Gaseous detectors

Katerina Kuznetsova

measurements

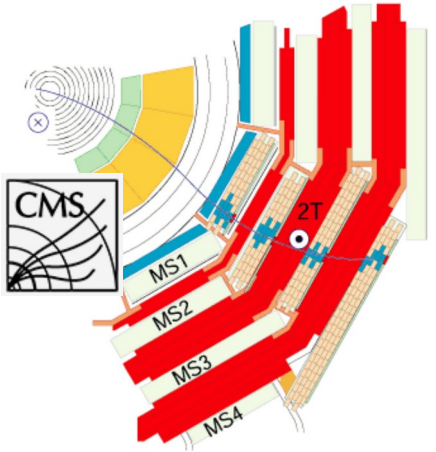
- charged particles; neutral – if conversion is possible
- simple registration / event time measurement (trigger) / coordinate (momentum) measurements / energy measurement

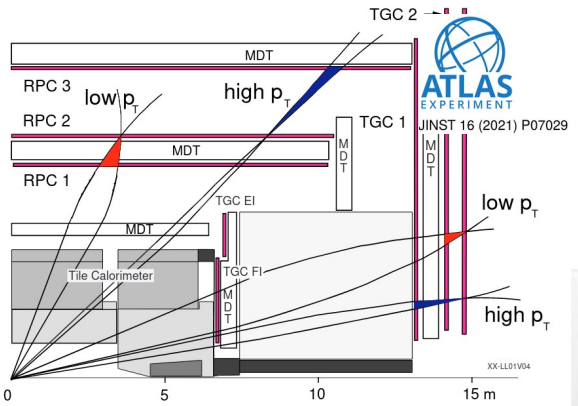
application

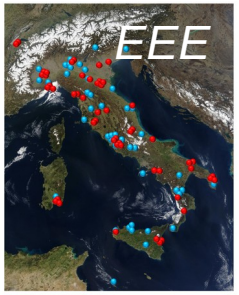
- counters
- coordinate measurements

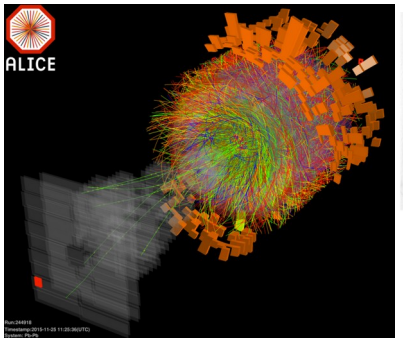
  inner tracker, muon detectors
- trigger
- Particle Identification (PID)
- Imaging

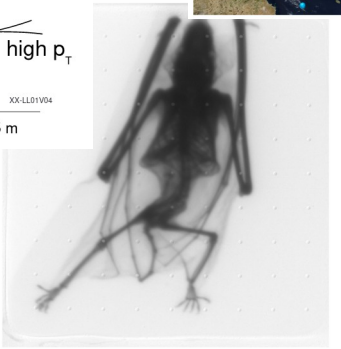
  can be of precise spatial resolution and/or significantly large area











X-ray radiography
(Glass Micromegas)

F. Brunbauer et al., Radiation imaging with glass Micromegas, https://doi.org/10.1016/j.nima.2019.163320

the simplest detector :)

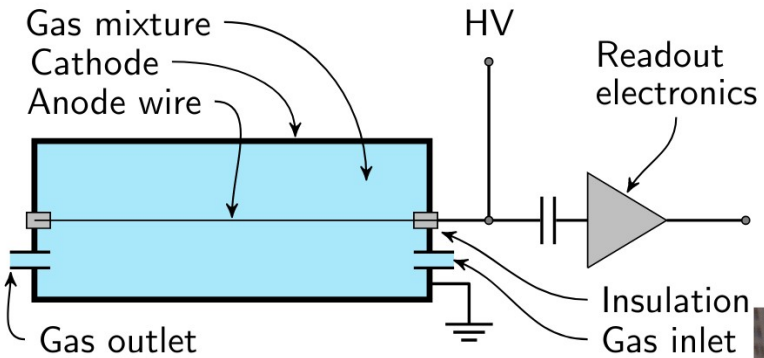
arXiv > physics > arXiv:1509.02379

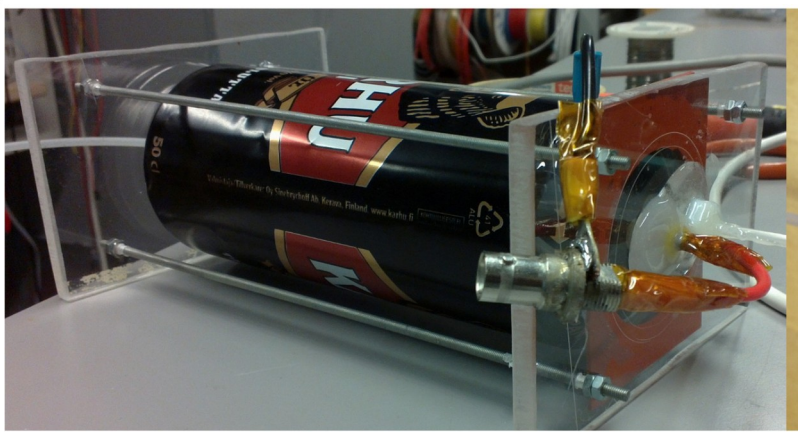
Physics > Physics Education

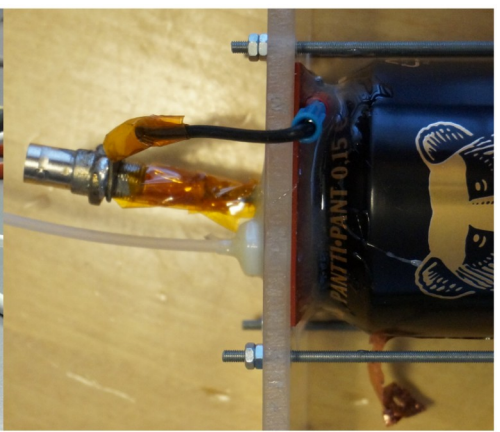
[Submitted on 8 Sep 2015]

A gaseous proportional counter built from a conventional aluminium beverage can

Alexander Winkler, Aneliya Karadzhinova, Timo Hildén, Francisco Garcia, Giacomo Fedi, Francesco Devoto, Erik J. Brücken

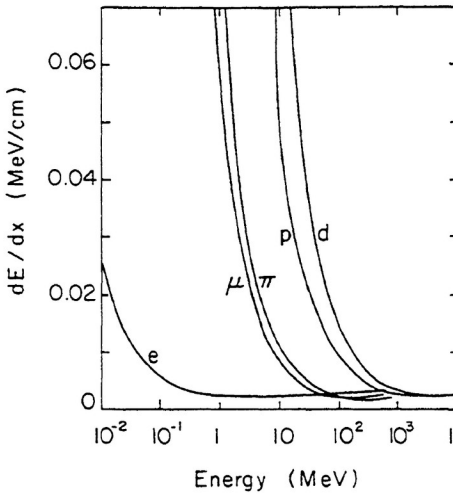




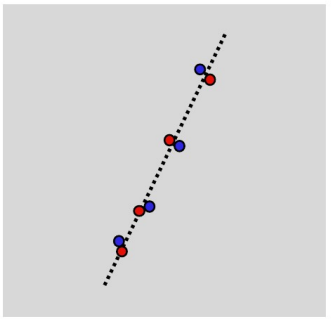


operation principle – primary ionization

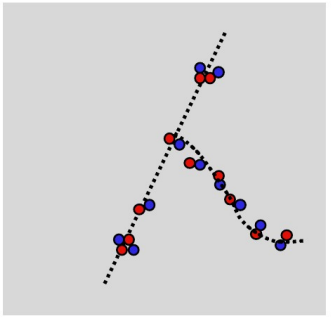
- charged particles – primary ionization



PRIMARY IONIZATION:



TOTAL IONIZATION:

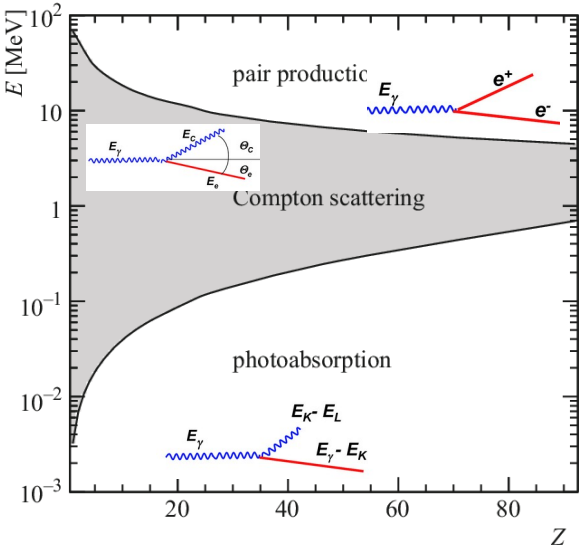


Fabio Sauli EDIT 2011

Gas	Density, mg cm^{-3}	E_x eV	E_I eV	W_I eV	$dE/dx\|_{\min}$ keV cm^{-1}	N_P cm^{-1}	N_T cm^{-1}
Ne	0.839	16.7	21.6	30	1.45	13	50
Ar	1.66	11.6	15.7	25	2.53	25	106
Xe	5.495	8.4	12.1	22	6.87	41	312
CH_4	0.667	8.8	12.6	30	1.61	37	54
C_2H_6	1.26	8.2	11.5	26	2.91	48	112
iC_4H_{10}	2.49	6.5	10.6	26	5.67	90	220
CO_2	1.84	7.0	13.8	34	3.35	35	100
CF_4	3.78	10.0	16.0	54	6.38	63	120

operation principle – primary ionization

gamma

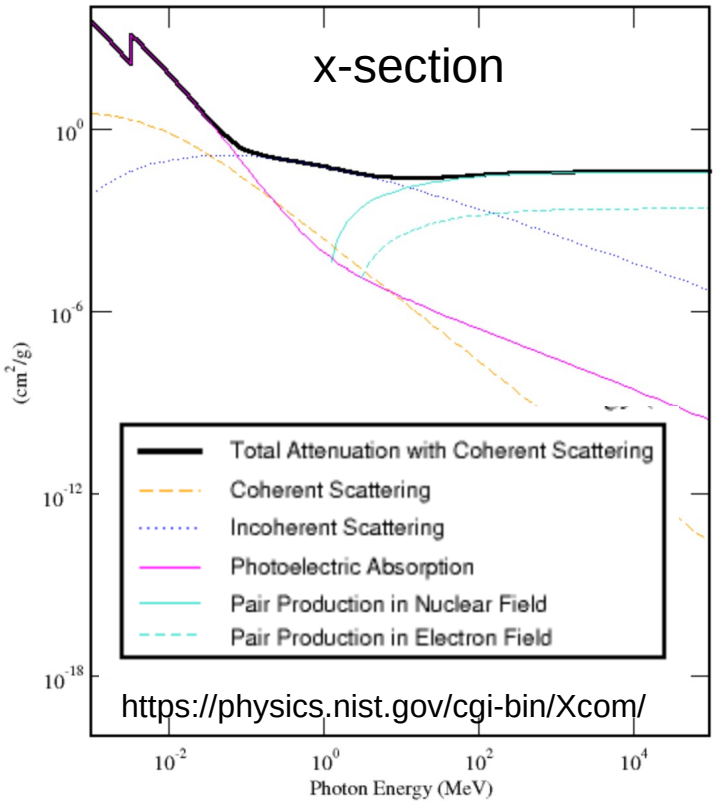


The Interaction of Radiation with Matter

September 2020
DOI:10.1007/978-3-030-35318-6_2
License · CC BY 4.0
In book: Particle Physics Reference Library, Volume 2: Detectors for Particles and Radiation (pp.5-44)

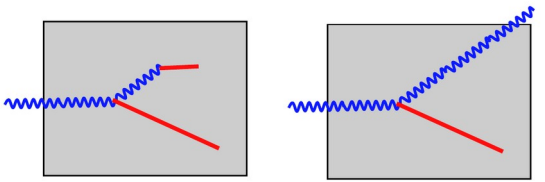
Authors:
Hans Bichsel
Heinrich Schindler

Argon

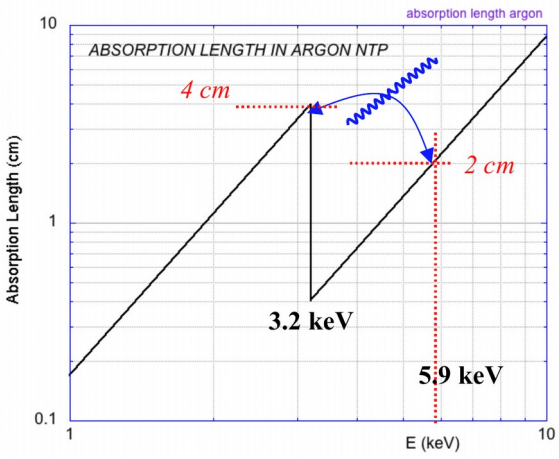


https://physics.nist.gov/cgi-bin/Xcom/

Photo-absorption



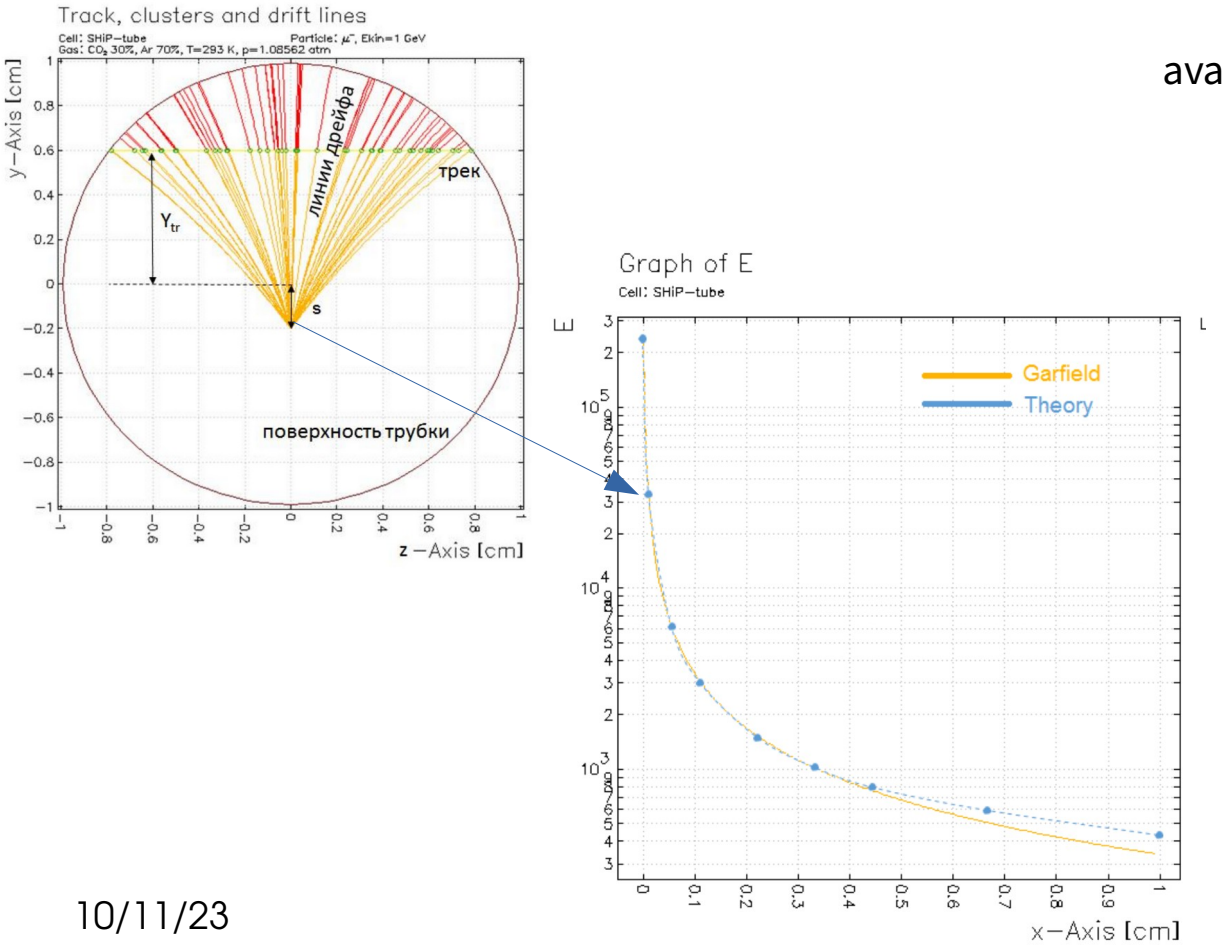
^{55}Fe 5.9 keV:



Fabio Sauli EDIT 2011

operation principle – amplification

- Total ionization O(100e-)
- Too small charge … but O(10) um anode wire with voltage of O(1000) V



avalanche amplification

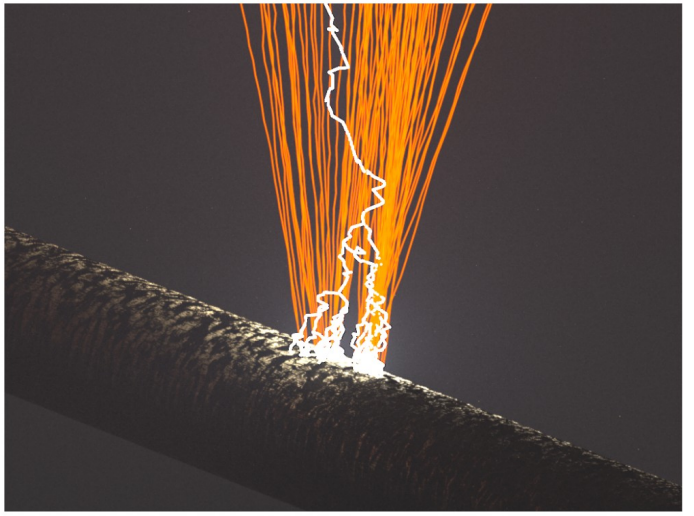


FIG. 2. Simulation of an avalanche caused by a single ionizing electron (white) in a proportional counter. The positive ions (orange) and part of the anode wire are shown as well.

operation principle – gas gain

$$A = n/n_0 = \exp \int \alpha(s)\, \mathrm{d}s = \exp \int \alpha(E)/\left(\mathrm{d}E/\mathrm{d}s\right) \mathrm{d}E,$$

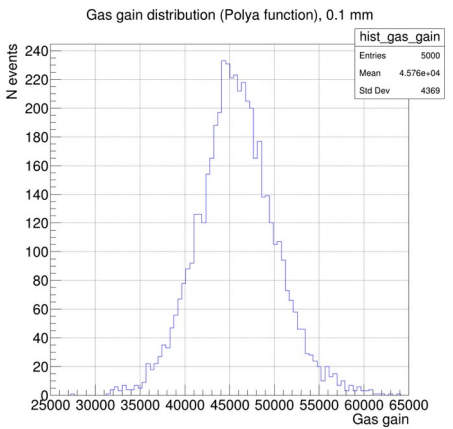
- Often $\alpha \rightarrow \alpha$-η; also Penning effect
- Proportional mode – 10e4-10e7: <A> = const
- A fluctuates of course :)
- A depends on

  - gas composition

  - voltage

  - pressure and temperature

Diethorn approximation: dG/G = a dT/T – b dP/P



Sauli, F.
Principles of Operation of Multiwire Proportional and Drift Chambers
1977-05

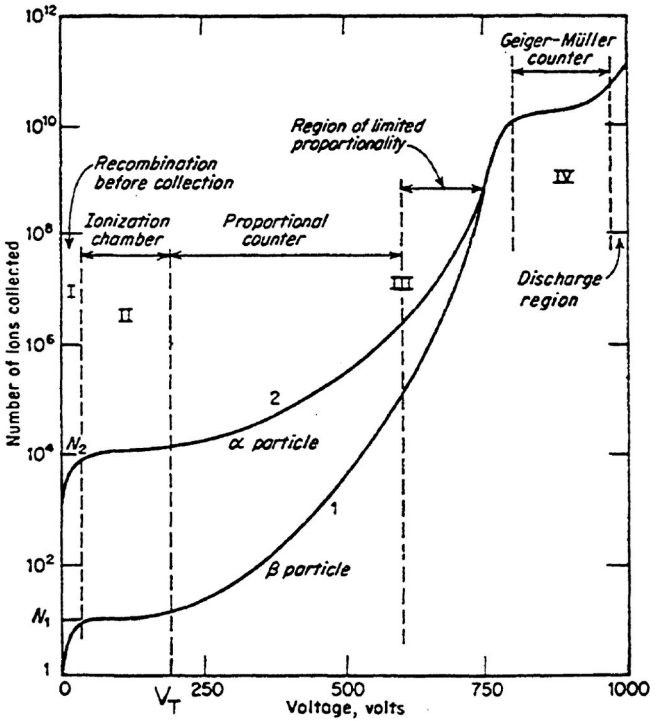
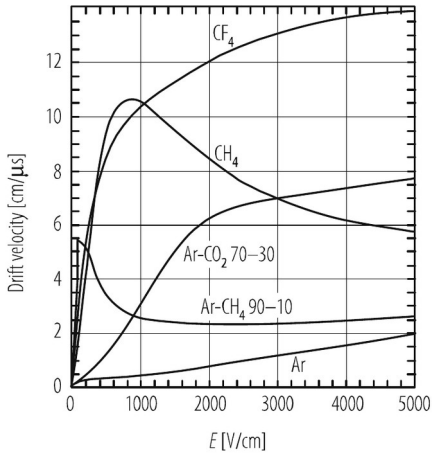
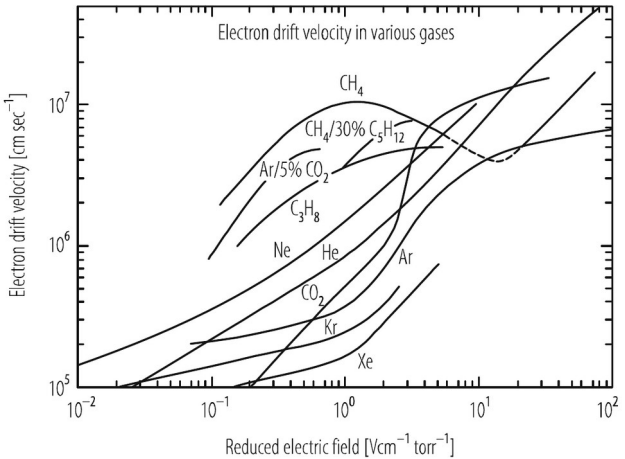


Fig. 50 Gain-voltage characteristics for a proportional counter, showing the different regions of operation (from W. Price, see bibliography for Sections 2 and 3).

operation principle – drift time

Drift velocity - electrons

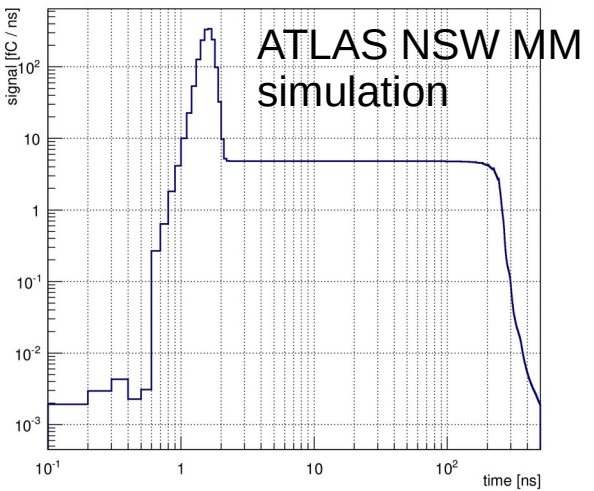




Hilke, H. J. / Riegler, W.
Gaseous Detectors
2020
Particle Physics Reference Library

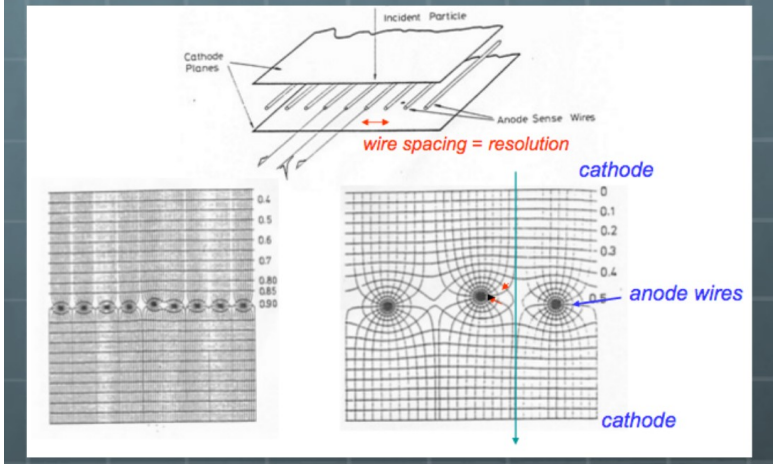
Drift velocity – ions significantly slower, but comparable charge distributed over long time – negligible?..

Of course also – diffusion..



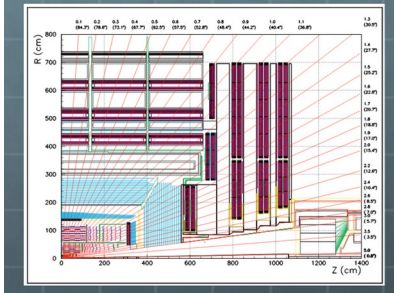
Wired detectors

MWPC



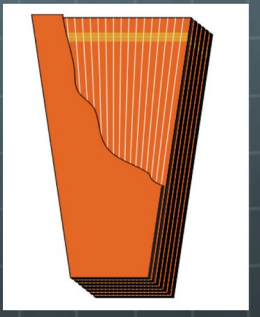
Georges Charpak
Nobel Prize 1992
Invention of the
Multi-wire Proportional Chamber (MWPC)

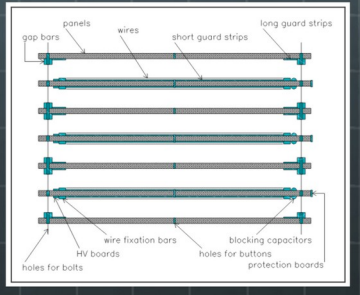
Example: CMS Cathode Strip Chambers

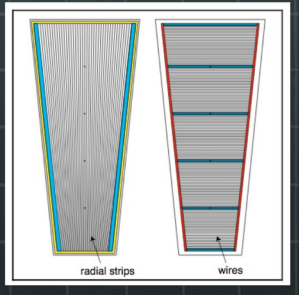


From practical point of view and based on MC simulation the decision was made:

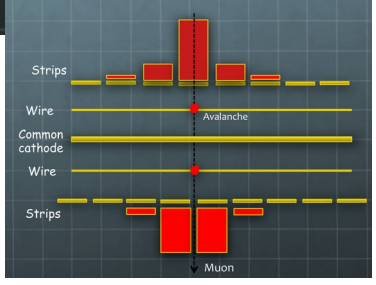
1. There would be 3 CSC rings in the station 1, 2 rings in the stations 2-4.
2. CSC would be trapezoid in shape with 6 sensitive gas gaps each.
3. CSC would be made from honeycomb panels.
4. Strips would be cut radially.
5. Wires would be stretched across strips and joint in wire groups.
6. To reduce readout efficiency losses in case a wire braked wires would be arranged in isolated HV segments.





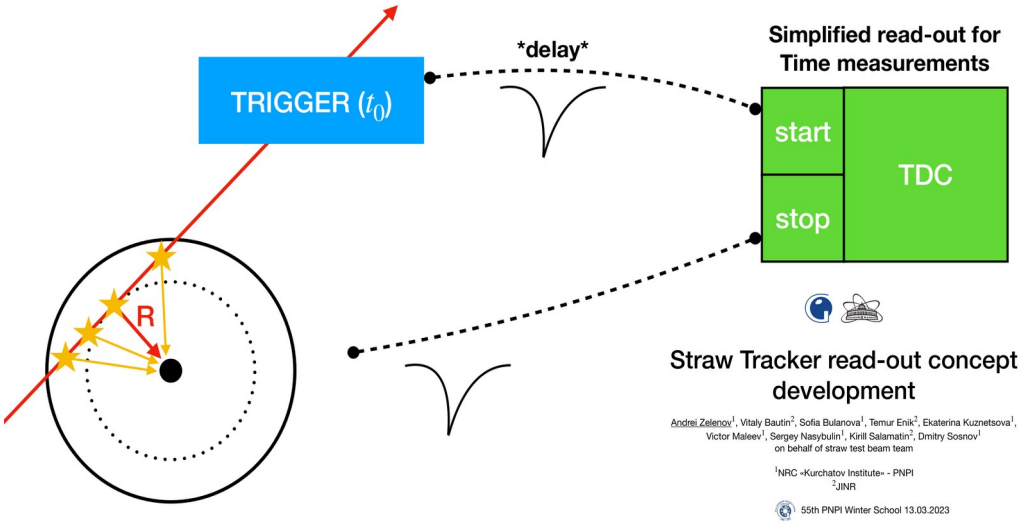


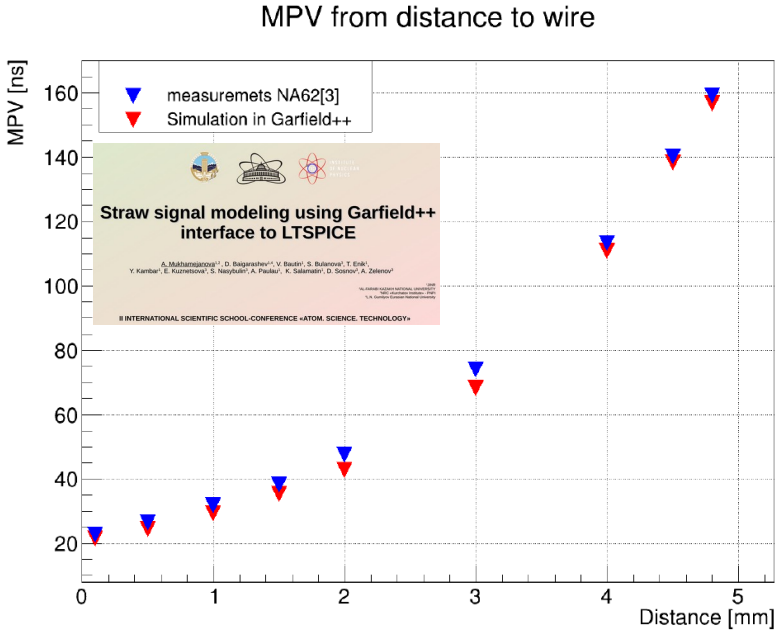
M. Ignatenko(UCLA)
CSC-101
CERN
May 30, 2016



Wired detectors

Straw trackers (see talk of Temur Enik on Friday)

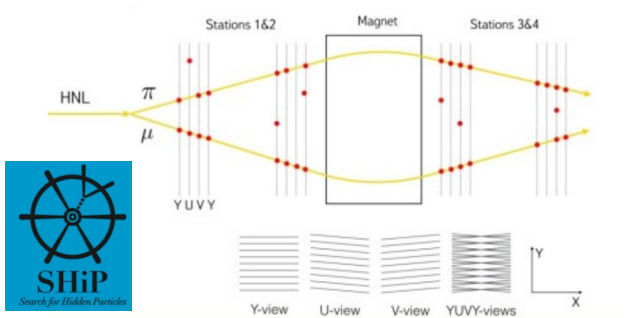




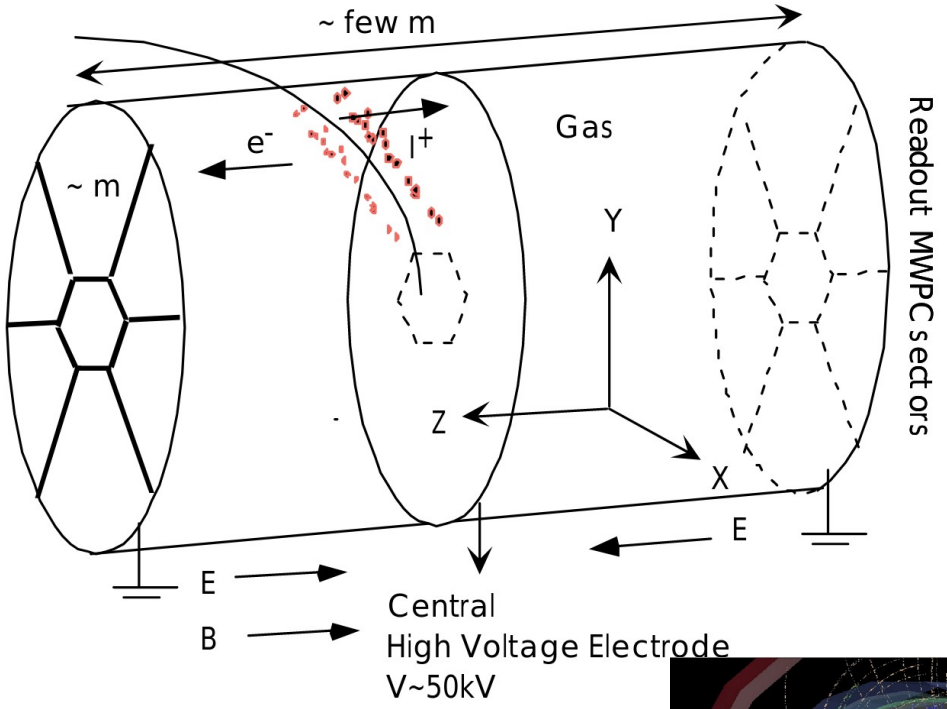
Significantly lower material budged

Examples: ATLAS TRT, NA62, NA64

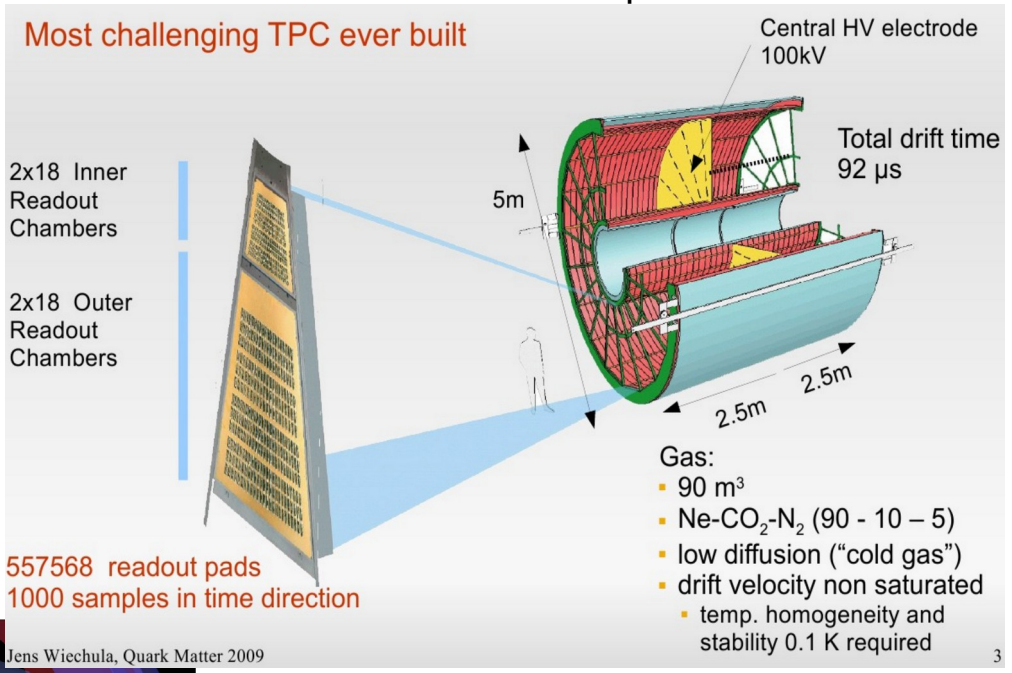
… and many future projects



Time Projection Chamber

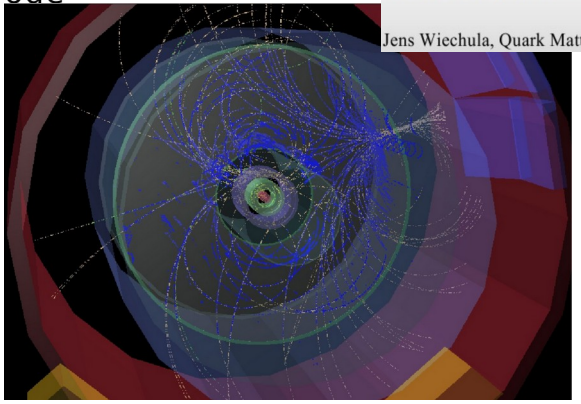


Example: ALICE TPC

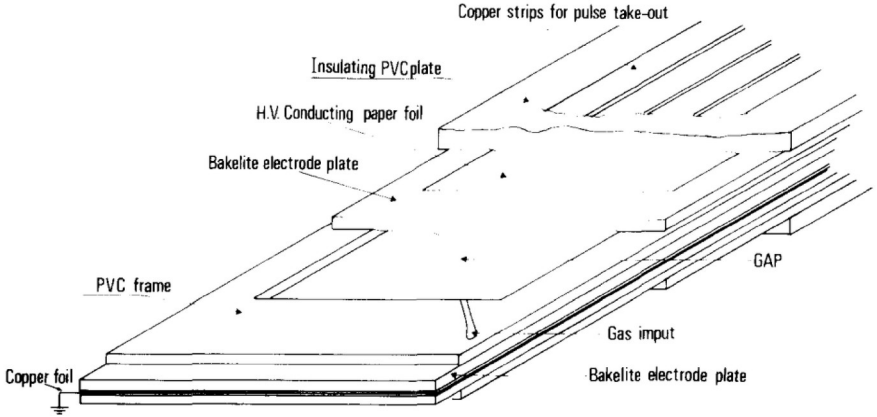


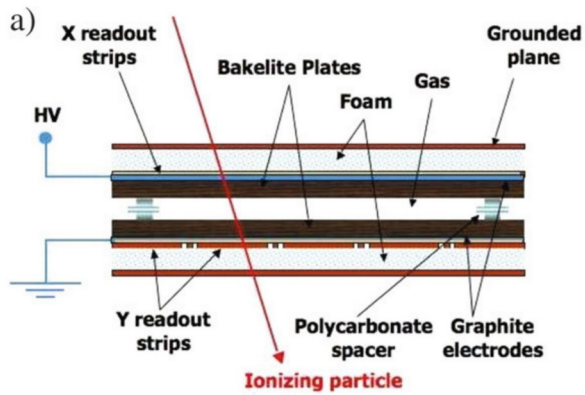
MULTIWIRE GASEOUS DETECTORS:
Basics and State-of-the-art [1]

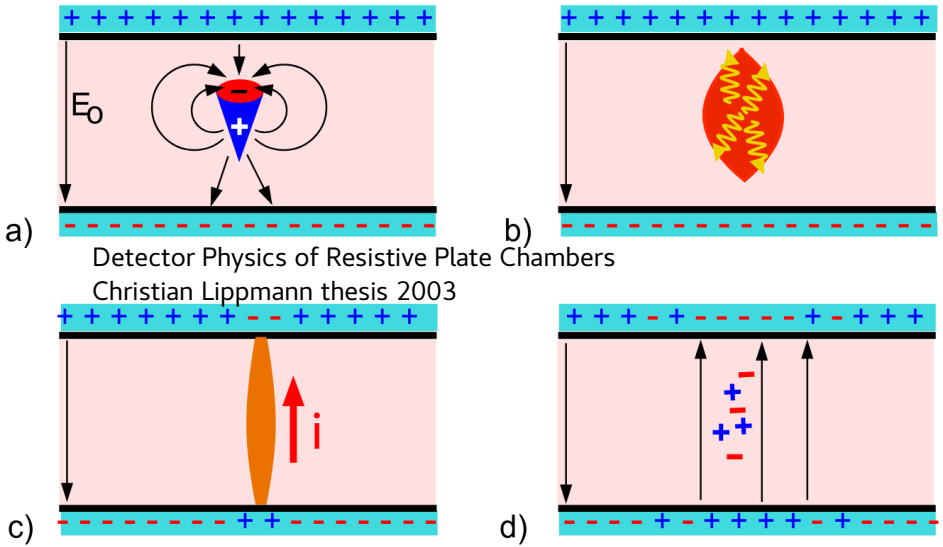
Archana SHARMA[2]



Resistive Plate Chambers







Detector Physics of Resistive Plate Chambers
Christian Lippmann thesis 2003

Examples:

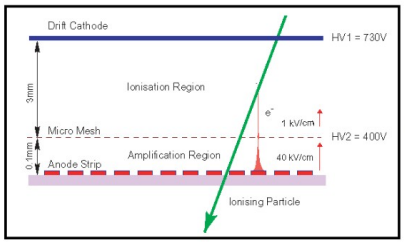
RPCs at the LHC experiments

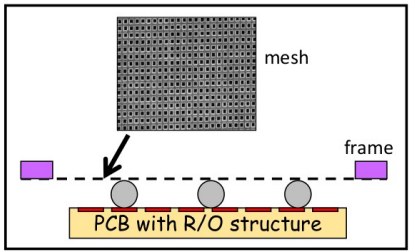
The EEE Project: a sparse array of telescop
the measurement of cosmic ray muons

To cite this article: P. La Rocca *et al* 2016 *JINST* **11** C12056

MicroPattern Gas Detectors

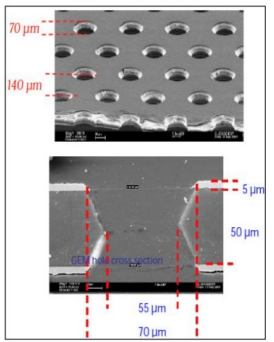
1997→Micromegas (Ioannis Giomataris)

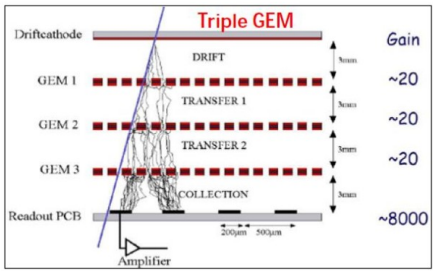




-Electroformed meshes, mechanically fragile.
-Spacers made with fishing wires.
-Delicate artisanal production.
-Special anode strip connection to FE to minimize sparks damages.
-The use of this structure stayed quite confidential till 2007 due to production difficulties.

1998→GEM foil and then triple GEM detector (Fabio Sauli)





Spark problem solved:
→triple GEM structure

Aging problem solved:
→no exponential A-field
→Specific gases
→Specific materials

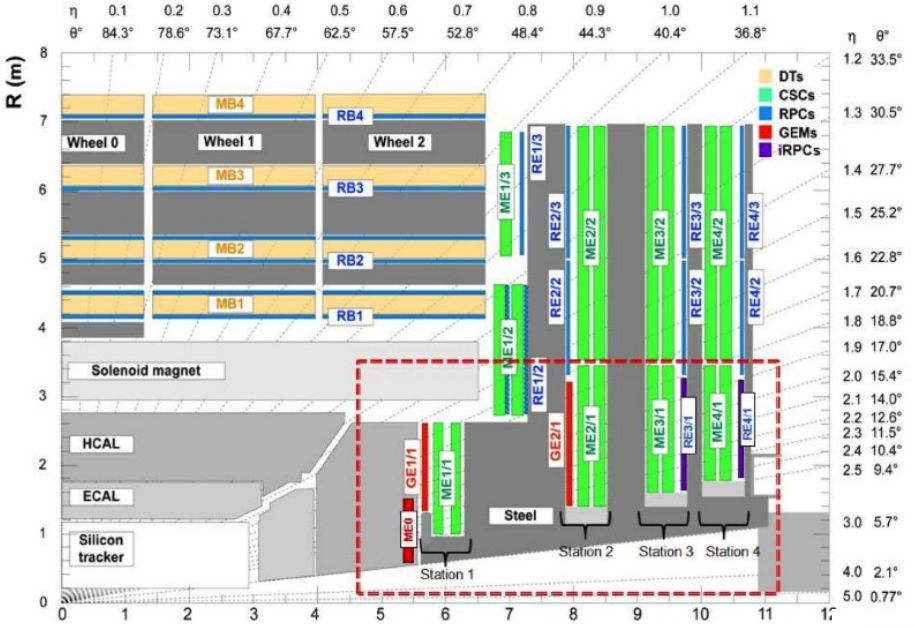
The amplification gaps are not affected by the detector size.

A GEM is only made with Photolithographic processes. Industrial by nature.

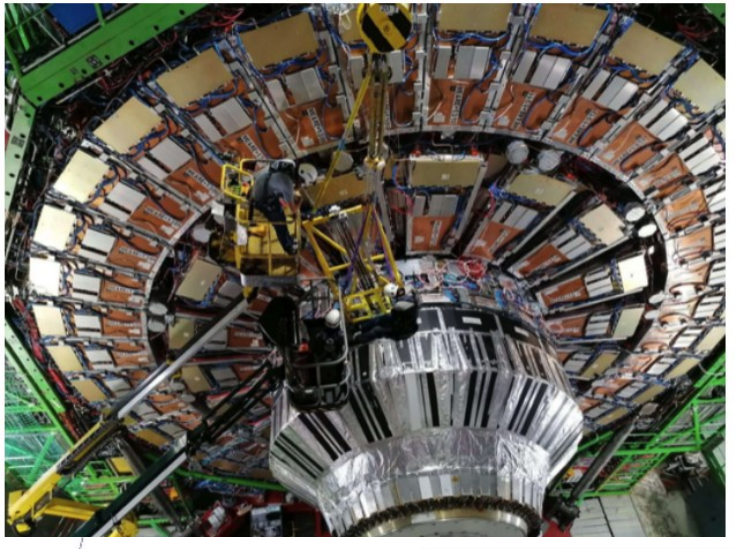
The technology grow was fast.

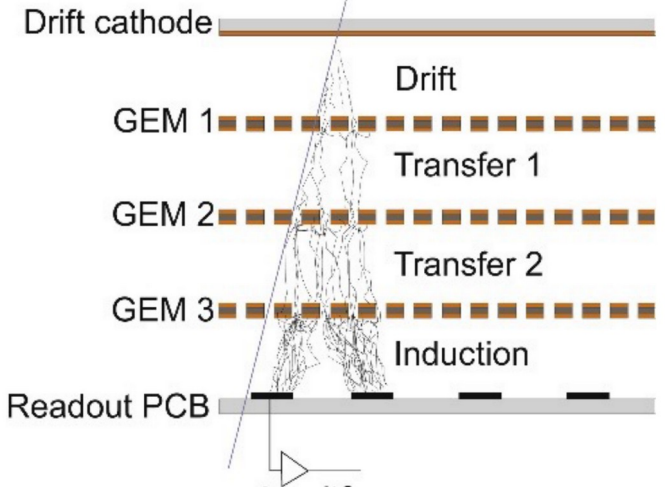
[MicroPattern Gaseous Detectors by Rui de Oliveira (CERN) @TIPP2023]

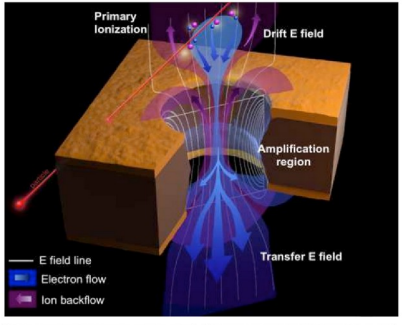
MPGD – GEMs @ CMS

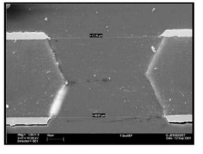


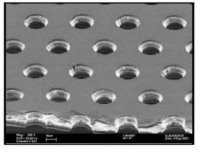
GE1/1 installed and operational from 2(







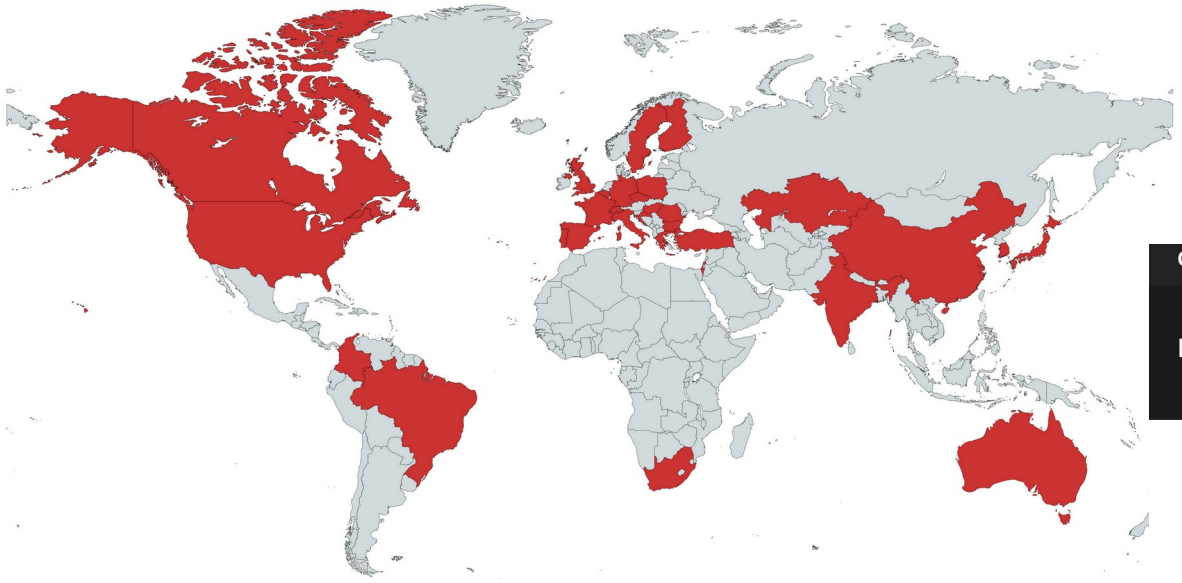




Technology R&D - DRD1

Starting in 2024

https://drd1.web.cern.ch/



At the moment: 138 institutes

…

77. Institute of Nuclear Physics (INP-Almaty),Kazakhstan

…

CERN Accelerating science

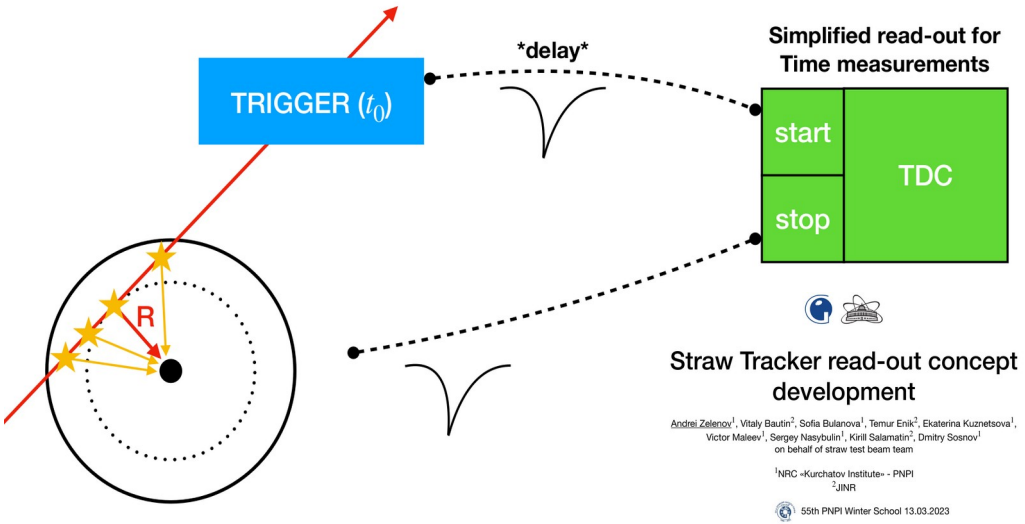
DRD1

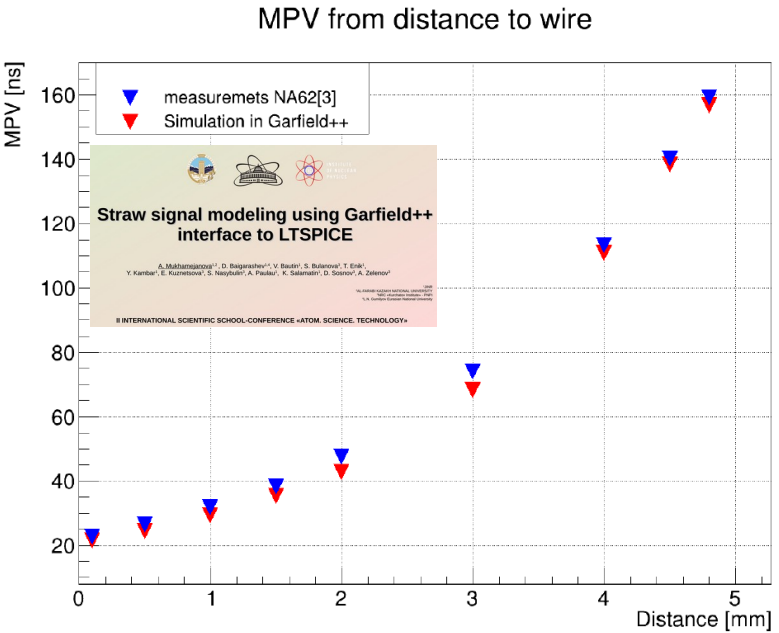
Working Groups

- WG1: Technological Aspects and Developments of New Detector Structures, Common Characterization and Physics Issues
- WG2: Applications
- WG3: Gas and Materials
- WG4: Modeling and Simulations
- WG5: Electronics for gaseous detectors
- WG6: Production and Technology Transfer
- WG7: Collaboration Laboratories and Facilities
- WG8: Knowledge Transfer, Training, Career Promotion

Wired detectors

Straw trackers (see talk of Temur Enik on Friday)





Significantly lower material budged