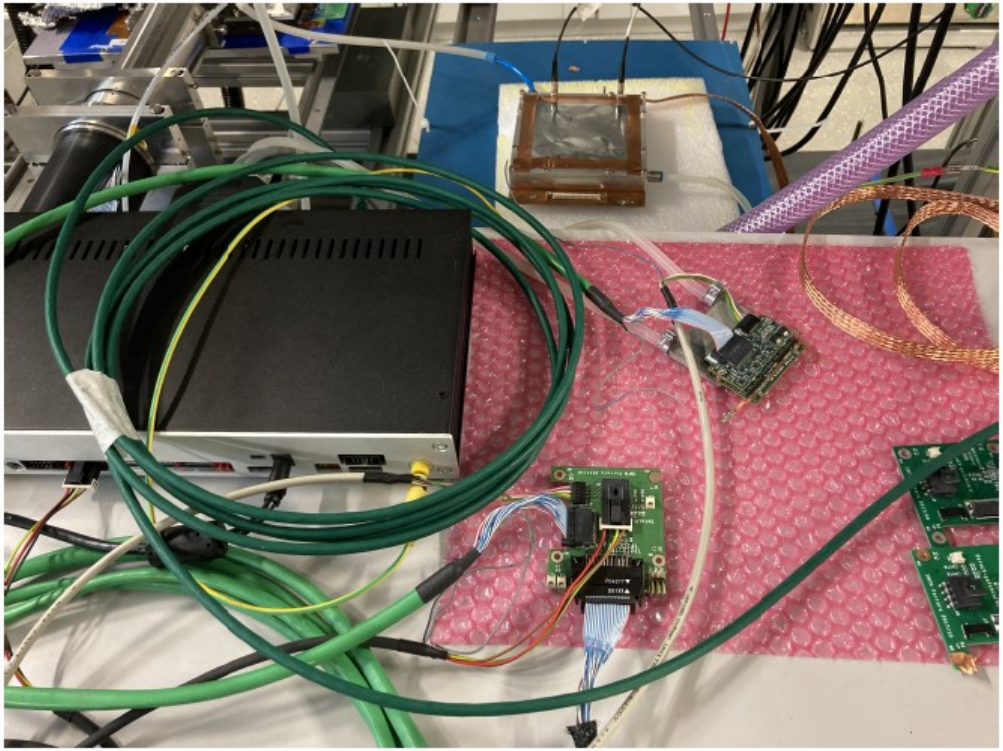
[1] Rivetti, A., et al. *TIGER: A front-end ASIC for timing and energy measurements with radiation detectors*, NIM A 924 (2019) 181-186.
[2] G. De Geronimo, G. Iakovidis, S. Martoiu and V. Polychronakos, *The VMM3a ASIC*, IEEE Transactions on Nuclear Science, doi: 10.1109/TNS.2022.3155818.
[3] Funded by the EU and INFN within the project BESIIICGEM RISE 645664 within the call H2020-MSCA-RISE-2014

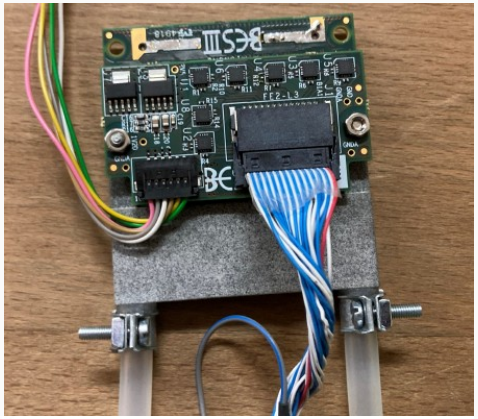
UNIVERSITÄT BONN

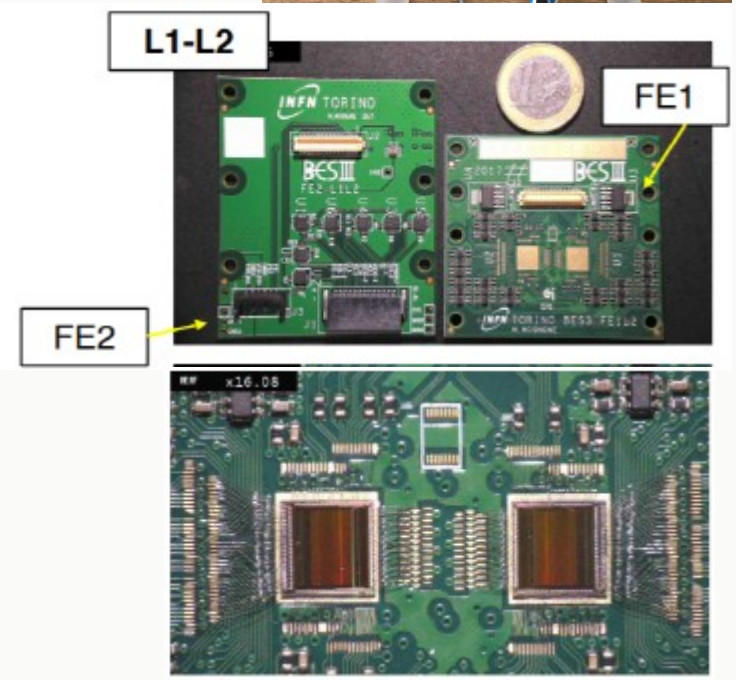
TIGER

Preparation for a test with a GEM detector

→ Visit of colleagues from INFN/Uni Torino to our institute



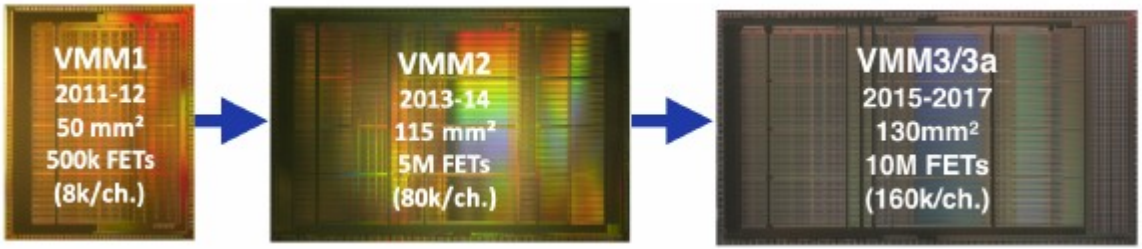


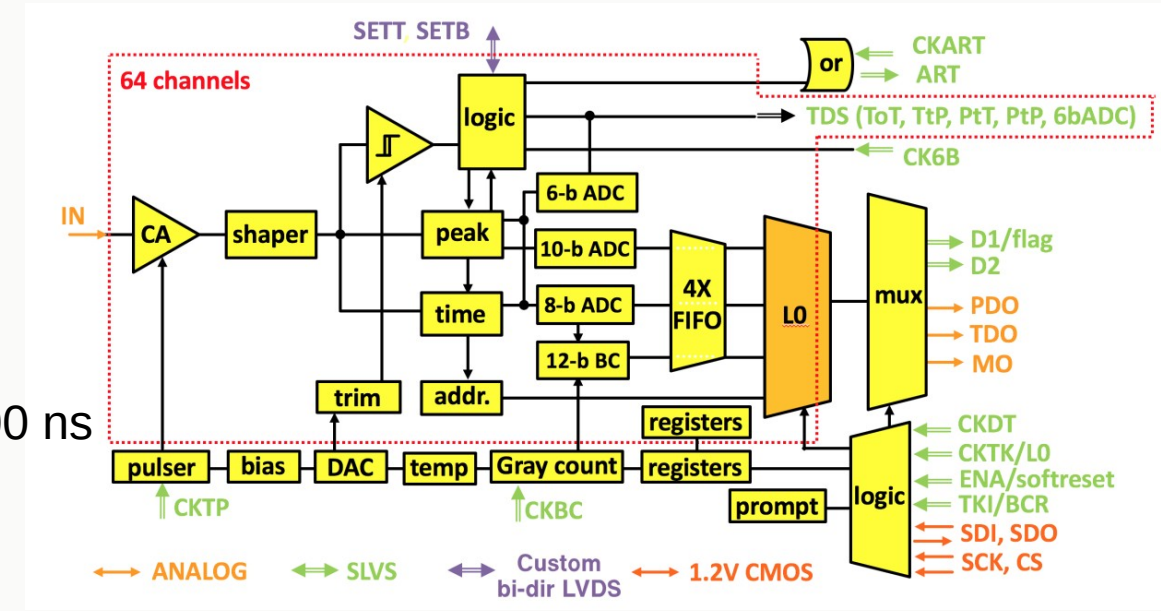


THE VMM ASIC

VMM developed for the ATLAS NSW upgrade by BNL [3]

- 130 nm CMOS technology
- 64 input channels, each w/ preamplifier, shaper, peak detector, several ADCs
- Pos. & neg. polarity sensitive
- Digital block w/ neighbouring logic, FIFO, multiplexer
- Adjustable gain 0.5-16 mV/fC
- Adjustable shaping time from 25 ns – 200 ns
- Input capacitance from few pF – 1 nF





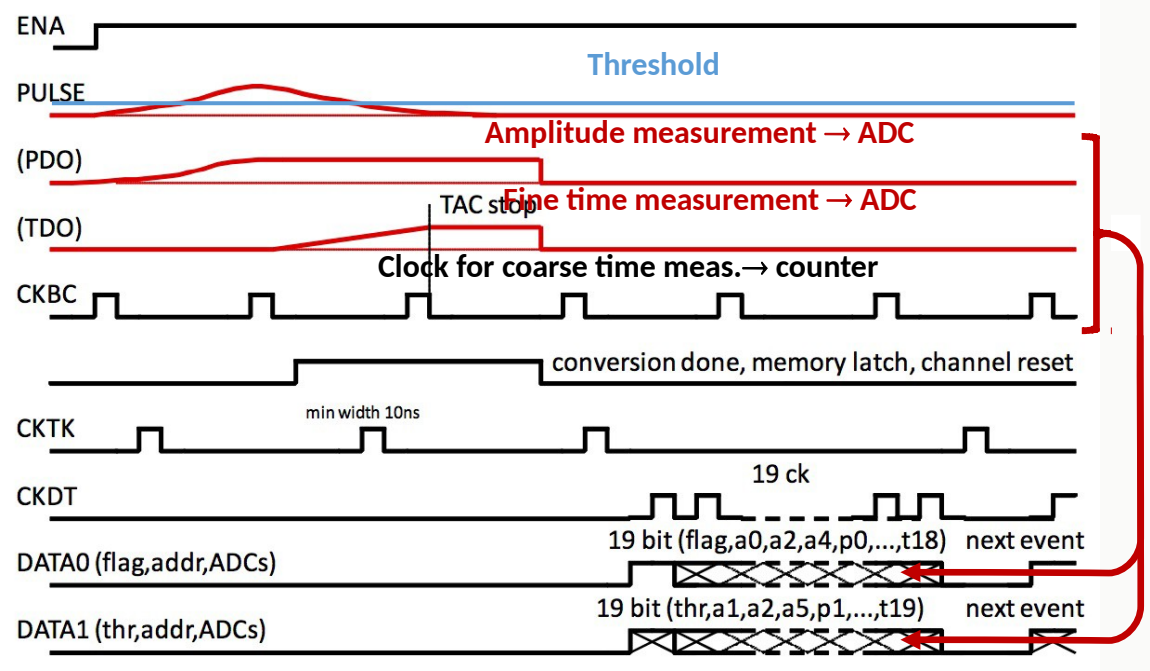
[3] De Geronimo, Gianluigi, et al. "The vmm3a asic." IEEE Transactions on Nuclear Science 69.4 (2022): 976-985.

THE VMM ASIC

Continuous data driven readout mode

- Internal test pulser with adjustable amplitude
- Global threshold & adjustment per channel
- Self-triggered, zero suppressed
- 38 bit per hit
  (if input charge goes over threshold)

1) Event flag (1 bit)
2) Over threshold flag (1 bit)
3) Channel number (6 bit)
4) Signal amplitude (10 bit)
5) Arrival time (20 bit)

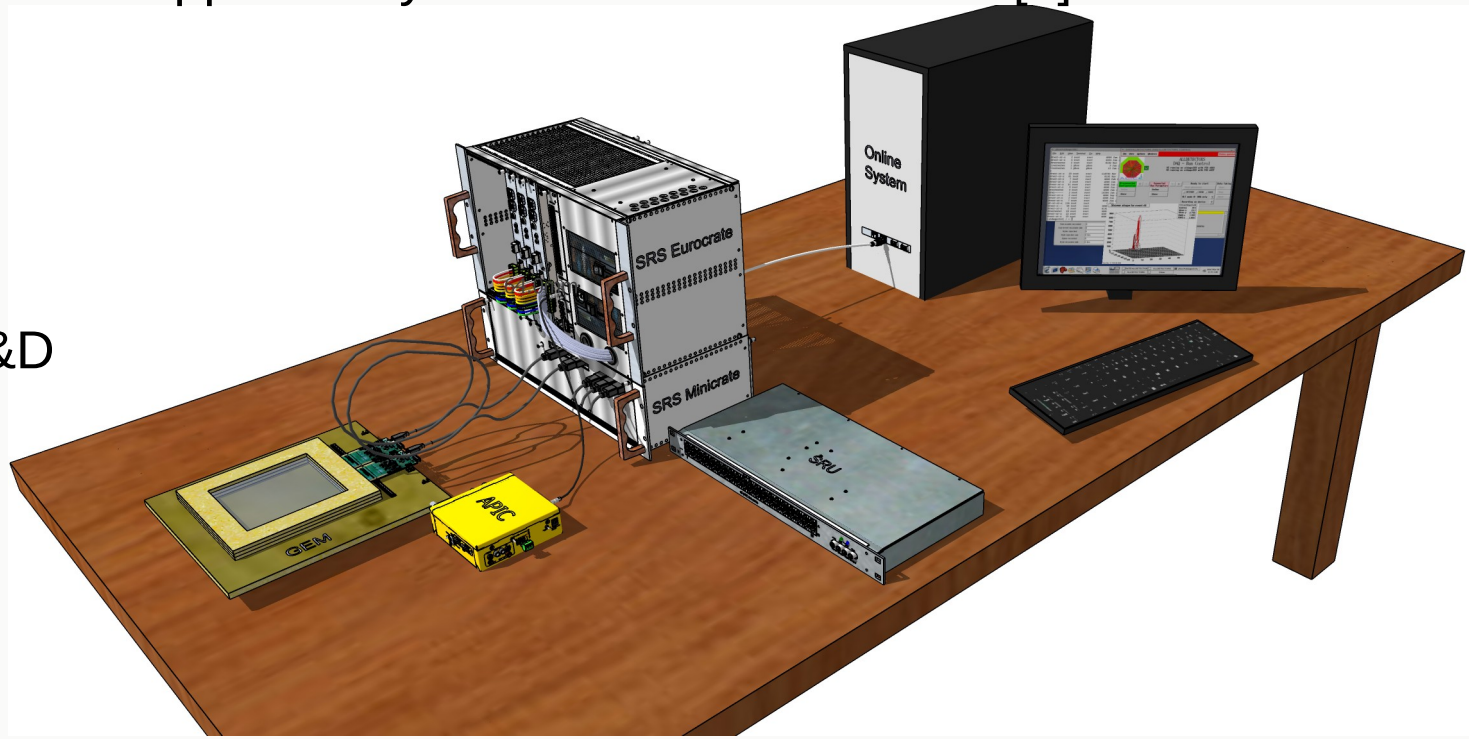


VMM INTEGRATION IN SRS

Scalable Readout System: A generic readout system for laboratory and detector instrumentation developed and supported by the RD51 Collaboration [4]

- Introduced 2009
- Front-end chip: APV25
- Inventor: H. Müller
- Workhorse for MPGD R&D

- Later: more front-ends
  - VFAT, Beetle
  - SiPMs
  - Timepix



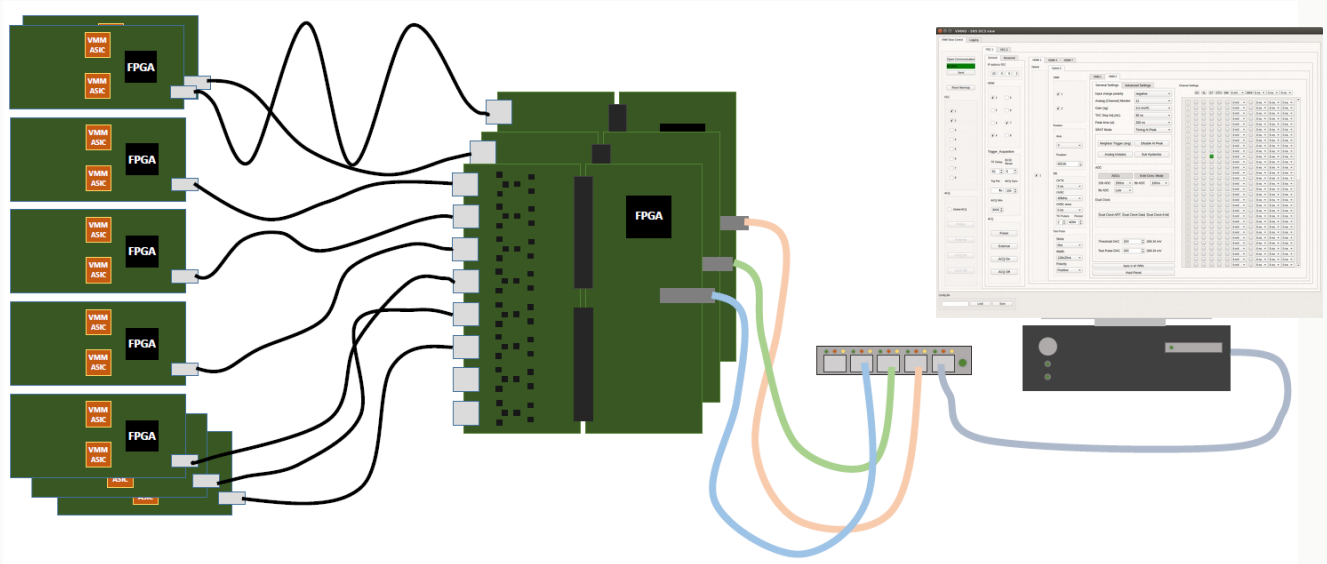
[4] S. Martoiu, H. Muller and J. Toledo, *Front-end electronics for the Scalable Readout System of RD51,* IEEE NSS Conference Record (2011) 2036-2038.

VMM INTEGRATION IN SRS

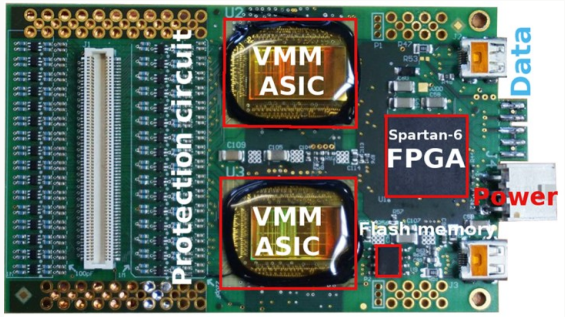
Implementation of VMM [5]

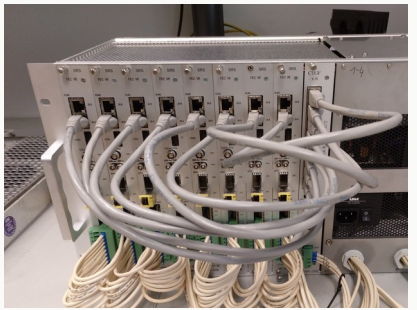
- First tests started 2014
- Continued at CERN for ESS NMX detector
- Finalised 2019
- 3rd hardware production run ongoing (~600 front-ends)

- Used for several upcoming experiments and R&D e.g. MAGIX, FAIR Hydra TPC, LSBB muon tomography



VMM Hybrid → HDMI cable → Adapter card + FEC → Ethernet → Switch →Ethernet → PC

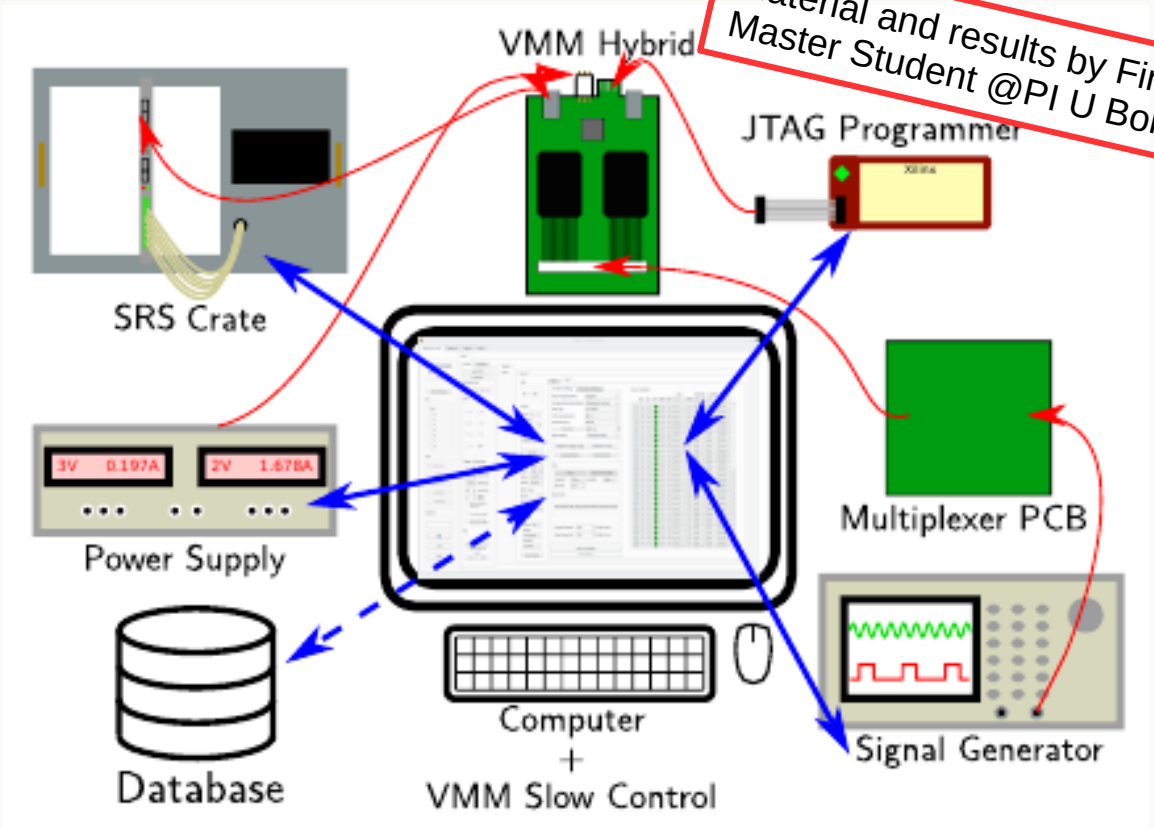


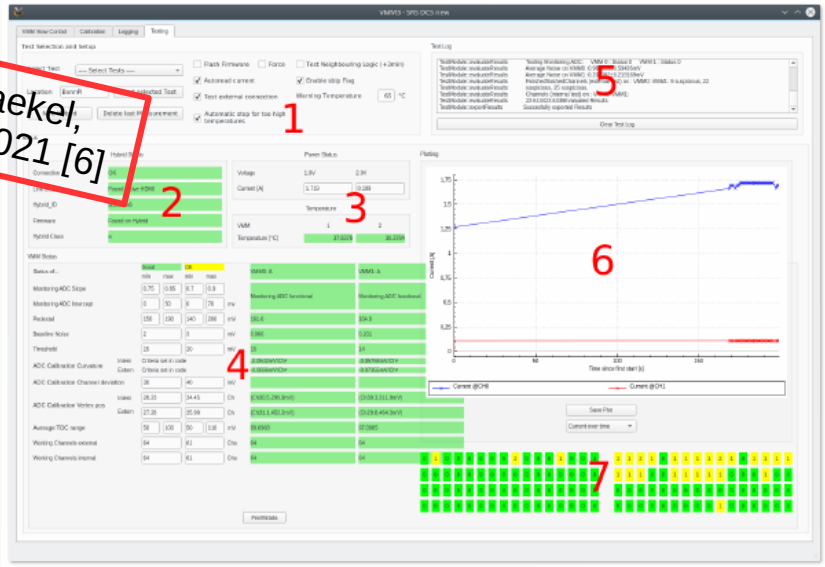


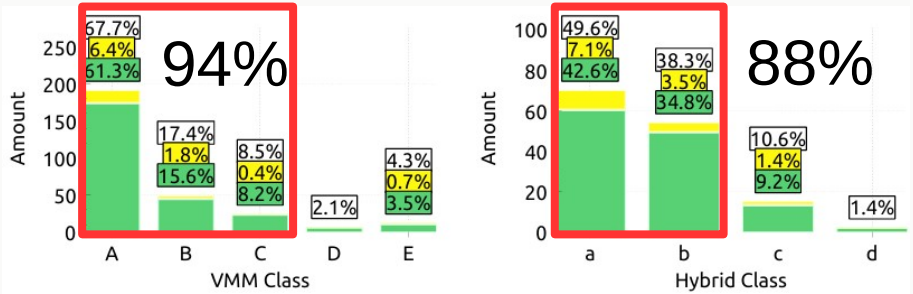
[5] M. Lupberger et al., *Implementation of the VMM ASIC in the Scalable Readout System*, NIM A 903 (2018) 91-98

SRS+VMM: AUOMATED TESTING SYSTEM FOR CHARACTERISAION

Material and results by Finn Jaekel, Master Student @PI U Bonn 2021 [6]

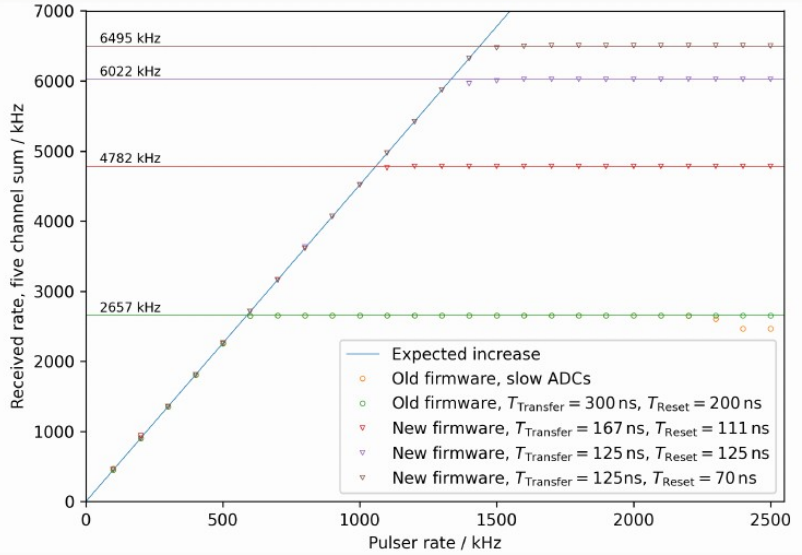


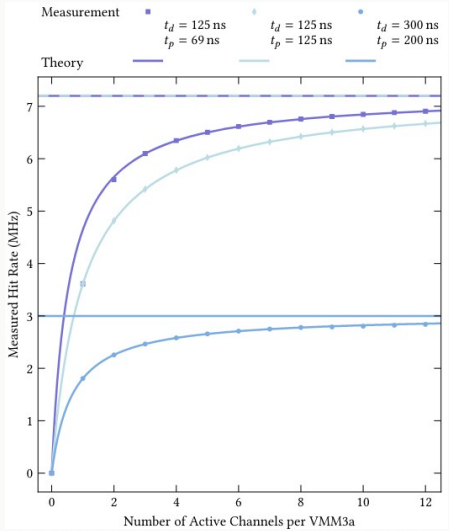


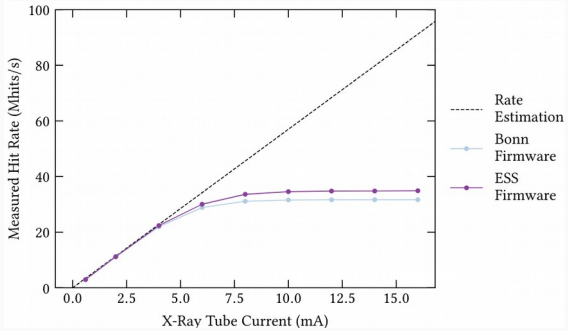


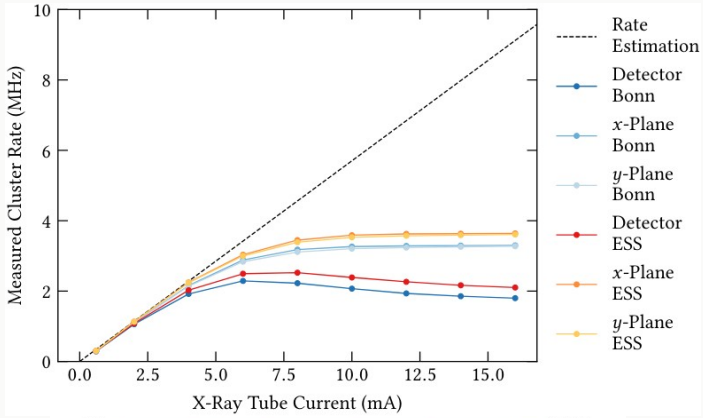
[6] Jaekel, Finn, et al. "An automated testing system for the RD51 VMM hybrid and yield measurement of the first production batches." arXiv preprint arXiv:2206.00033 (2022).

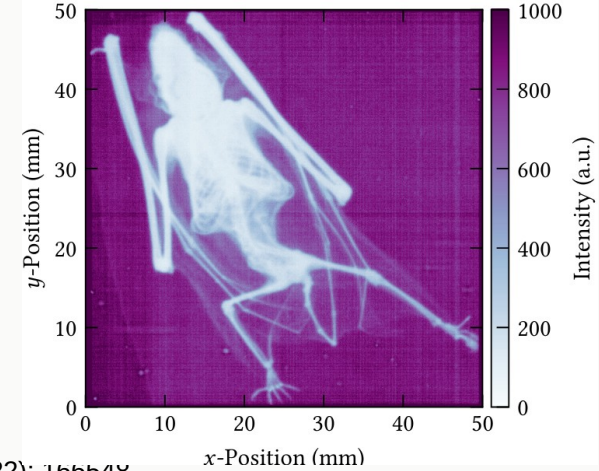
READOUT RATE FIRMWARE IMPROVEMENTS











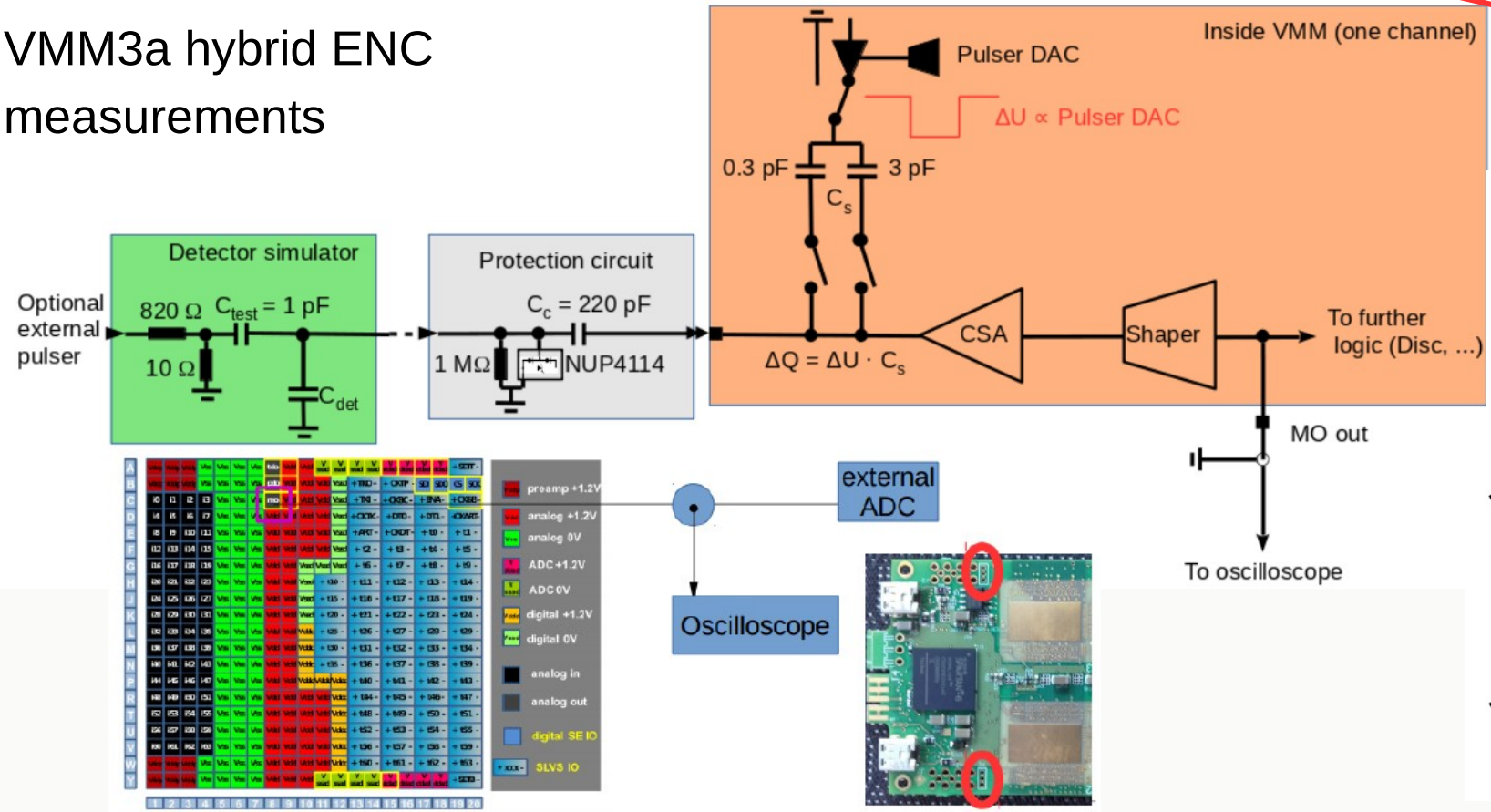
Material and results by Patrick Schwäbig, Master Student @PI U Bonn 2021 [7]

[7] Pfeiffer, D., et al. "Rate-capability of the VMM3a front-end in the RD51 Scalable Readout System." NIMA 1031 (2022): 166548.

NOISE EVALUATION

Material and results by Emorfili Terzimpasoglou, Master Student @HISKP U Bonn (2021)

VMM3a hybrid ENC measurements



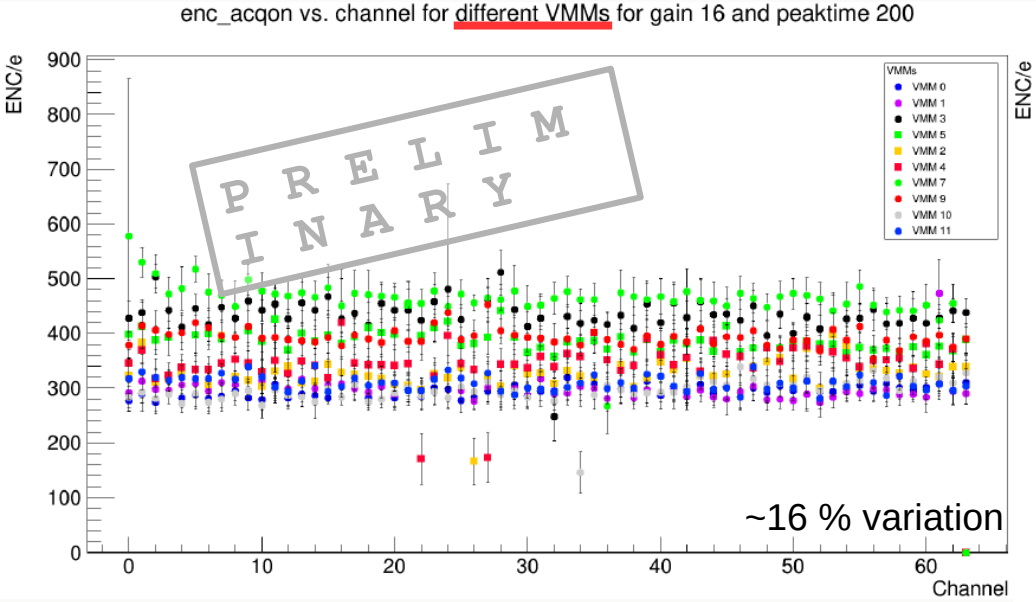
- ✓ **Used configurations:**
  - Gains [mV/fC]: 0.5, 1, 3, 4.5, 6, 9, 12, 16.
  - Peaktime [ns]: 25, 50, 100, 200.
- ✓ **# of chips:**
  - 10 VMMs (5 hybrids, 2 VMMs/hybrid).
- ✓ **Input capacitance:**
  - No input capacitance
  - Detector simulator PCB [pF]: 8, 30, 76, 98, 338, 360, 406, 428.
- ✓ **Settings:**
  - All for 1-2 chips.
  - Standard for others.

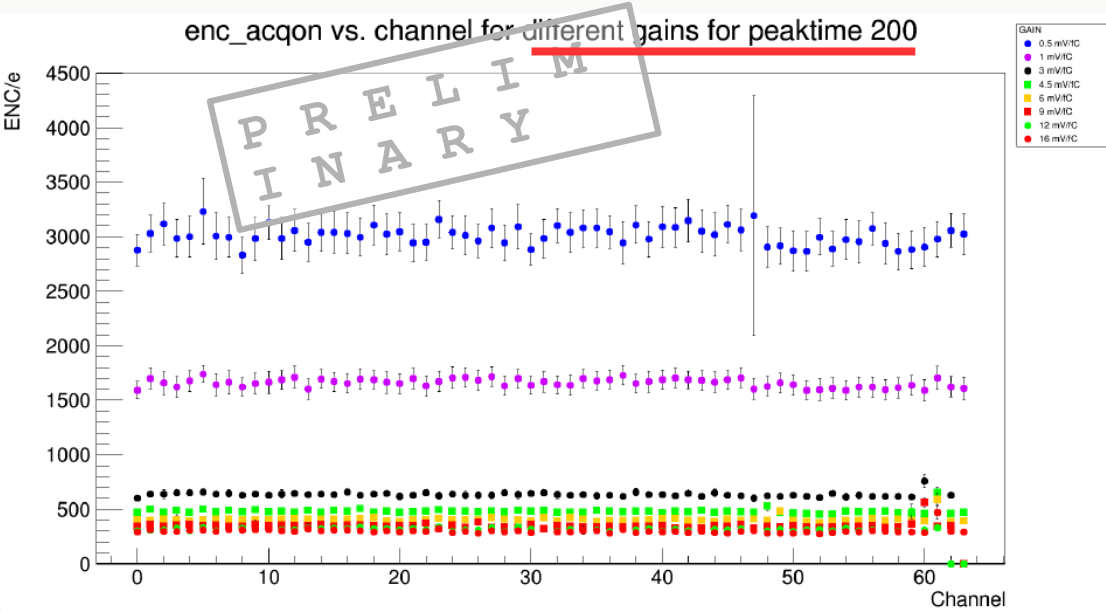
[8] E. Emorfili Terzimpasoglou, et al. "Investigations on ASIC for Triple-GEM Detectors" Master Thesis Uni Bonn (2021)

NOISE EVALUATION

Material and results by Emorfili Terzimpasoglou, Master Student @HISKP U Bonn (2021)

VMM3a hybrid ENC measurements





Study continued to get S/N in a GEM detector with cosmic muons

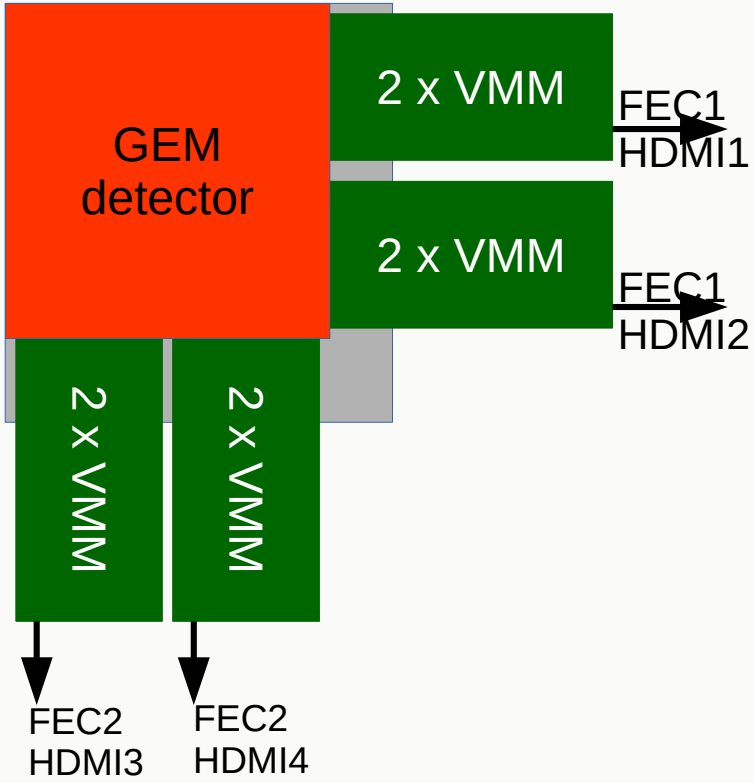
[8] E. Emorfili Terzimpasoglou, et al. "Investigations on ASIC for Triple-GEM Detectors" Master Thesis Uni Bonn (2021)

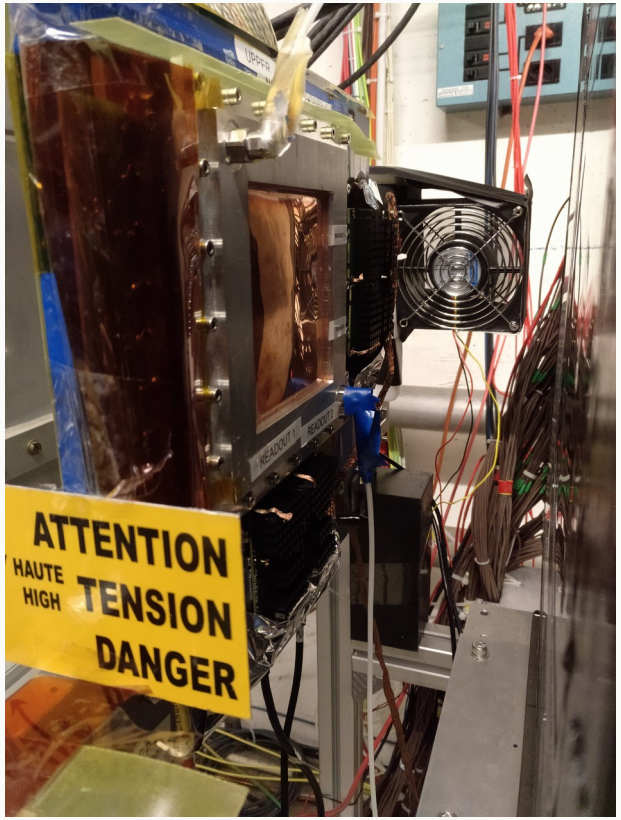
VMM TEST FOR AMBER

AMBER Pilot Run October 2022: Setup

VMM TEST FOR AMBER

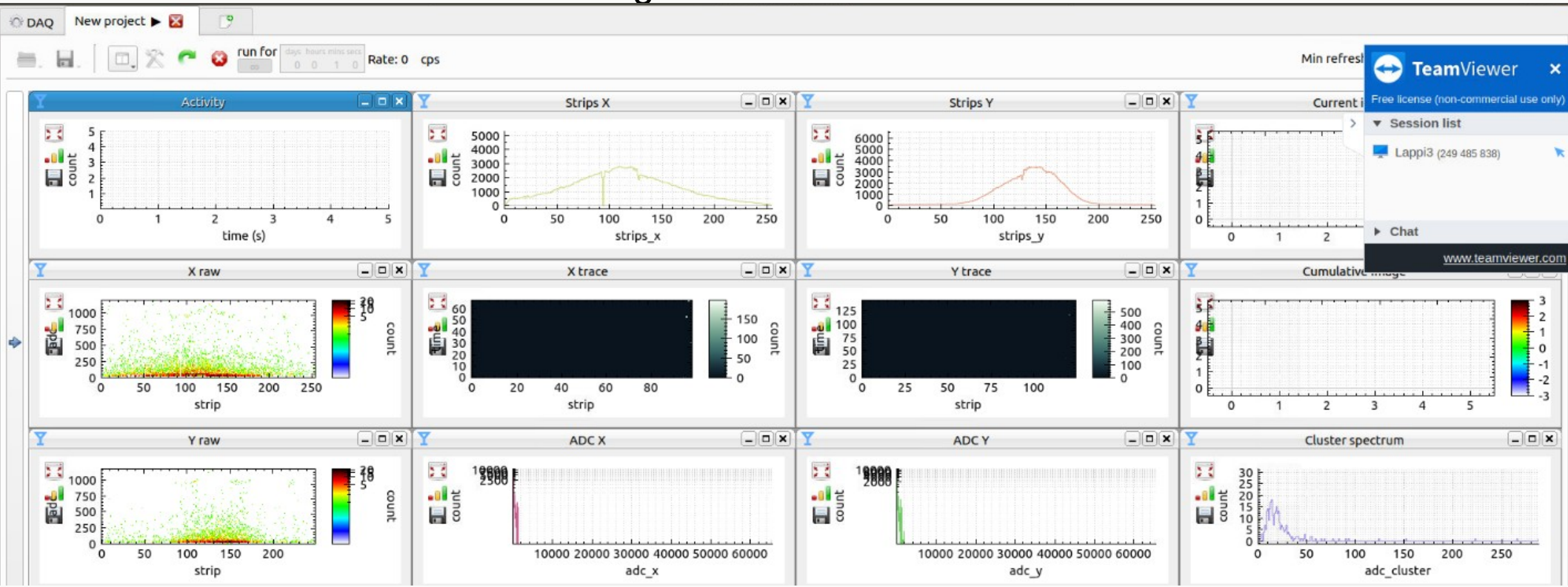
AMBER Pilot Run: Setup





VMM TEST FOR AMBER

AMBER Pilot Run: Online monitoring



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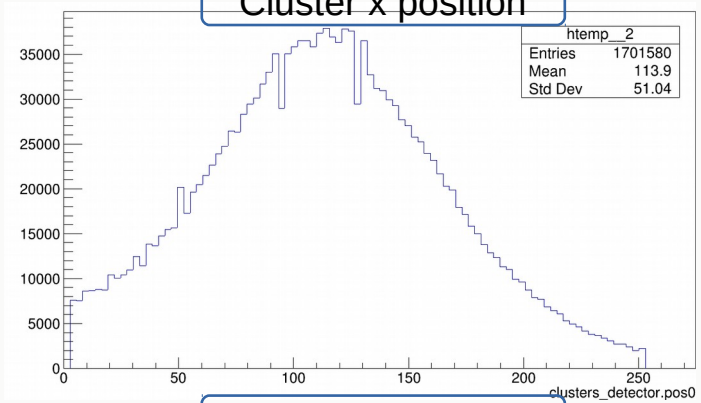
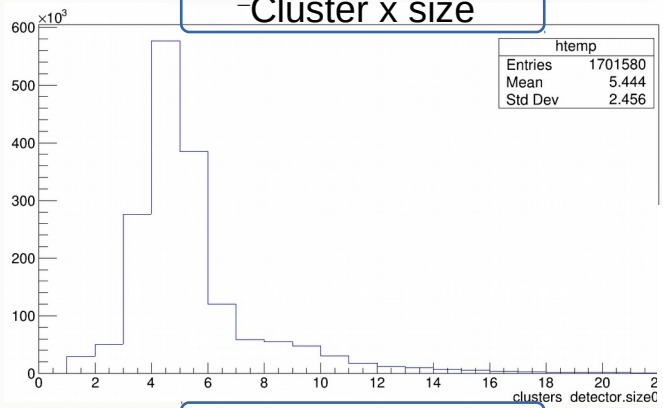
VMM RECO

AMBER Pilot Run: Reconstructed data

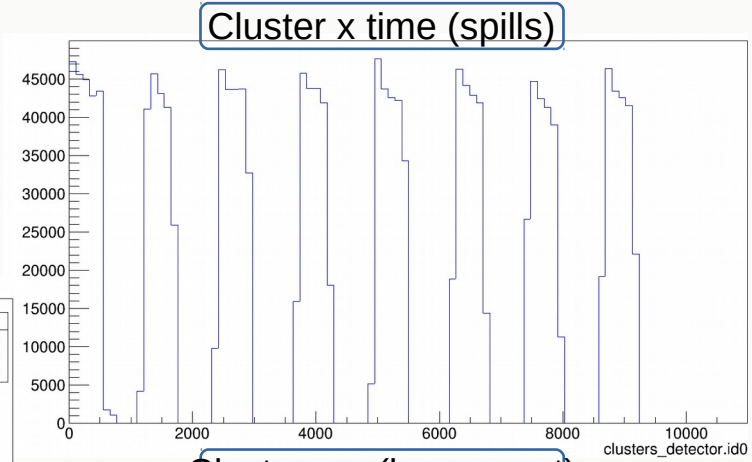
Cluster x position



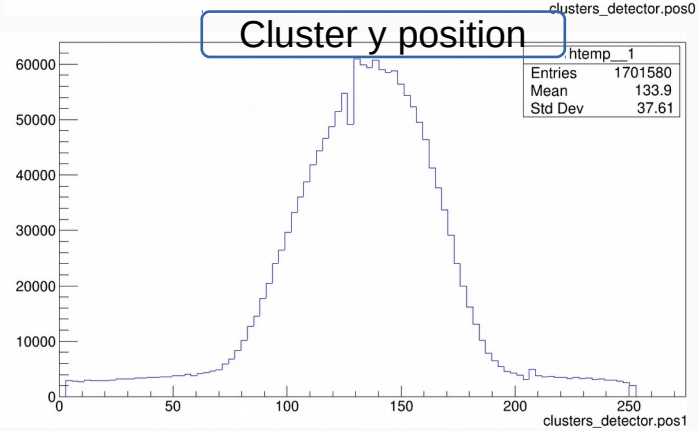
Cluster x size



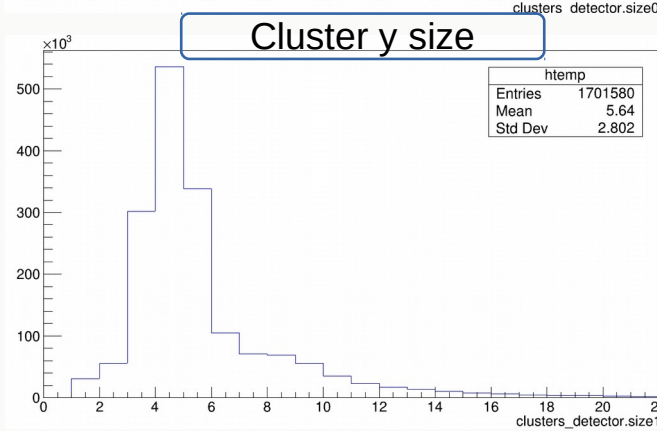
Cluster x time (spills)



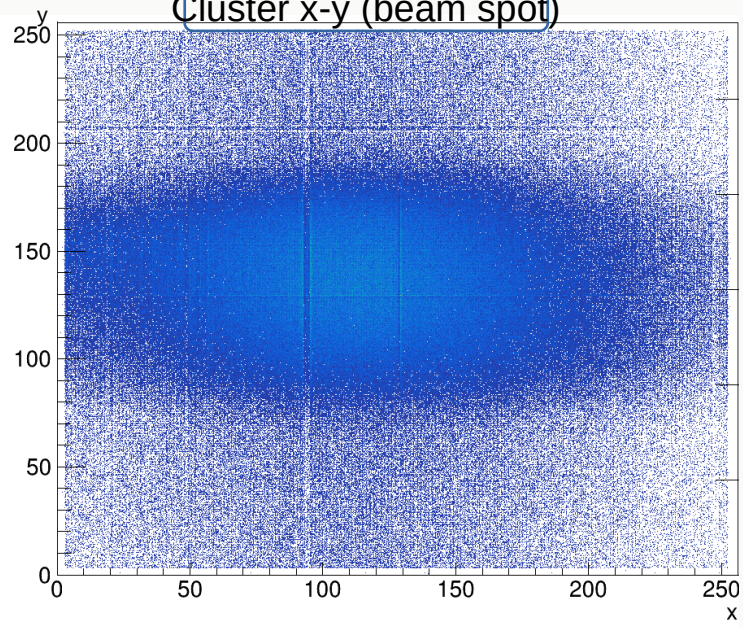
Cluster y position



Cluster y size



Cluster x-y (beam spot)



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CONCLUSION

Summary

- AMBER: New experiment at CERN
- Upgrade of existing COMPASS GEMs required
  - New, self-triggered and streaming-capable frontend chip
  - TIGER and VMM under evaluation
- VMM applied in laboratory and test beam with SRS readout

Outlook

- Get to know the new GEM detectors in COMPASS → build more
- Support Torino colleagues with TIGER tests on GEM detector
- A lot of VMM data to analyse (Cosmics, AMBER Pilot Run) → VMM S/N, rate, thl...
- Prepare decision on AMBER GEM detector frontend chip

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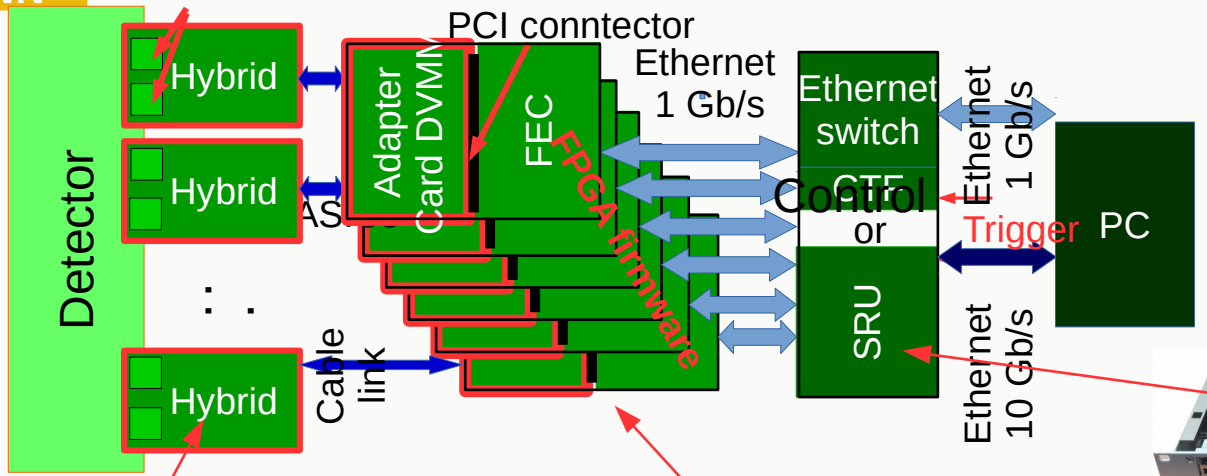
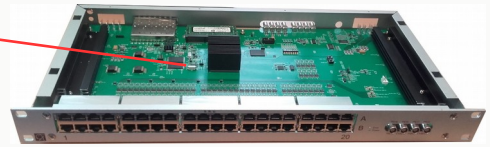
Merci de votre attention!

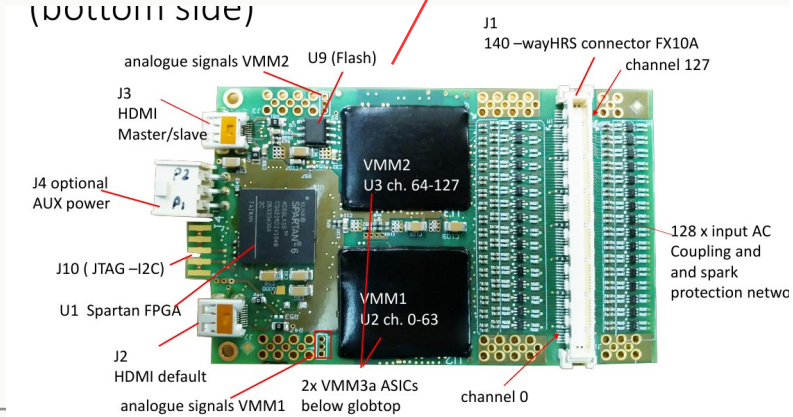
Merci aussi de l'invitation et la possibilité de retourner à Saclay après 12 ans

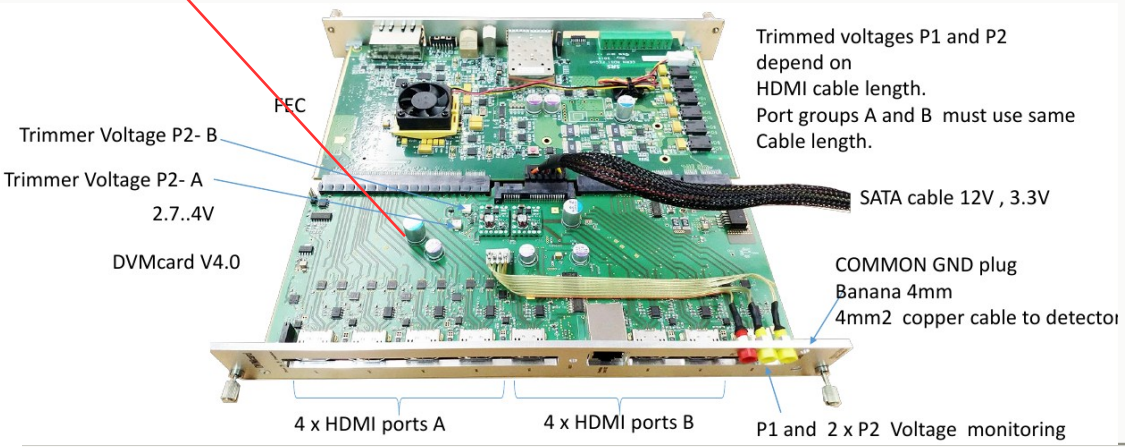
BACKUP: SRS



Images from: H. Müller New SRS hardware, Presentation given at the RD51 Collaboration meeting 2019, CERN





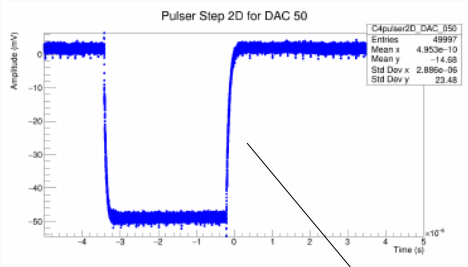


VMM HYBRID ENC

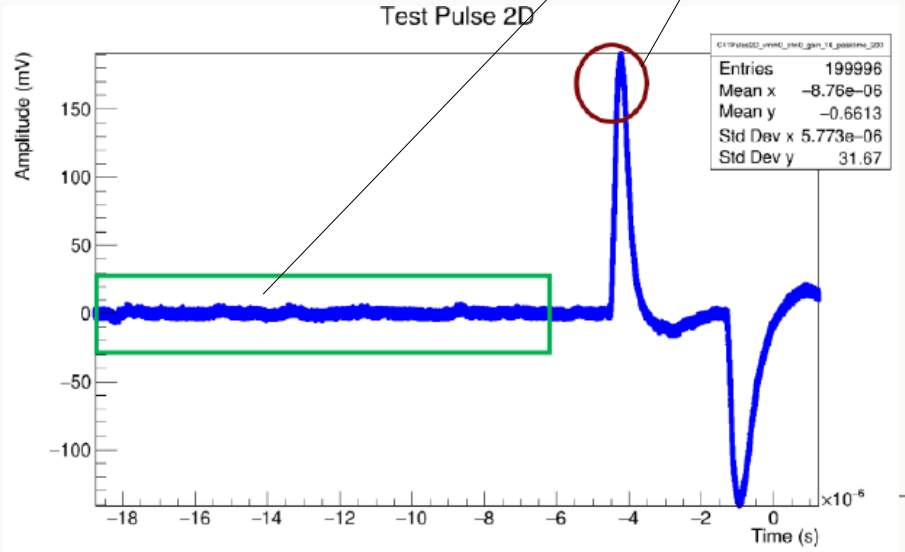
Material and results by Emorfili Terzimpasoglou, Master Student @HISKP U Bonn (2021)

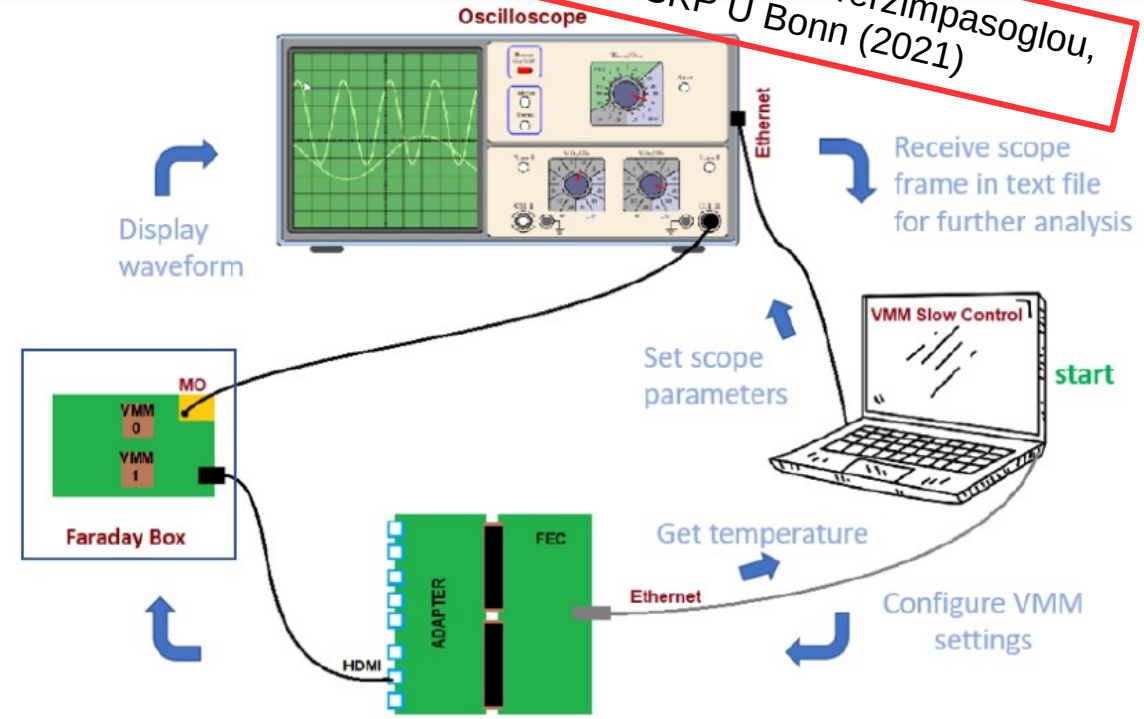
$$ENC[e^-] = \frac{\Delta Q_{in}}{e} \cdot \frac{U_{RMS}}{U_{pulse}}$$

$$\Delta Q_{in} = \Delta U \cdot C_s$$



$$ENC[e^-] = (1.8645 \times 10^6) \frac{U_{RMS}}{U_{pulse}} \cdot \Delta U$$





[8] E. Emorfili Terzimpasoglou, et al. "Investigations on ASIC for Triple-GEM Detectors" Master Thesis Uni Bonn (2021)

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BACKUP: ENC MEASUREMENT