668. WE-Heraeus-Seminar on
Baryon Form Factors: Where do we stand?

April 23rd - 27th, 2018 Physikzentrum Bad Honnef, Germany

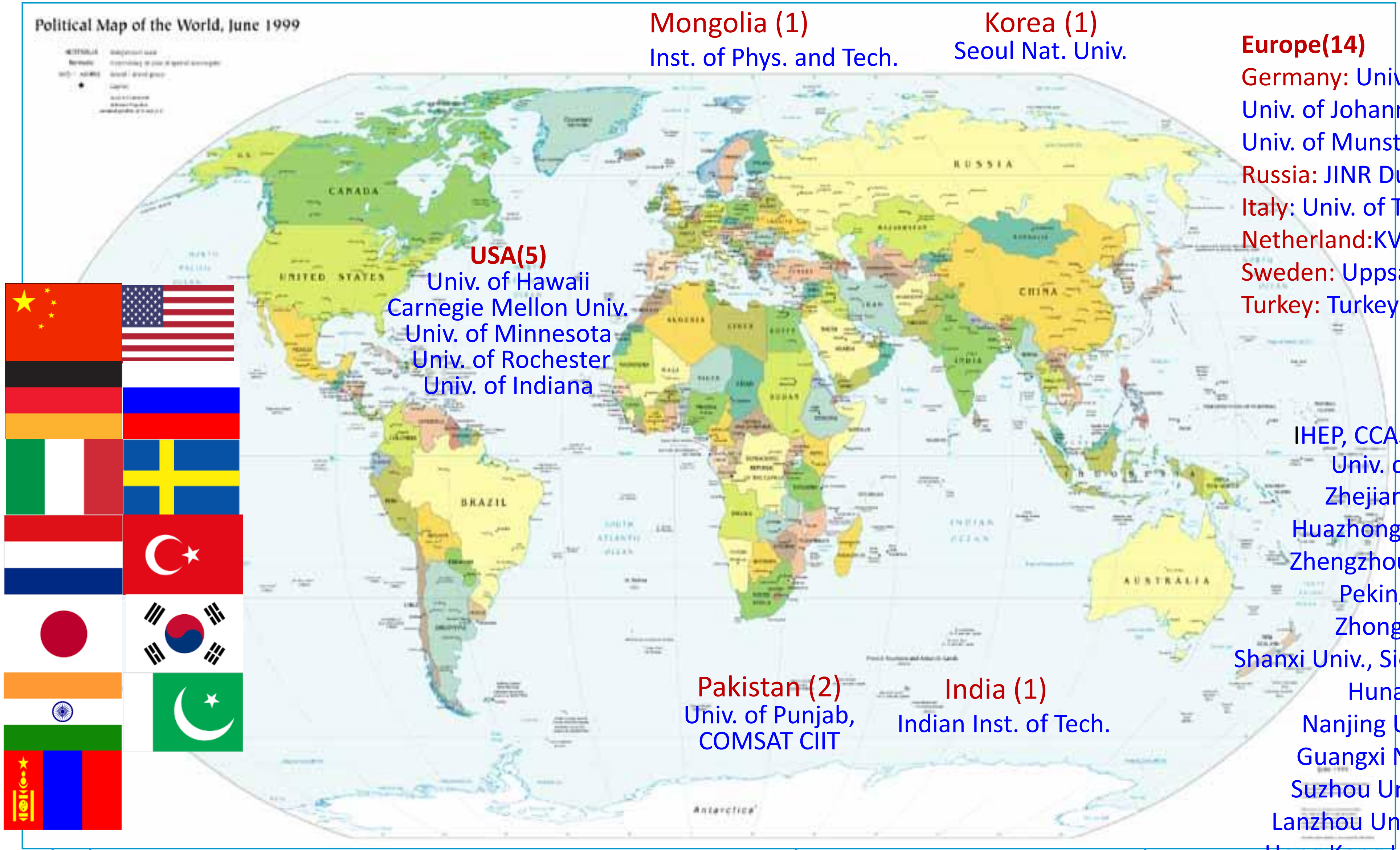
Perspectives in Hadron Physics, an example of international collaboration

M. Maggiora

- BESIII CGEM-IT: on behalf of the BESIIICGEM Group
- I2JL: on behalf of the IHEP-INFN Joint Collaborations

BESIII Collaboration

~450 authors, 58 Institutions, 13 Countries



Mongolia (1)
Inst. of Phys. and Tech.

Korea (1)
Seoul Nat. Univ.

USA(5)
Univ. of Hawaii
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

Europe(14)
Germany: Univ. of Bochum, Univ. of Giessen, GSI
Univ. of Johannes Gutenberg, Helmholtz Ins. In Mainz,
Univ. of Munster
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino, Frascati Lab, Ferrara Univ.
Netherland:KVI/Univ. of Groningen
Sweden: Uppsala Univ.
Turkey: Turkey Accelerator Center

Japan (1)
Tokyo Univ.

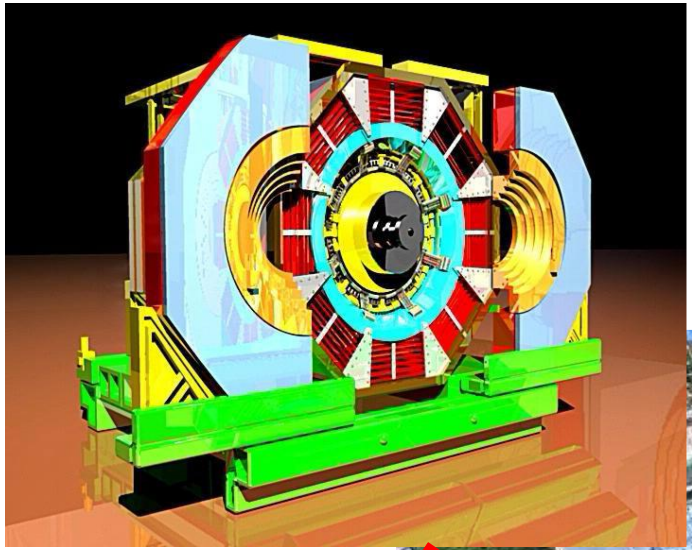
China(32)
IHEP, CCAST, GUCAS, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. ,
Zhongshan Univ.,Nankai Univ.
Shanxi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Hong Kong Univ., Hong Kong Chinese Univ.

Pakistan (2)
Univ. of Punjab,
COMSAT CIIT

India (1)
Indian Inst. of Tech.

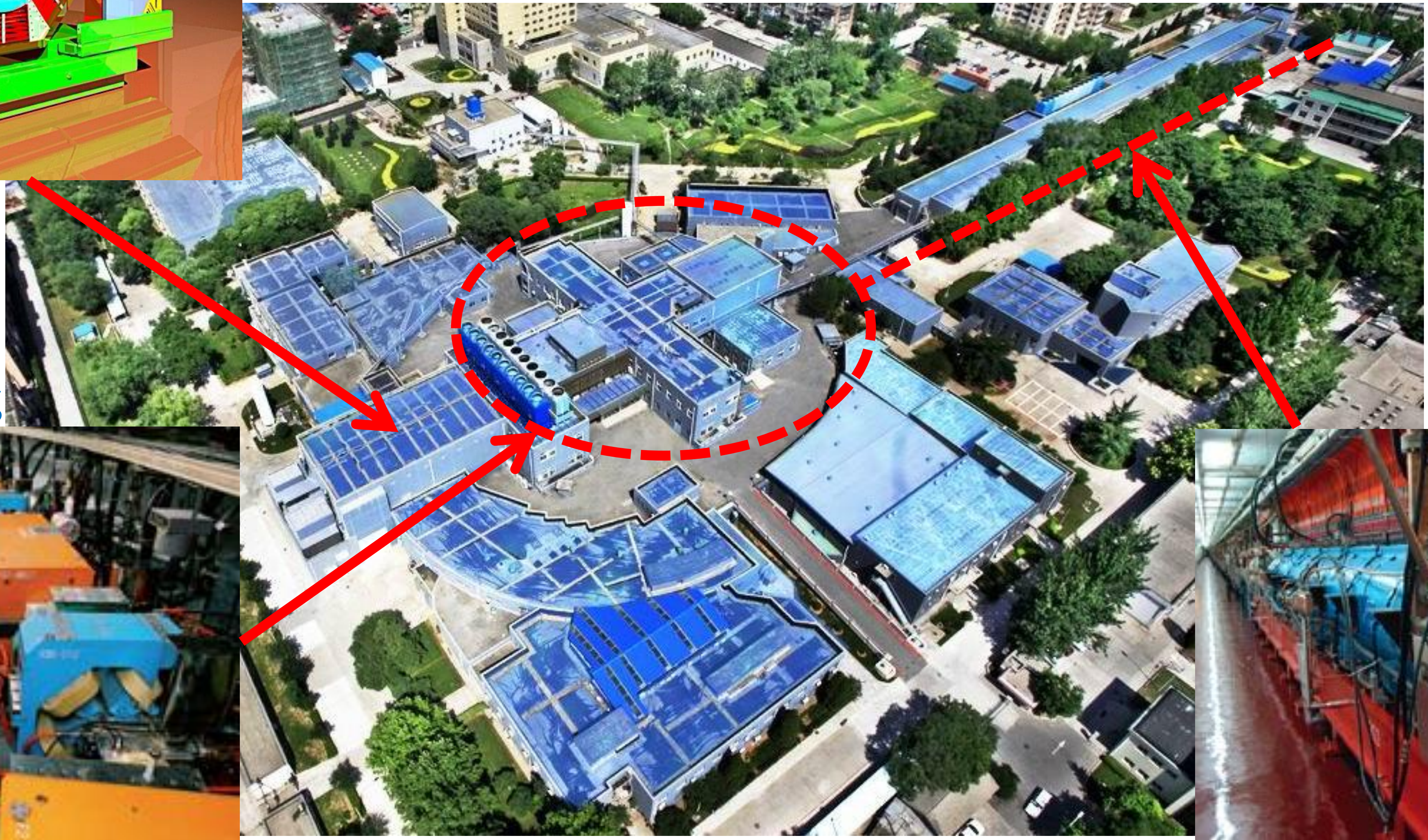
BESIII @ BEPC-II

- Center of mass energy range: 2-4.6 GeV
- achieved design luminosity $L_{design} = 1 \times 10^{33}\ cm^{-2}s^{-1}$



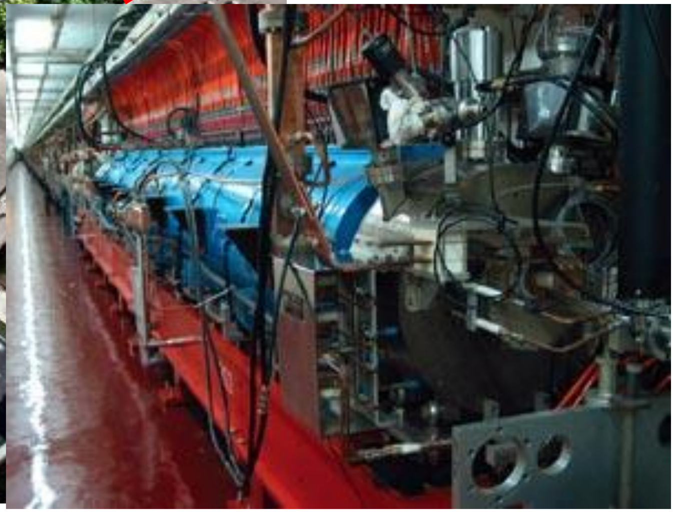
2016/04/05 22:29:47		
Luminosity	10.00	E32/cm^2/s
	e+	e−
Energy [GeV]	1.8831	1.8831
Current [mA]	849.18	852.31
Lifetime [hr]	1.53	2.30
Inj.Rate [mA/min]	0.00	0.00

BESIII experiment



BEPC-II
e^+e^- storage ring

injection LINAC



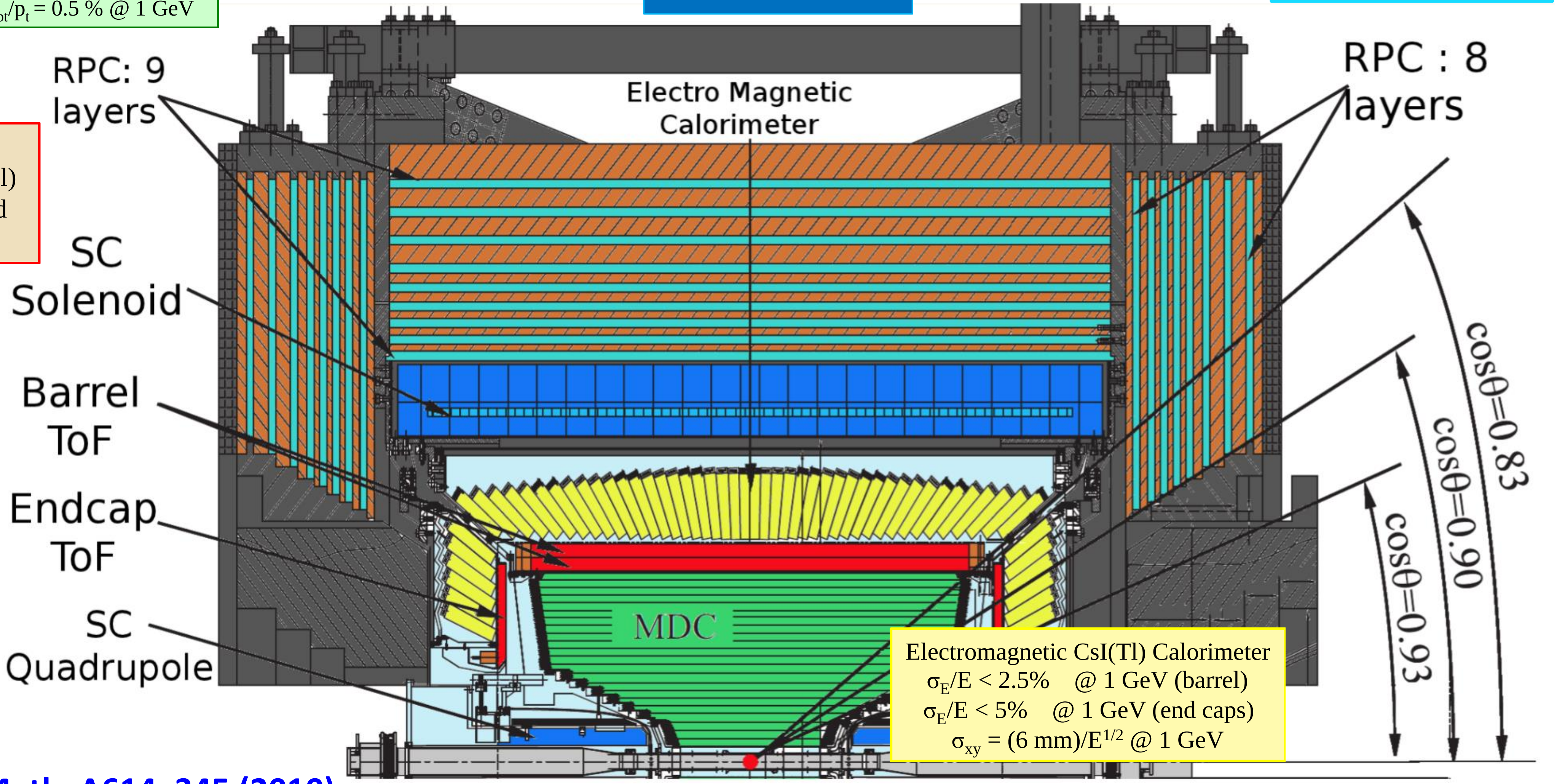
BESIII Spectrometer

1 Tesla
SC solenoid

Drift Chamber
$\sigma_{r\phi}$ = 130 μm (single wire)
σ_{pt}/p_t = 0.5 % @ 1 GeV

RPC Muon Detector
$\Delta\Omega/4\pi$=93%

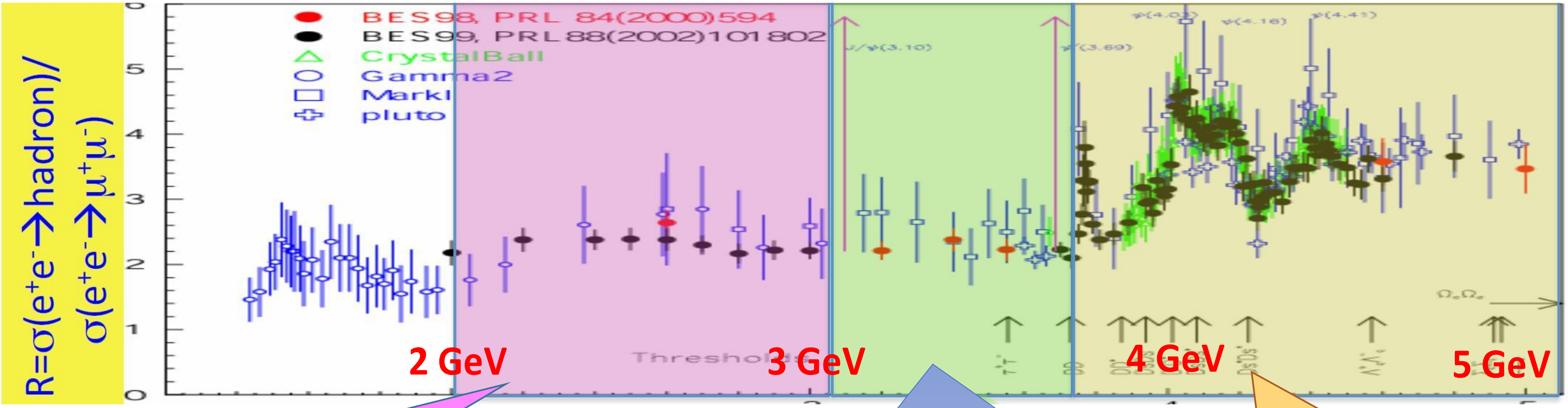
ToF
σ_t = 90 ps (barrel)
σ_t = 120 ps (end caps)



Electromagnetic CsI(Tl) Calorimeter
$\sigma_E/E < 2.5\%$ @ 1 GeV (barrel)
$\sigma_E/E < 5\%$ @ 1 GeV (end caps)
$\sigma_{xy} = (6\ \text{mm})/E^{1/2}$ @ 1 GeV

Nucl. Instr. Meth. A614, 345 (2010)

Physics @ BESIII



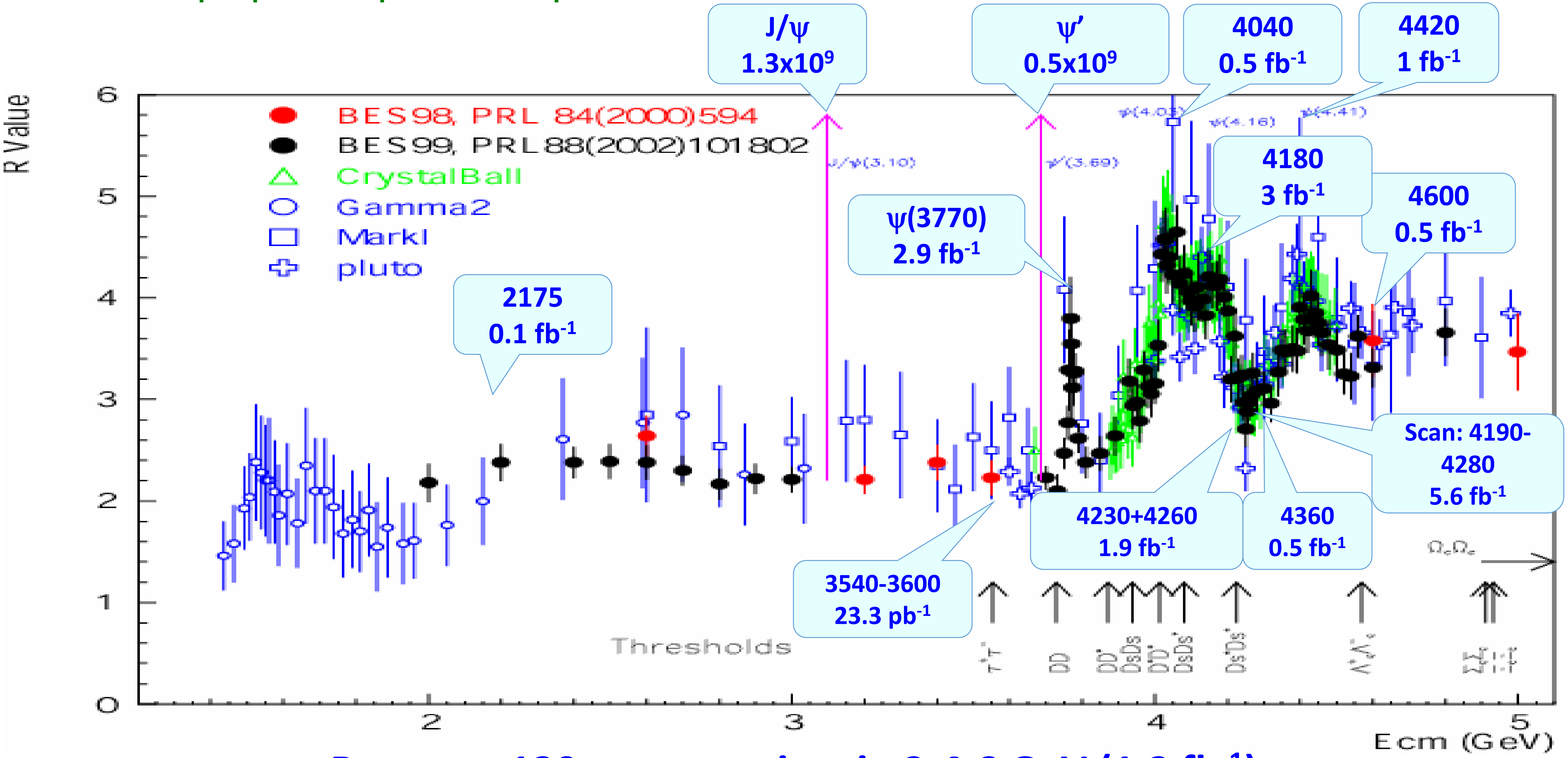
- Hadron form factors
- Y(2175)
- Zs states?
- QCD test

- Light hadron spectroscopy
- Glueballs, hybrids, multi-quark states
- Rare decays
- Tau physics

- XYZ
- D and Ds physics (f_D and f_{Ds}, mixing, CP)
- Charmed baryons

BESIII data samples

World larges data samples directly produced from e^+e^- collision at
J/ψ, $\psi(2S)$, $\psi(3770)$, $\psi(4170)$ $Y(4260)$…



R scan at 130 energy points in 2-4.6 GeV (1.3 fb^{-1})

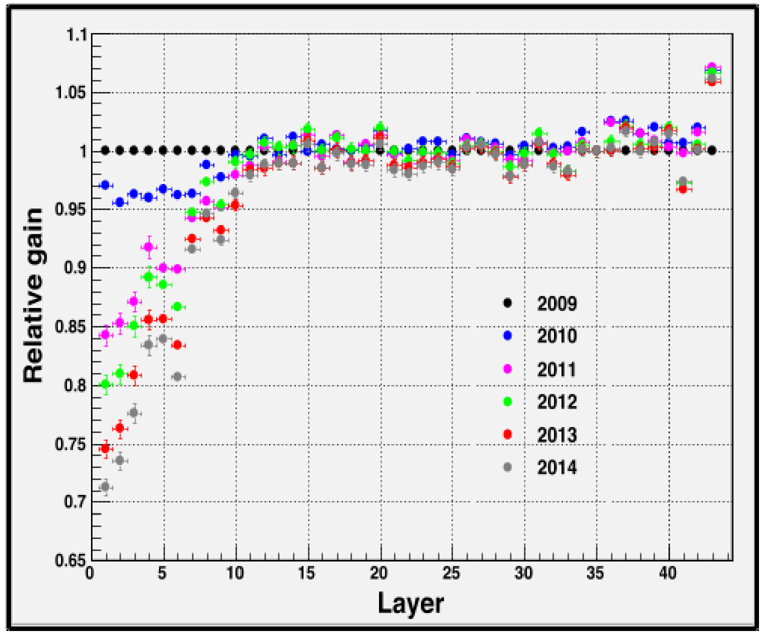
BESIII detector performance

Experiments	**MDC** Spatial resolution	**MDC** dE/dx resolution	**EMC** Energy resolution
CLEOc	110 μm	5%	2.2-2.4 %
Babar	125 μm	7%	2.67 %
Belle	130 μm	5.6%	2.2 %
BESIII	115 μm	<5% (Bhabha)	2.4%

Experiments	**TOF** Time resolution
CDFII	100 ps
Belle	90 ps
BESIII	68 ps (BTOF) 60 ps (ETOF)

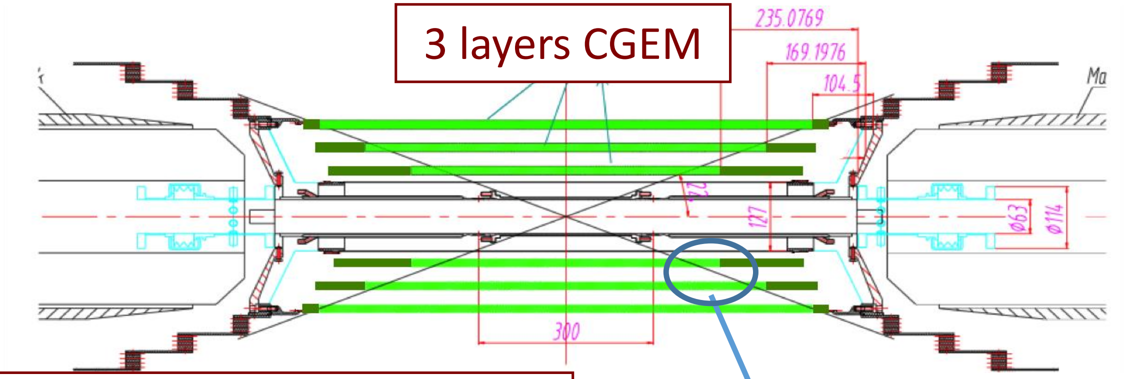
A Cylindrical GEM Inner Tracker (CGEM-IT) for BESIII

Inner Drift Chamber is showing aging effects

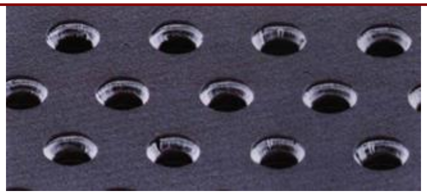


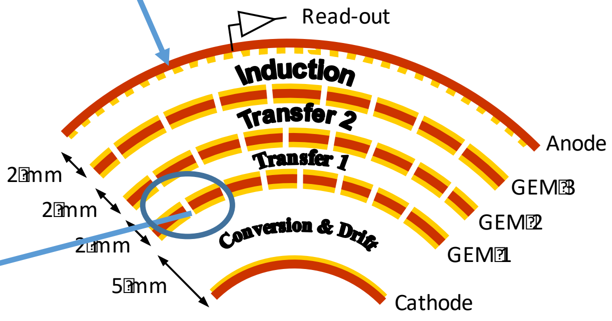
We are building a new Inner Tracker based on three layers of triple cylindrical GEM

3 layers CGEM



each CGEM layer composed by a triple GEM detector with cylindrical shape

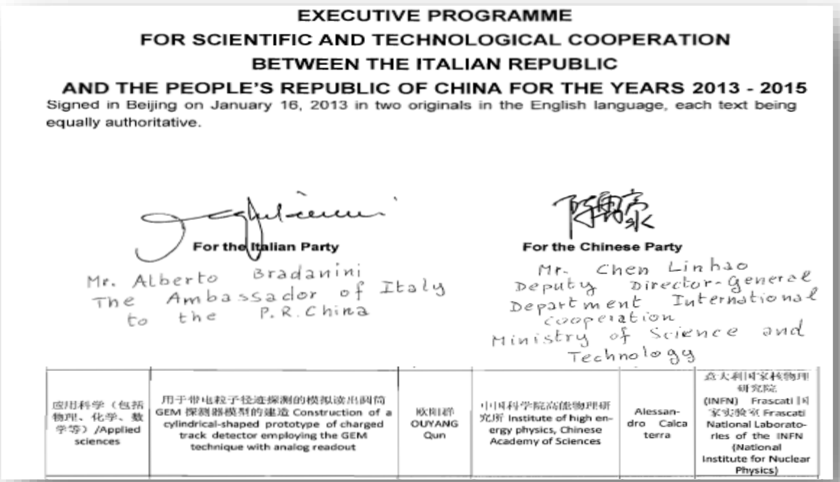




- Low Material budget ≤ 1.5% of X_0 for all layers
- Momentum resolution:: σ_{pt}/P_t =~0.5% @1 GeV
- High Rate capability: ~10^4 Hz/cm^2
- Coverage: 93%
- Spatial resolution s_{rf} 130 μm, s_z <1 mm
- **1 T magnetic field**
- Operation duration at least 5 years
- Radii: inner 78 mm, outer radius: 179 mm

External Funding

- DESIGN, CONSTRUCTION AND TEST OF A CGEM PROTOTYPE FUNDED BY THE FOREIGN AFFAIRS MINISTRY (MAE) AGREEMENT OF SCIENTIFIC COOPERATION FOR AN "INFN-IHEP" JOINT LABORATORY.
- ALMOST AT THE END OF THE PROJECT: READY TO PROCEED WITH THE FINAL ASSEMBLY OF THE FIRST CYLINDRICAL GEM.
- IT ALLOWED TO DEVELOP THE BESIII CGEM BASELINE DESIGN AND TO START BUILDING A GROUP.



EXECUTIVE PROGRAMME
FOR SCIENTIFIC AND TECHNOLOGICAL COOPERATION
BETWEEN THE ITALIAN REPUBLIC
AND THE PEOPLE'S REPUBLIC OF CHINA FOR THE YEARS 2013 - 2015
Signed in Beijing on January 16, 2013 in two originals in the English language, each text being equally authoritative.

For the Italian Party
Mr. Alberto Bradanini
The Ambassador of Italy
to the P.R.China

For the Chinese Party
Mr. Chen Linhao
Deputy Director-General
Department International Cooperation
Ministry of Science and Technology

应用科学（包括物理、化学、数学等）/Applied sciences	用于带电粒子径迹探测的模拟读出圆筒GEM探测器模型的建造 Construction of a cylindrical-shaped prototype of charged track detector employing the GEM technique with analog readout	欧阳群 OUYANG Qun	中国科学院高能物理研究所 Institute of high energy physics, Chinese Academy of Sciences	Alessandro Calcaterra	意大利国家核物理研究院 (INFN) Frascati 国家实验室 Frascati National Laboratories of the INFN (National Institute for Nuclear Physics)

- H2020 BESIIICGEM
- RESEARCH AND INNOVATION STAFF EXCHANGE (RISE) FUNDS SHORT-TERM EXCHANGES COMBINING SCIENTIFIC EXCELLENCE WITH EXPOSURE TO OTHER COUNTRIES.
- BUDGET FROM E.C.: ABOUT 1.5 M€.
- CONSOLIDATION OF THE GROUP ↔ FORMATION OF A CONSORTIUM (ITALY, CHINA, GERMANY, SWEDEN).

Work Package No	Work Package Title	Activity Type (e.g. Research, Training, Management, Communication, Dissemination...)	Number of person-months involved
1	CGEM design	Research, Training	16
2	CGEM construction	Research, Training	62
3	CGEM electronics	Research, Training	74
4	Data simulation and analysis	Research, Training	229
5	Data challenge	Research, Training	2
6	Outreach	Training, Dissemination	0

BESIII CGEM-IT inherits from KLOE-2 with few relevant peculariaties

	KLOE-2	BESIII	action
Number of detector layers	4	3	→ 5 mm drift gap
Drift gap	3 mm	5 mm	also for μTPC
Material budget per layer	0.5% X_0	0.4% X_0	rohacell and anode
Momentum resolution @1 GeV	not used	σ_{pt}/P_t =~0.5%	
Rate capability – radiation hardness	< 10 kHz/cm^2	few 10 kHz/cm^2	
Spatial resolution ϕ	250-350 μm (B=0.5T)	100-150 μm (B=1T)	with μTPC
Spatial resolution Z	~1 mm	<500 μm	with μTPC
Magnetic filed	B = 0.52 T	B = 1 T	→ μTPC
Internal/external diameter	244/440 mm	156/356 mm	higher rate
Readout	digital	charge + time	new ASIC chip

Pecularities of BESIII CGEM-IT

	KLOE-2		action
Number of detector layers	4		5 mm drift gap
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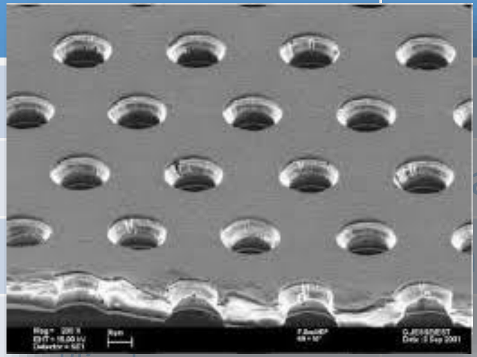
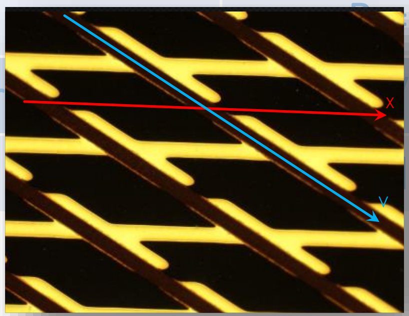
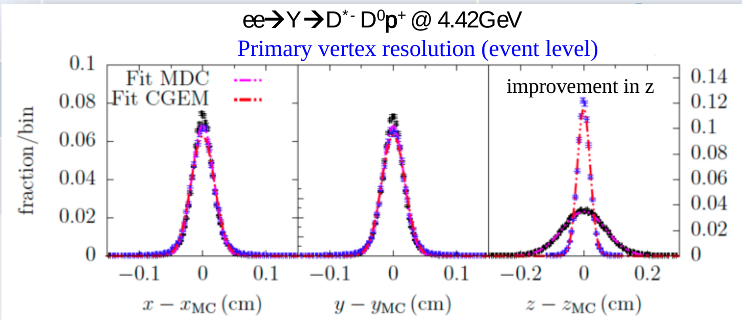
Spatial resolution Z	~1 mm	<500 µm	with µTPC
Magnetic filed	0.52 T		C
Internal/external diameter	440 mm		ate
Readout	igital		chip







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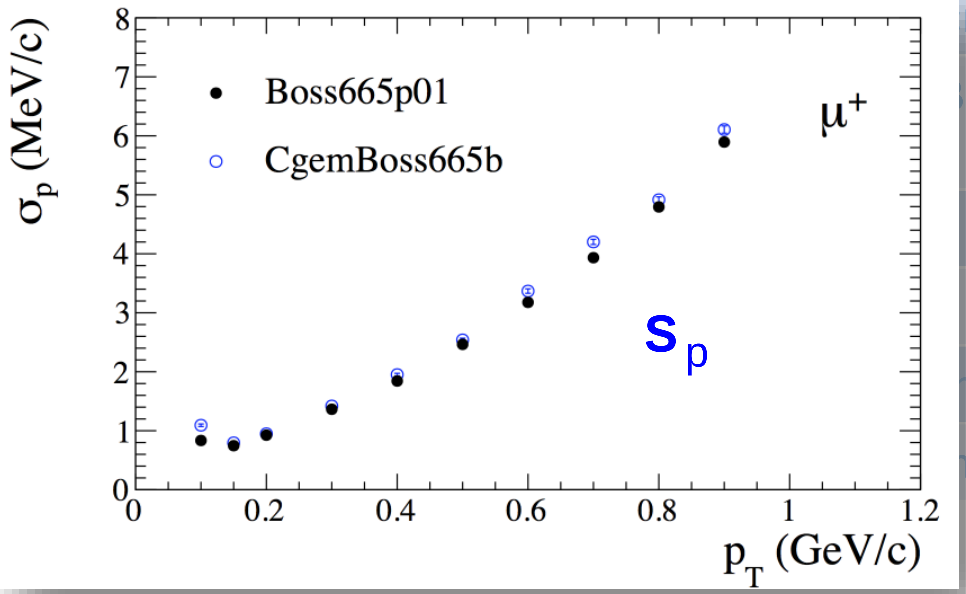
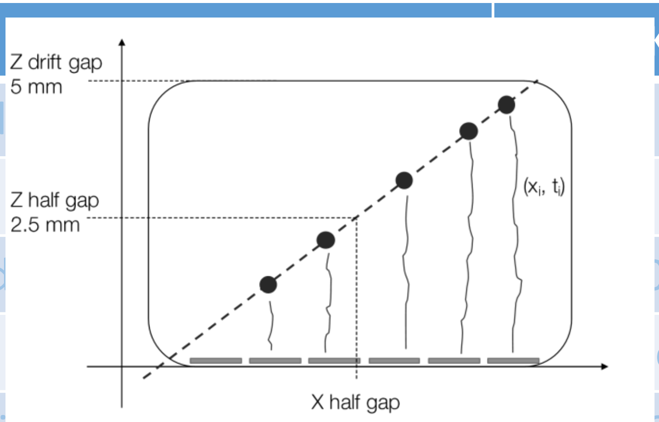
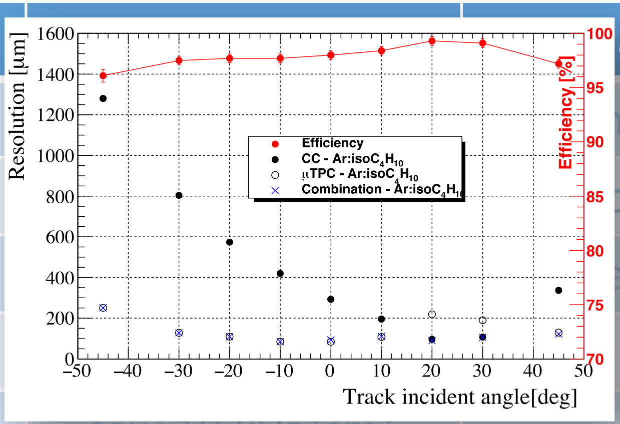
Magnetic filed			→ μTPC
Internal/external diameter		m	higher rate
Readout		ne	new ASIC chip



Pecularities of BESIII CGEM-IT





	KLOE-2		action
Number of d	4		mm drift gap
Drift gap	3 m		for µTPC
Material bud	0.5% X_0		ll and anode
Momentum	ot used		
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Pecularìatìes of BESIII CGEM-IT

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Momentum resol		σ_{pt}/	
Rate capability –		few 1	
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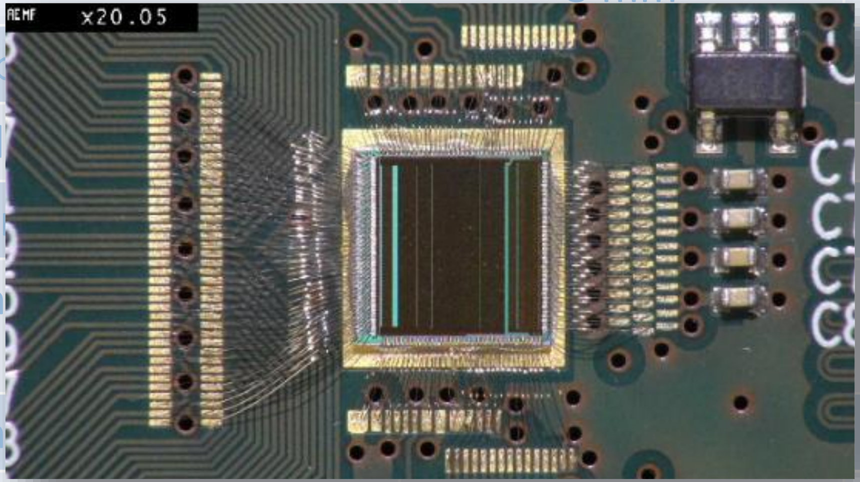
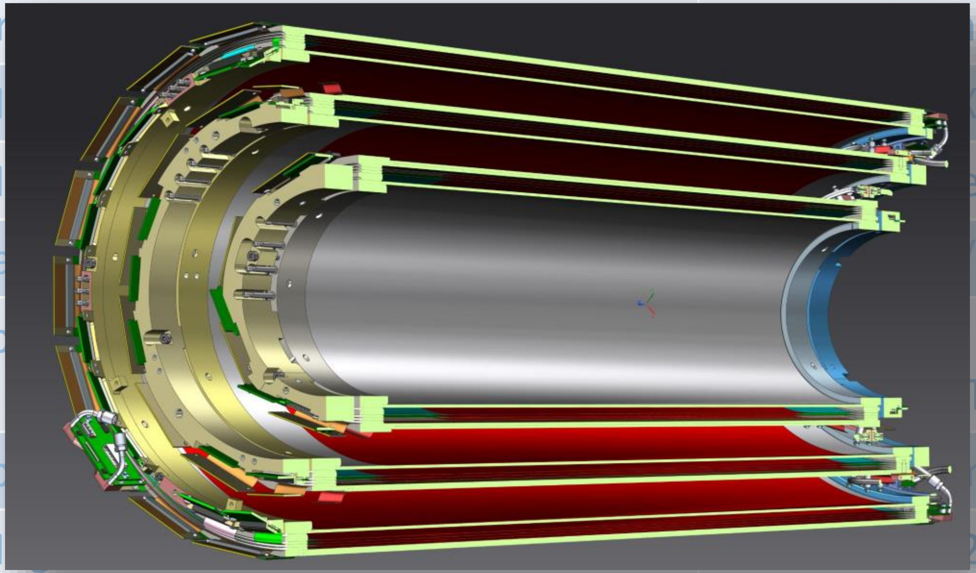
Readout	digital	charge + time	new ASIC chip



Pecularities of BESIII CGEM-IT

	KLOE-2	BESIII	action
Number of detector layers	4	3	→ 5 mm drift gap
Dr		5 mm	also for µTPC
M	X_0	0.4% X_0	rohacell and anode
M	ed	σ_{pt}/P_t =~0.5%	
Ra	/cm^2	few 10 kHz/cm^2	
Sp	µm T)	100-150 µm (B=1T)	with µTPC
Sp	n	<500 µm	with µTPC
M	2 T	B = 1 T	→ µTPC
Internal/external diameter	244/440 mm	156/356 mm	higher rate
Readout	digital	charge + time	new ASIC chip



Pecularities of BESIII CGEM-IT

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Drift gap	3 mm	5 mm	also for μTPC
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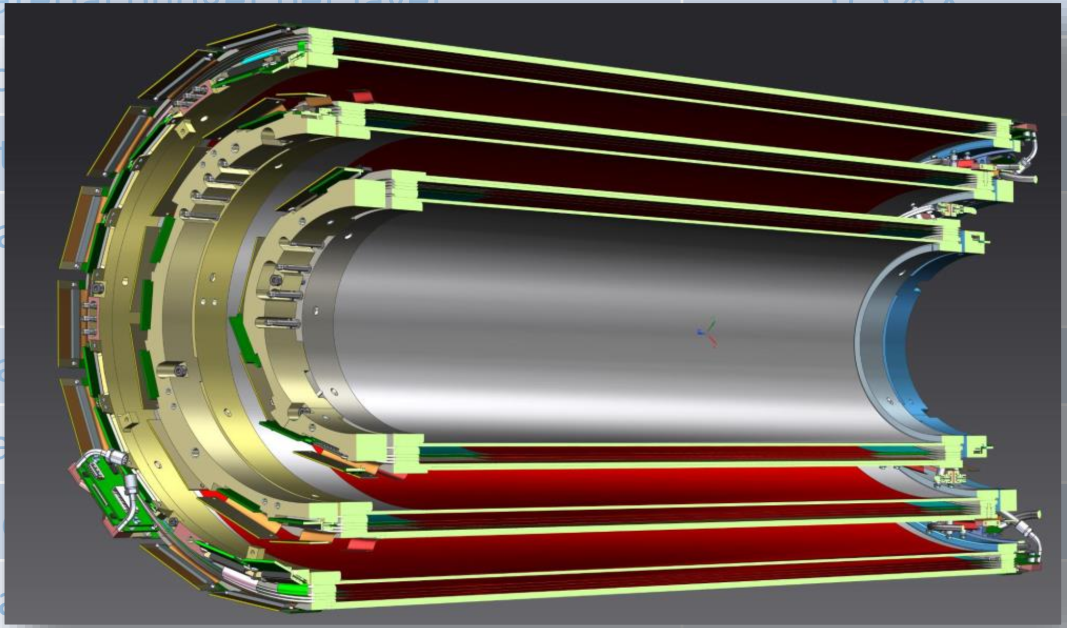
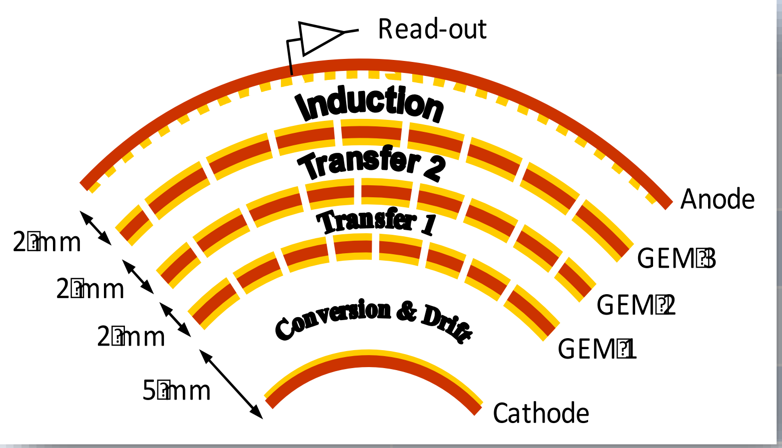
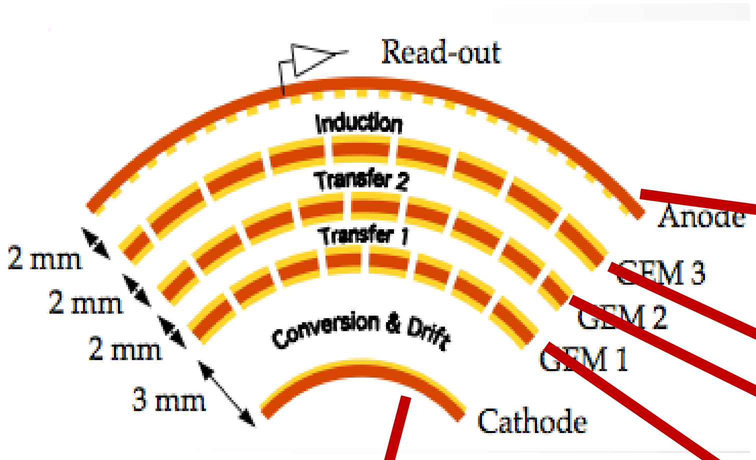
Mo		σ_{pt}/P_t =~0.5%	
Ra			
Sp		1	
Sp			
Ma			
Int			
Re		charge + time	new ASIC chip

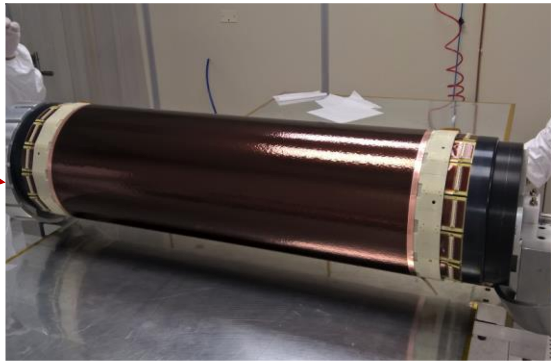




BESIII CGEM-IT construction technique

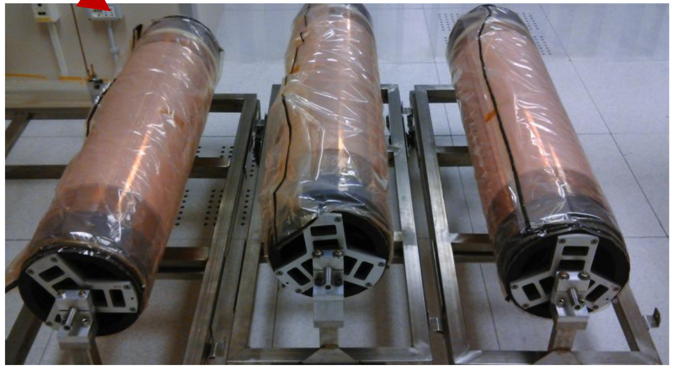


Anode



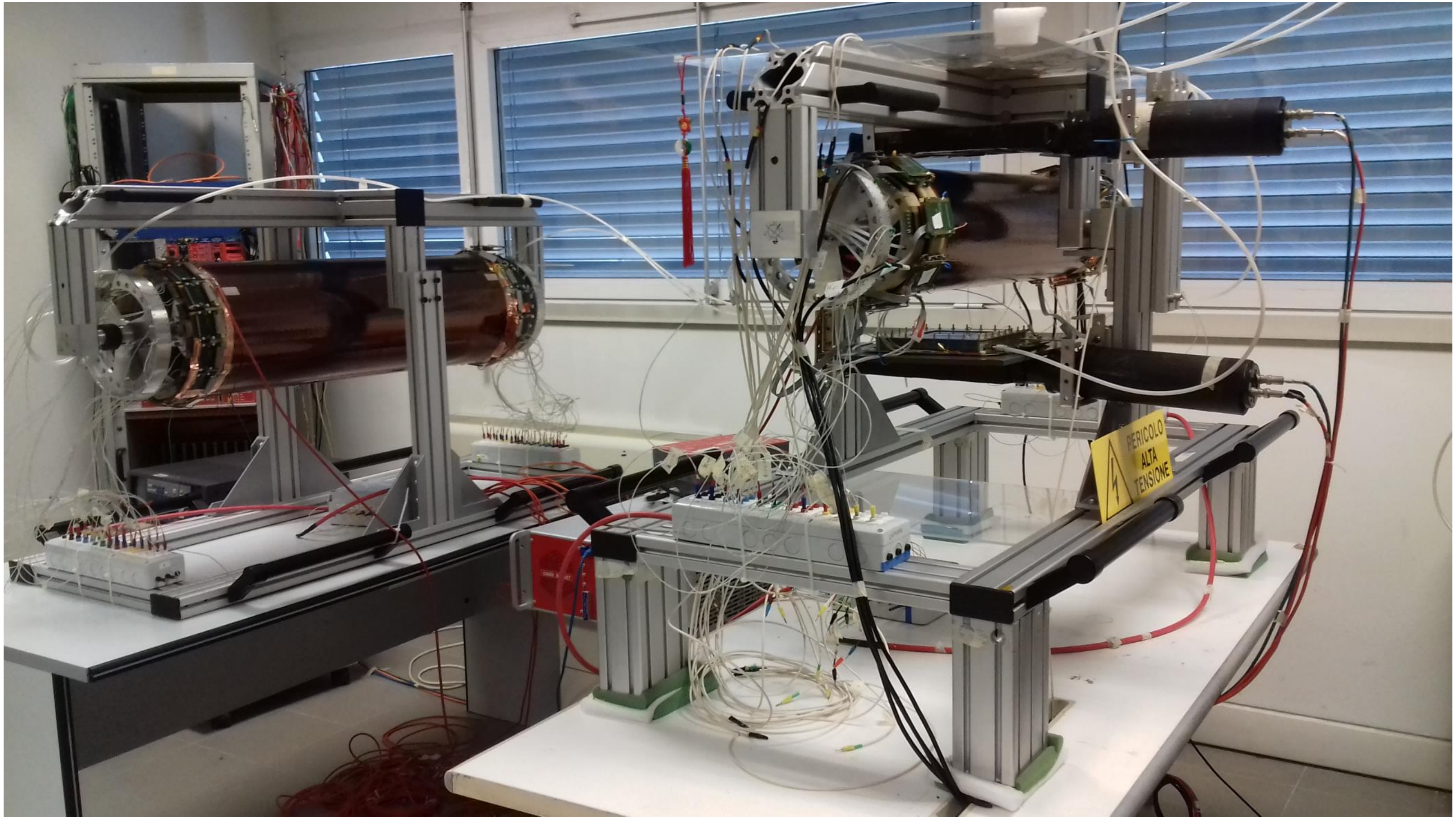
Vertical assembly

Cathode



Three GEMs

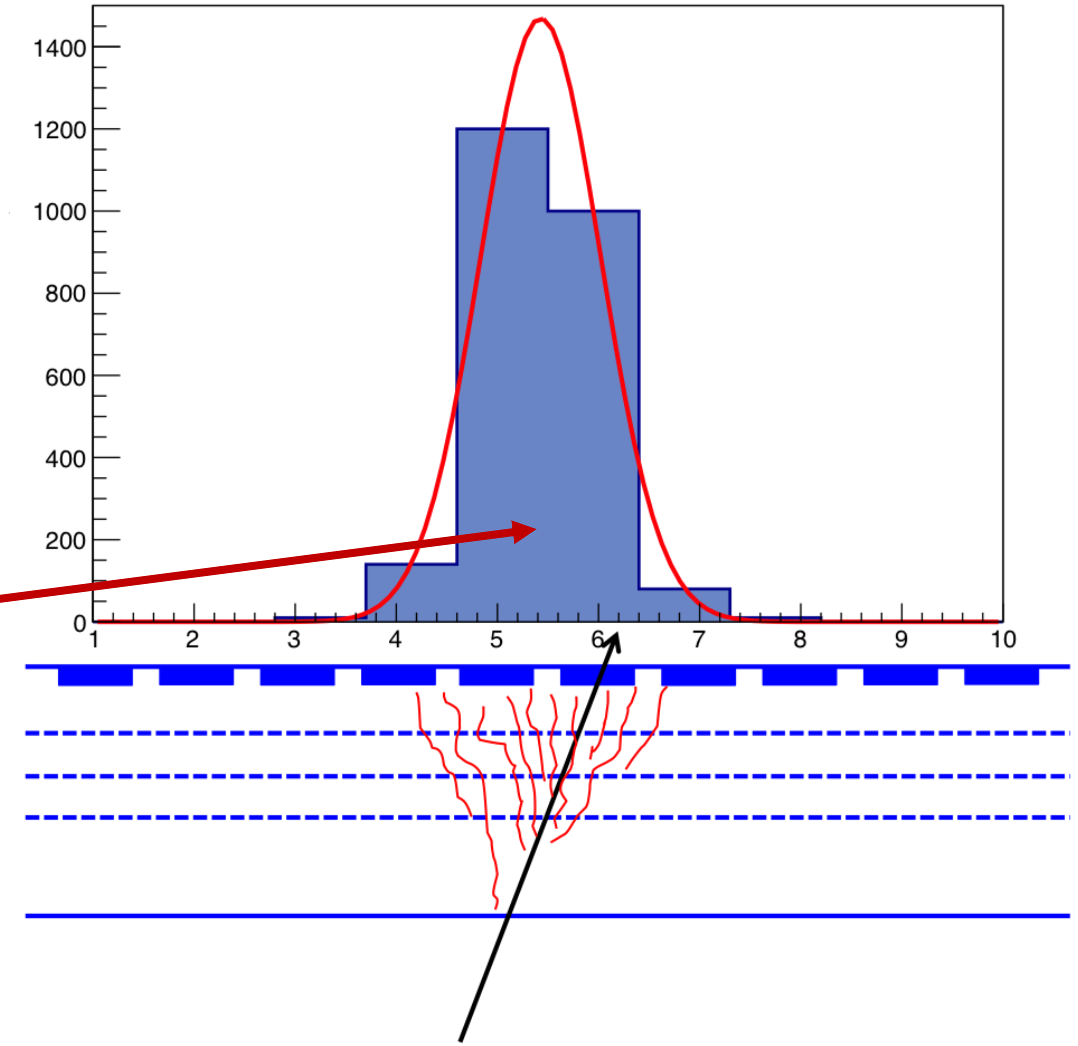
First BESIII CGEM layers



BESIII CGEM-IT analogue readout

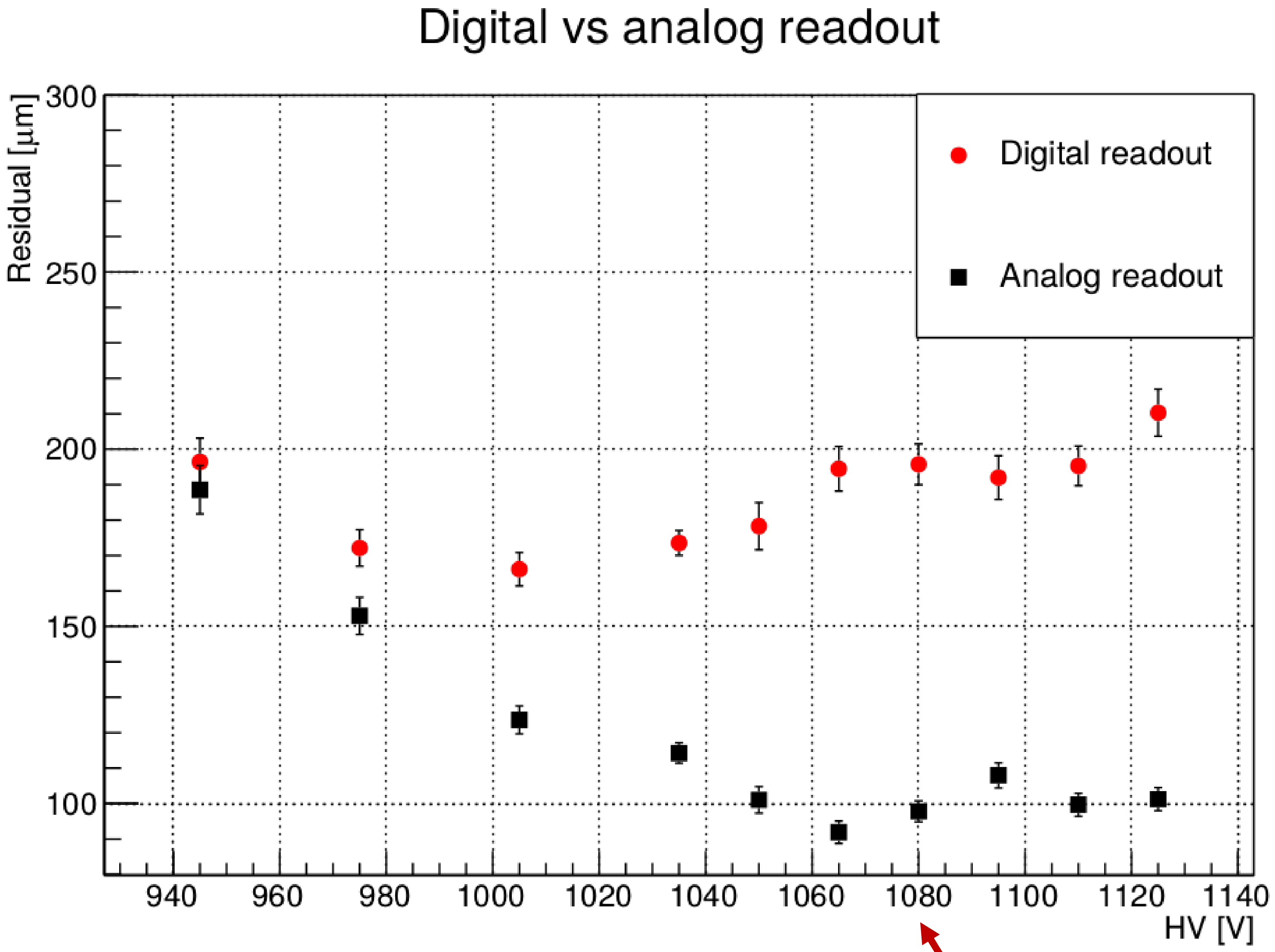
Analog readout: best compromise among number of readout channels and spatial performances

To achieve desired resolution:
charge centroid method was implemented



BESIII CGEM-IT analogue readout

Comparable results with state-of-art planar GEM **without magnetic field**



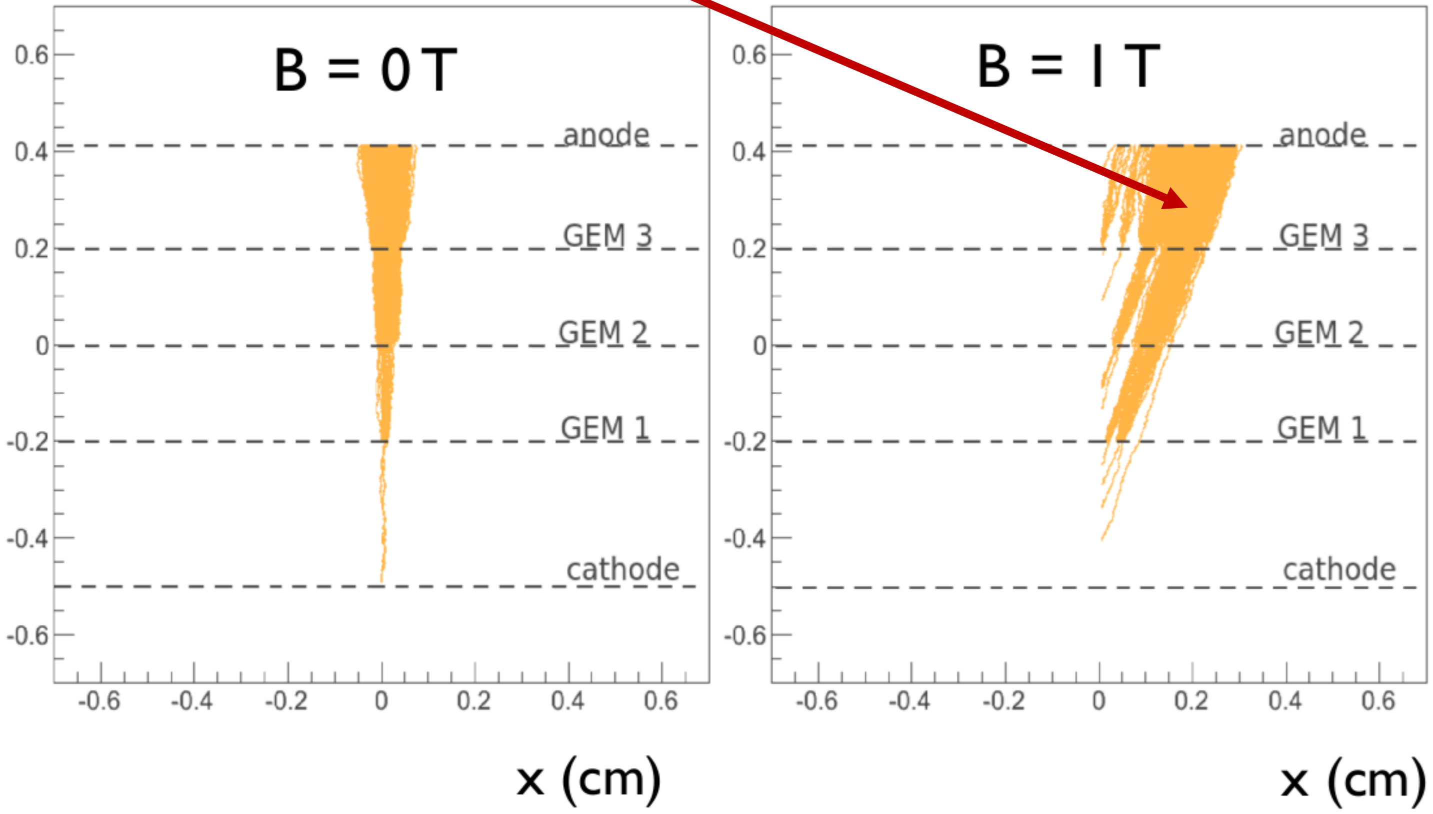
Gain ~ 10K

Effects of the magnetic field

Two main effects occur:

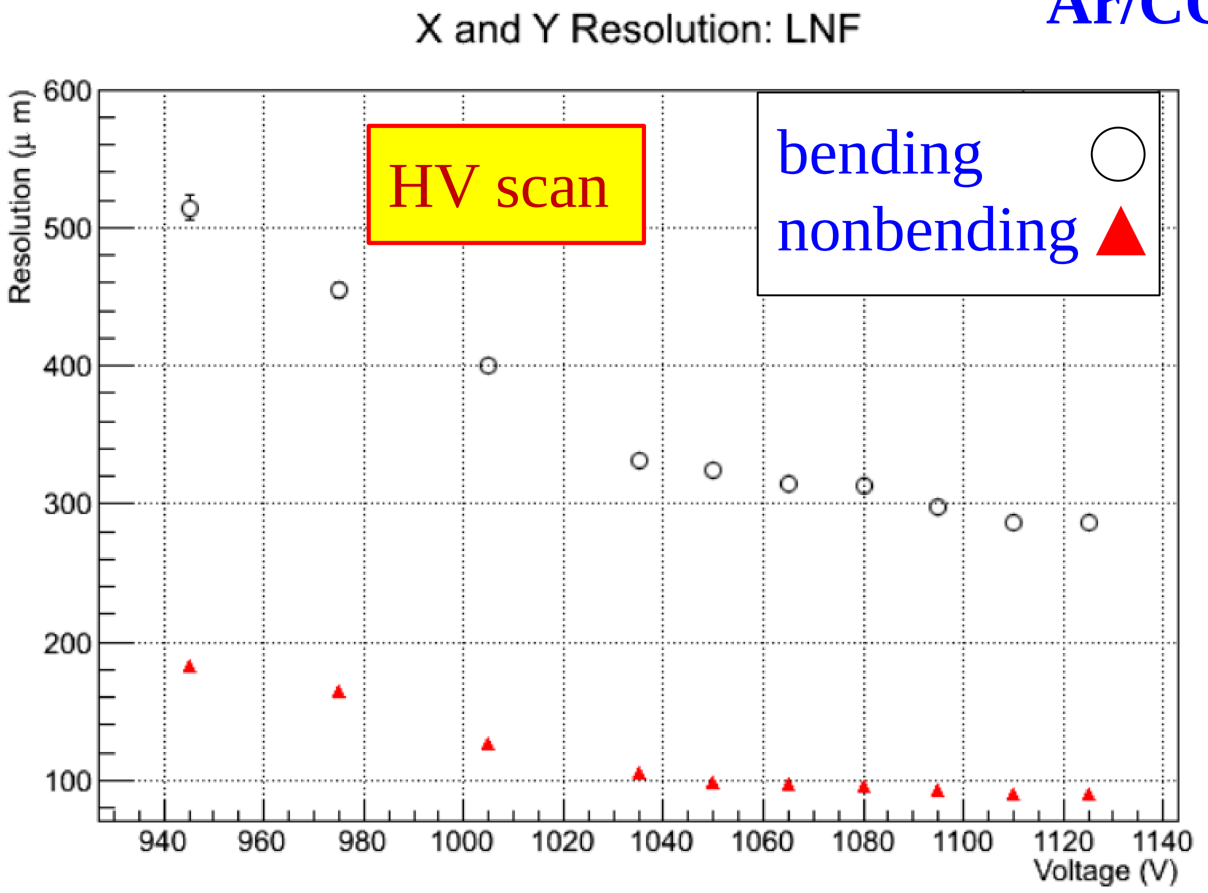
- bending of the particle trajectory in the lab ⇨ correction to alignment (TRIVIAL)
- broadening of charge distribution ⇨ Lorentz angle

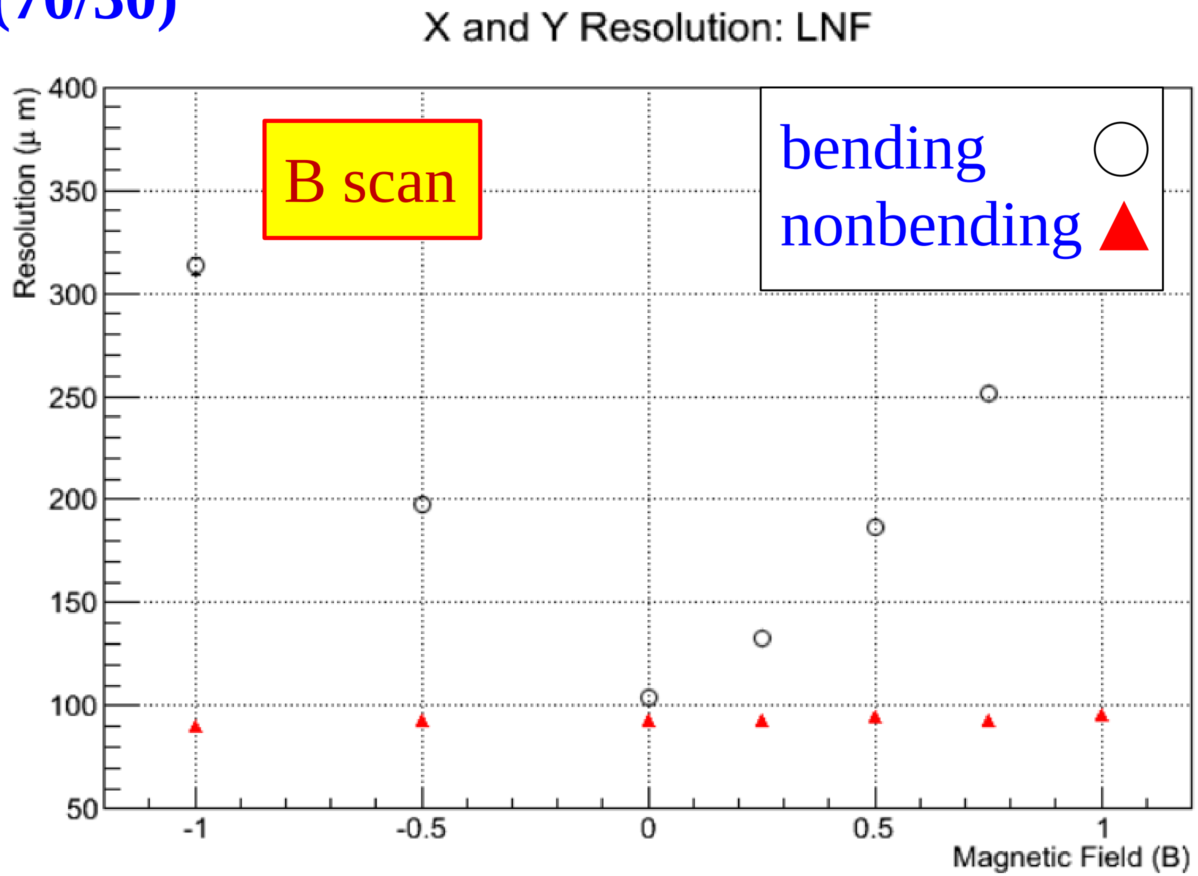
Charge distribution
no longer gaussian.
Expected worsening of the charge centroid method performances



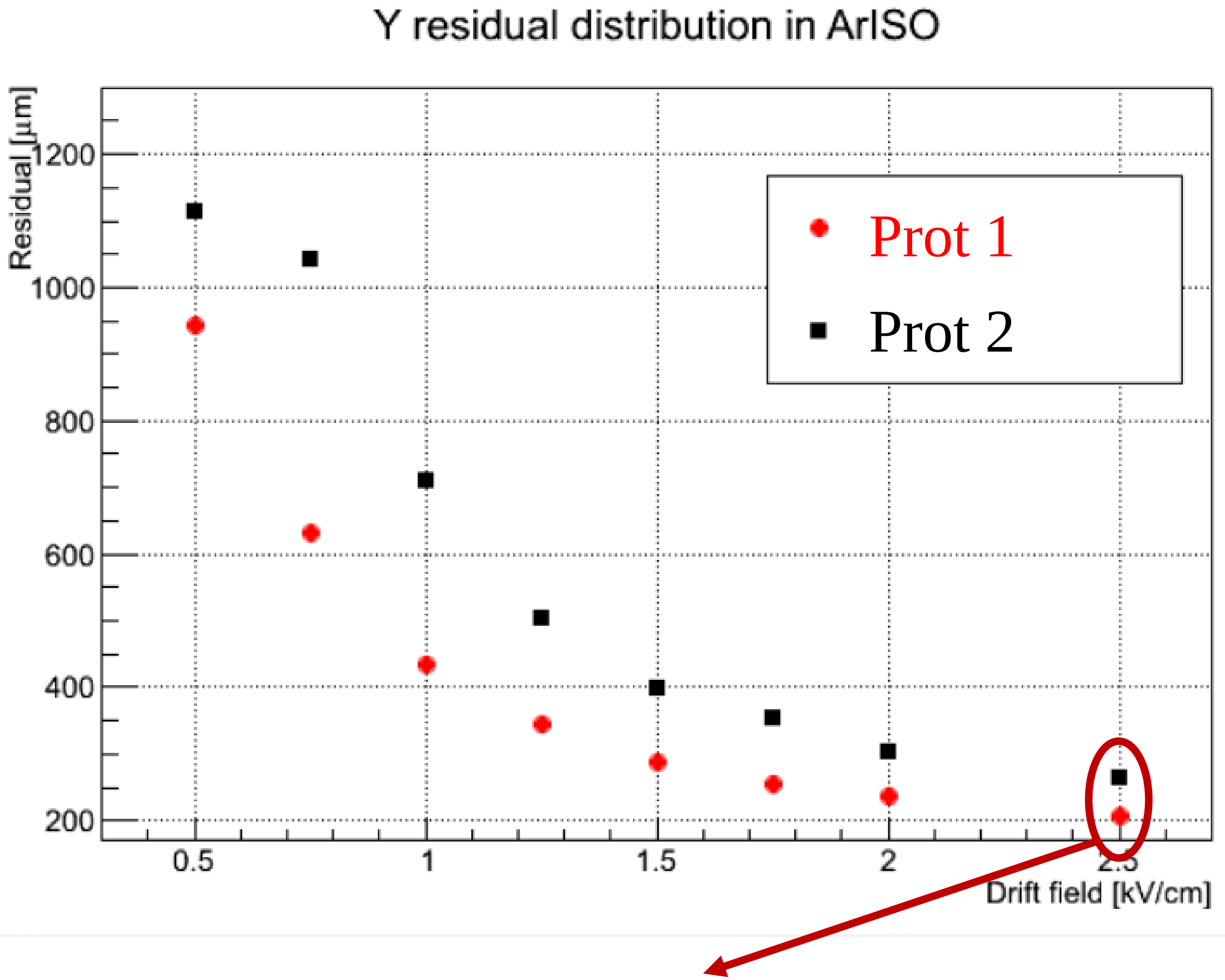
Effects of the magnetic field

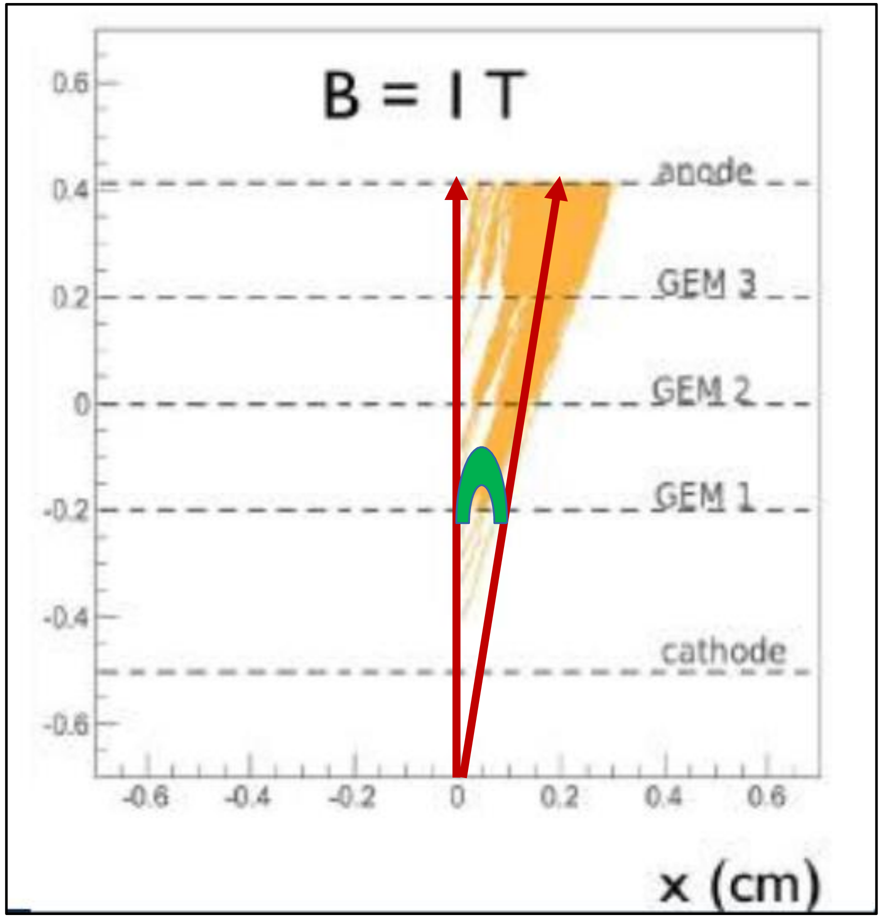
Ar/CO_2 (70/30)





Effects of the magnetic field





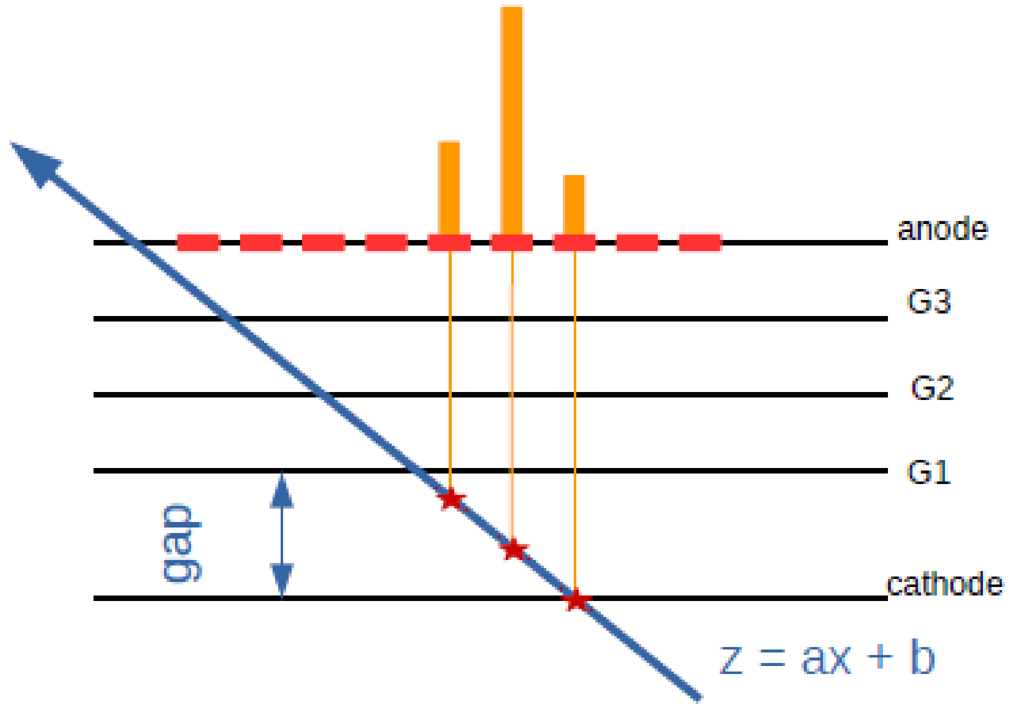
Resolution close to 200 µm

Best result with GEM in high magnetic field

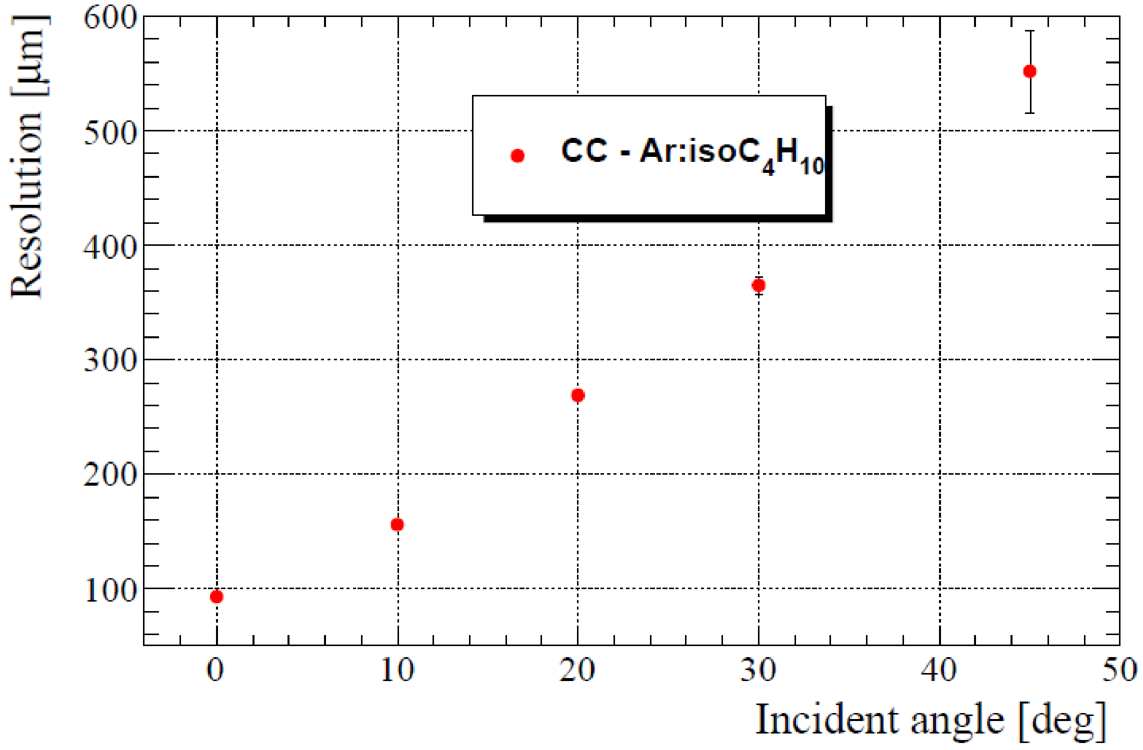
Lorentz angle dominates the trasversal diffusion

Charged centroid and angular distribution

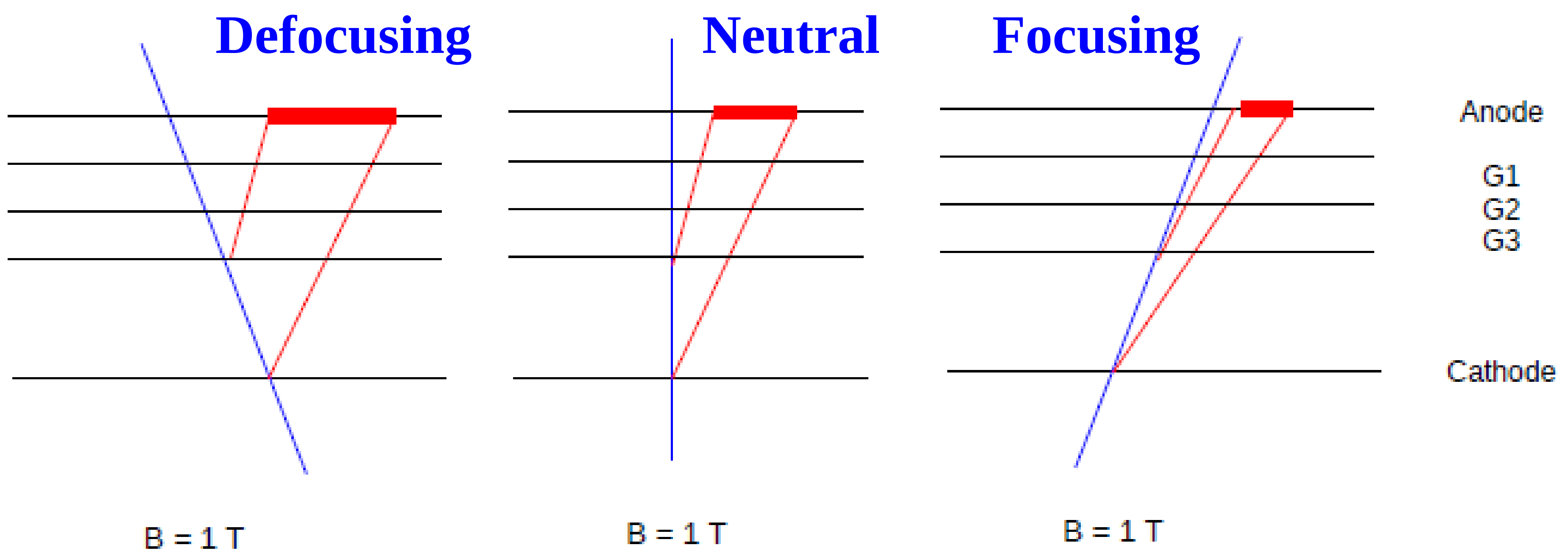
$$< x > = \frac{\sum_i x_i q_i}{\sum_i q_i}$$



Distorted gaussian shape



Charged centroid, inclined tracks and magnetic field



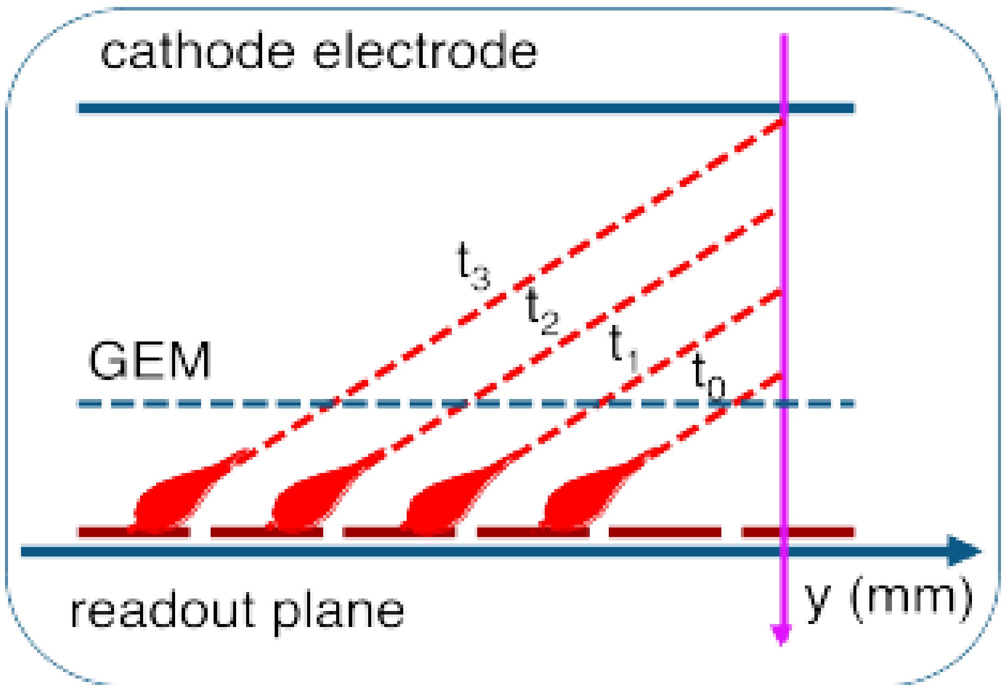
Two angles must be considered:

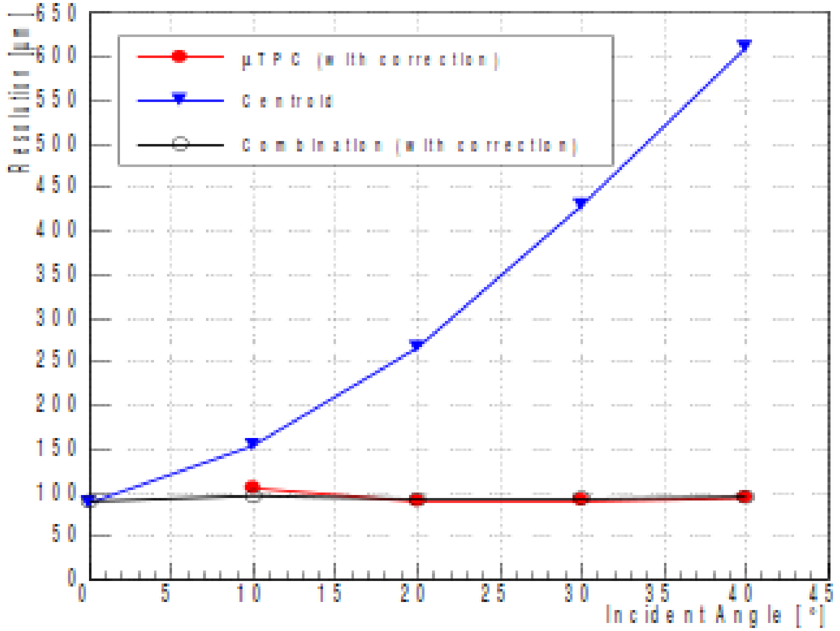
- $\theta_{Lorentz}$, due to magnetic field
- θ_{track}, incident track angle

In the focusing case ($\theta_{Lorentz} \sim \theta_{track}$), the charge centroid works at its best, but in both the other two cases suffers from same effects as shown before

Principles of μTPC readout

Time information of the hit can be used to identify the **track path inside the gap**, operating the GEM as a **small TPC** (i.e. **μTPC**)
Due to the **charge spread**, at **large angles** or with **high magnetic field**, time measurement is **more precise** than **charge centroid**





Technique has been successfully tested for ATLAS small wheel upgrade with MicroMegas

Also proposed to improve space resolution for GEM based neutron detectors

T. Alexopoulos - 4th LNF workshop on Cylindrical GEM detector

BESIII CGEM-IT μTPC readout

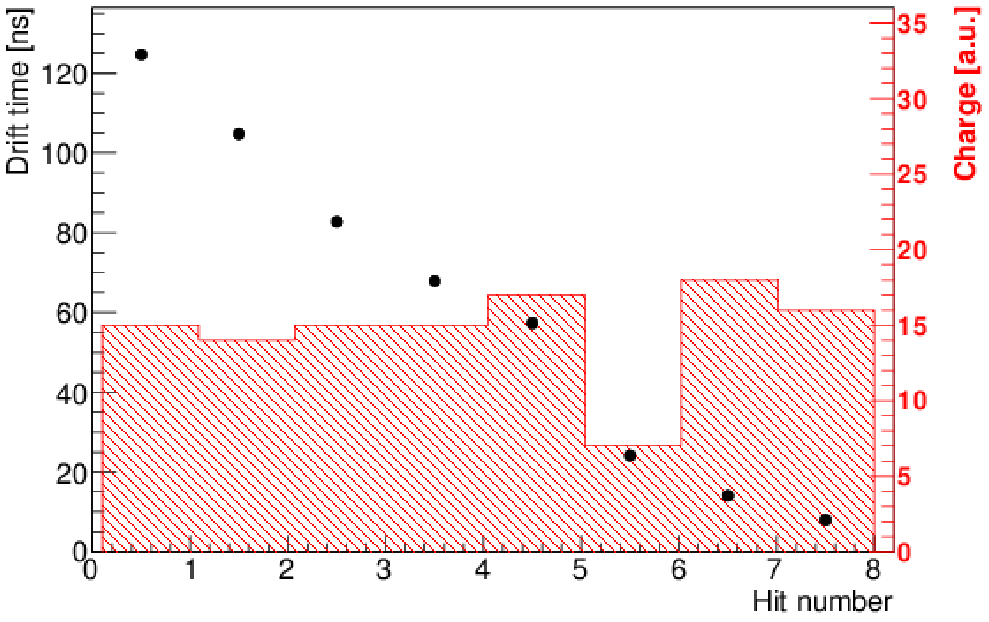
Take advantage of time information to extract track position

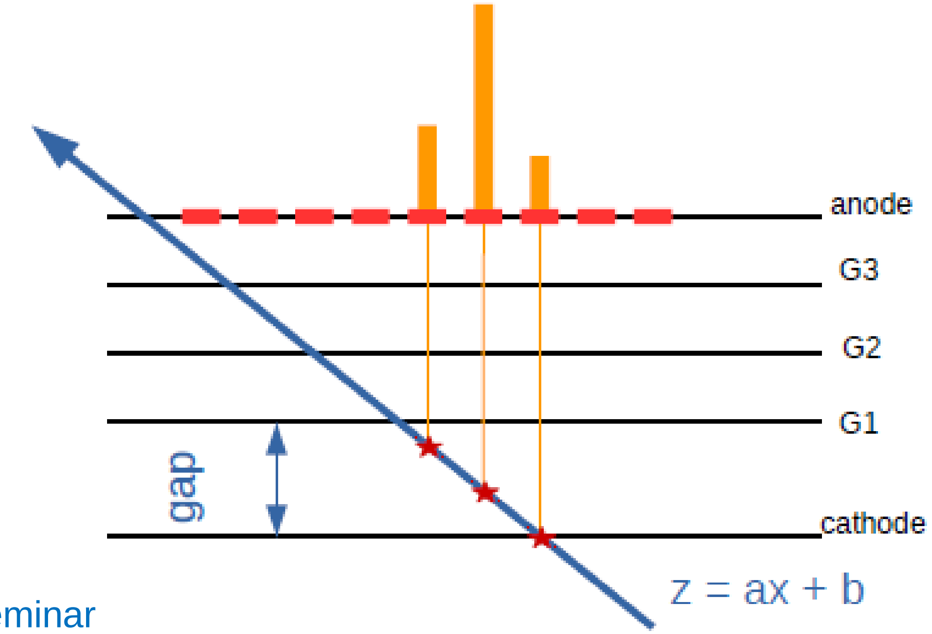
Drift velocity extracted from GARFIELD simulations

Measuring a set of 2D-points in the conversion region

Position is extracted from a linear fit

$$x = \frac{\frac{gap}{2} - b}{a}$$



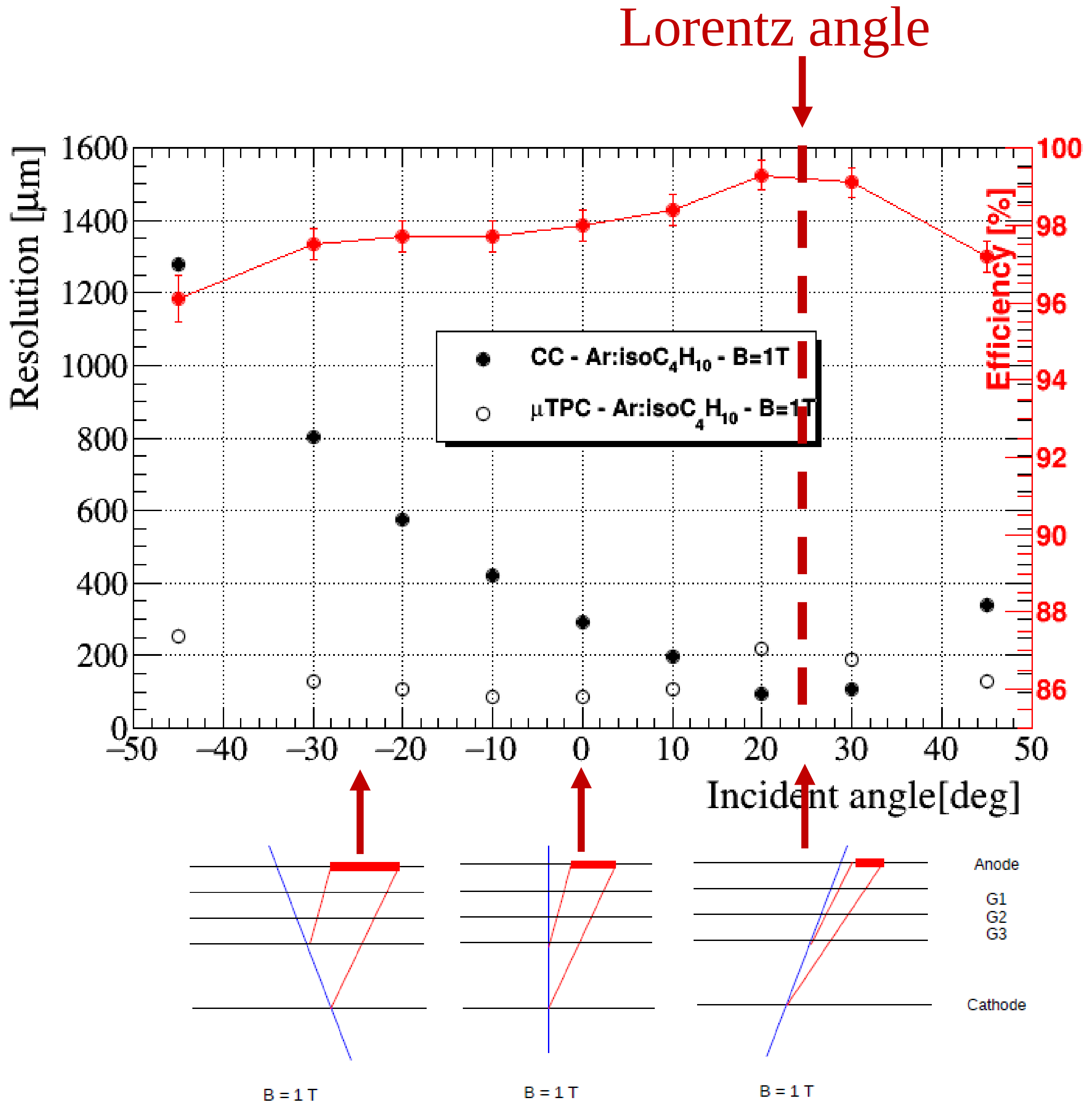


BESIII CGEM-IT spatial resolutions in B = 1 T

- **µTPC** must account for the **Lorentz angle** to reconstruct tracks within **large magnetic fields**. That angle is evaluated by **simulations**.

- **Lorentz angle** in **ArC4H10** @ 1,5 kV/cm drift field is **~ 26°.**
  CC is more efficient in this region.
  In other regions **µTPC** achieves a flat **resolution ~ 100 µm**

- A **combination of the two methods can offer stable resolution** in the **full range of incident angles**



IHEP-INFN Joint Laboratory
I2JL

In a nutshell

Denomination	**IHEP-INFN Joint Laboratory – I2JL**
Location	Beijing (PRC) – Rome (IT)
Organisations	Institute of High Energy Physics (IHEP) of CAS, P.R.C. Italian Institute of Nuclear Physics (INFN), Italy
Fields of research	High Energy Physics and Nuclear Physics Detector and Accelerator technologies Astroparticle Physics and Cosmic Ray measurements Physics in the space IT, High Performance Computing, GRID- & cloud- Computing Technologies
Collaboration details	**Established on 2012** Heir of the Agreement CAS and INFN signed in **2008** for a Joint Laboratory coordinated by IHEP.
Director	Marco MAGGIORA (former and first: Rinaldo BALDINI)

CAS-INFN General Framework Agreement

- **CAS and INFN (thanks to IHEP!):**
  - CAS and INFN signed on November 16th, 2015:
    - **the CAS-INFN General Framework Agreement**
  - renewal of the existent 2011 CAS-INFN GFA (originally since 2006)

- **goals:**
  - provide a more general ground to I2JL and to present and future IHEP-INFN Agreements expanding the collaboration framework from IHEP to CAS
  - support short term stays (for junior and senior researchers): bidirectional CAS-INFN

- **means:**
  - supporting exchange of information, technologies, and equipment
  - a bidirectional Mobility Programme for young and senior researchers
  - supporting joint projects of experimental and R&D efforts

Research activities supported by the CAS-INFN GFA

THE CORE!

Article 3
Specific Projects

3.1 Specific projects implementing the collaboration defined in Articles 1 and 2 shall be established in bilateral Memoranda of Understanding between INFN and the relevant CAS Institutes retaining specific competence in the fields listed in Articles 1 and 2.

Signed on November 16^{th}, 2015

Research activities supported by the CAS-INFN GFA

- **priority areas: <u>any</u> joint CAS-INFN research activity, experimental or theoretical**
  - High Energy Physics and Nuclear Physics, particularly as regards accelerator technologies
  - Astroparticle Physics and cosmic ray measurements
  - IT, High Performance Computing, GRID- and cloud-based technologies
  - Physics in the space
  - Nuclear Physics/Accelerator Technologies, including synchrotron radiation and FEL (Free Electron Laser) researches and technologies, to be applied particularly to cultural heritage, hadrotherapy, biomedical imaging and environmental sciences, nano-sciences and nano-technologies
  - exchange of information and technologies
  - exchange of equipment
  - exchange of junior and senior researchers
  - joint projects of experiments and R&D efforts
  - organisation of Seminars, symposia and workshops

The collaboration may be extended to any other activities the Parties may agree upon

IHEP-INFN MoU

- **the IHEP-INFN MoU has been renewed on May 27th, 2016 :**
  - within the CAS-INFN GFA;
  - within the framework of I2JL ;
  - priority activities:
    - exchange of information and technologies
    - exchange of equipment
    - exchange of senior and junior researchers
    - joint IHEP-INFN Postdoctoral Fellowships
    - joint projects of experiments and R&D efforts
    - organization of seminars and workshops
  - possible addenda on:
    - scientific projects
    - development and technological transfer
    - advanced training
    - dissemination and education
    - any other activities recognized as useful and coherent with the spirit of the cooperation

IHEP and INFN can safely expect many more years of exciting collaboration!!

China – INFN Partnerships

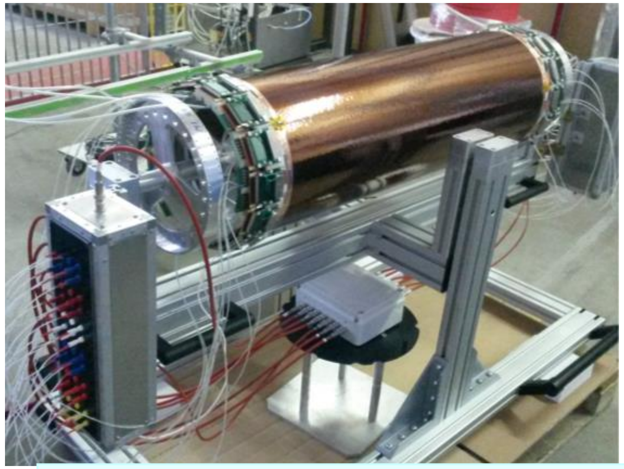
- **CAS and INFN:**
  - CAS – INFN GFA supports any point to point agreement and collaboration among CAS Institutions and INFN

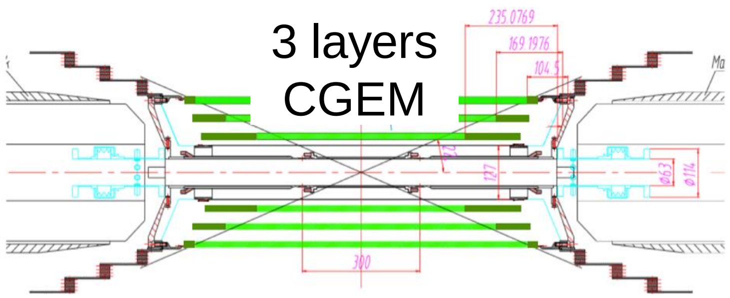
- **IHEP and INFN:**
  - IHEP and INFN established I2JL in 2012
  - IHEP and INFN signed **two bilateral Agreements** on May 15th, 2015:
    - **the IHEP-INFN Joint Fellowships Programme**
    - **IHEP-INFN Microelectronics Joint Projects within the Doctoral School in Electronics of Politecnico di Torino**
  - a large INFN community is frequently hosted by IHEP
  - INFN is involved with IHEP in several International Collaborations: BESIII, CSES, DAMPE, HERD, JUNO…
  - the mutual cooperation can expand further in the near future, within new Collaborations or new Accelerator Facilities

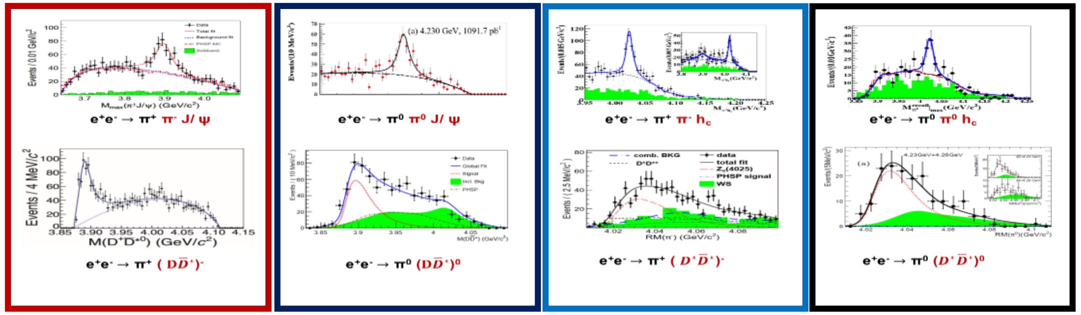
IHEP – INFN Partnerships: BESIII @ BEPC-II

- **Beijing Electron Spectrometer III @ Beijing Electron Positron Collider II:**
  - luminosity record: 1.0 x10^{33}/cm^2 (May 4th, 2016)
  - world largest J/ψ, ψ(2S), ψ (3770), ψ(4180), Y(4260) data sample
  - GEM chamber Inner Tracker construction in progress (EU RISE and MAECI grants)
  - first application of CAS-INFN Agreement
  - outstanding contributions to data analysis and papers

INFN: 4 Sections (~40 researchers)
Ferrara, Frascati, Perugia, Torino







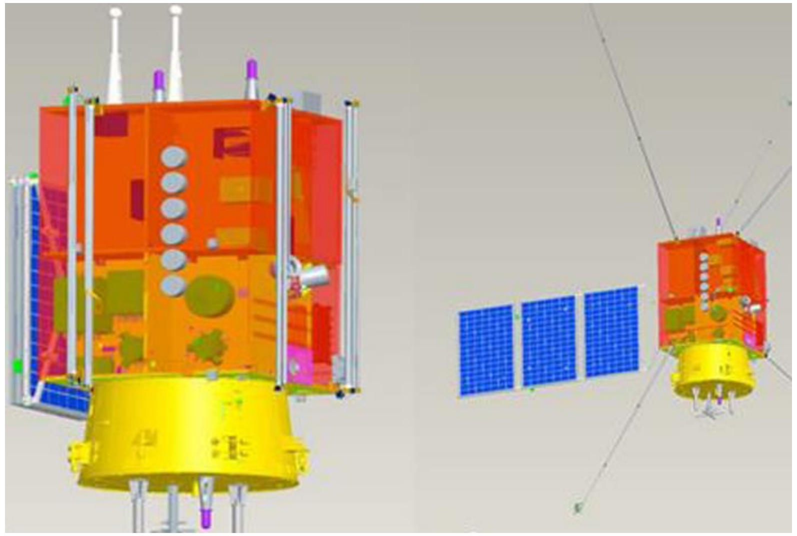
The Italian collaboration is leading the project for the development of a cylindrical GEM detector to replace the BESIII Inner drift chamber to improve the secondary vertex resolution.

The project is co-funded by the European Commission Research and Innovation Staff Exchange (RISE) project 2015-2018. Consortium composed of: China, Germany, Sweden and Italy.

IHEP – INFN Partnerships: CSES

INFN: 5 Sections (~30 researchers)
Bologna, Frascati, Napoli, Roma2, TIFPA

- **China Seismo-Electromagnetic Satellite**
  - mission of the Chinese National Space Agency (CNSA)
  - identification of seismic precursors
  - monitor electromagnetic fields and waves, plasma, particles
  - will complement AMS and PAMELA data



INFN and Italian Space Agency:
- contribute particle detector
- participate to the construction of the electric field detector

Launched on Feb. 2nd, 2018

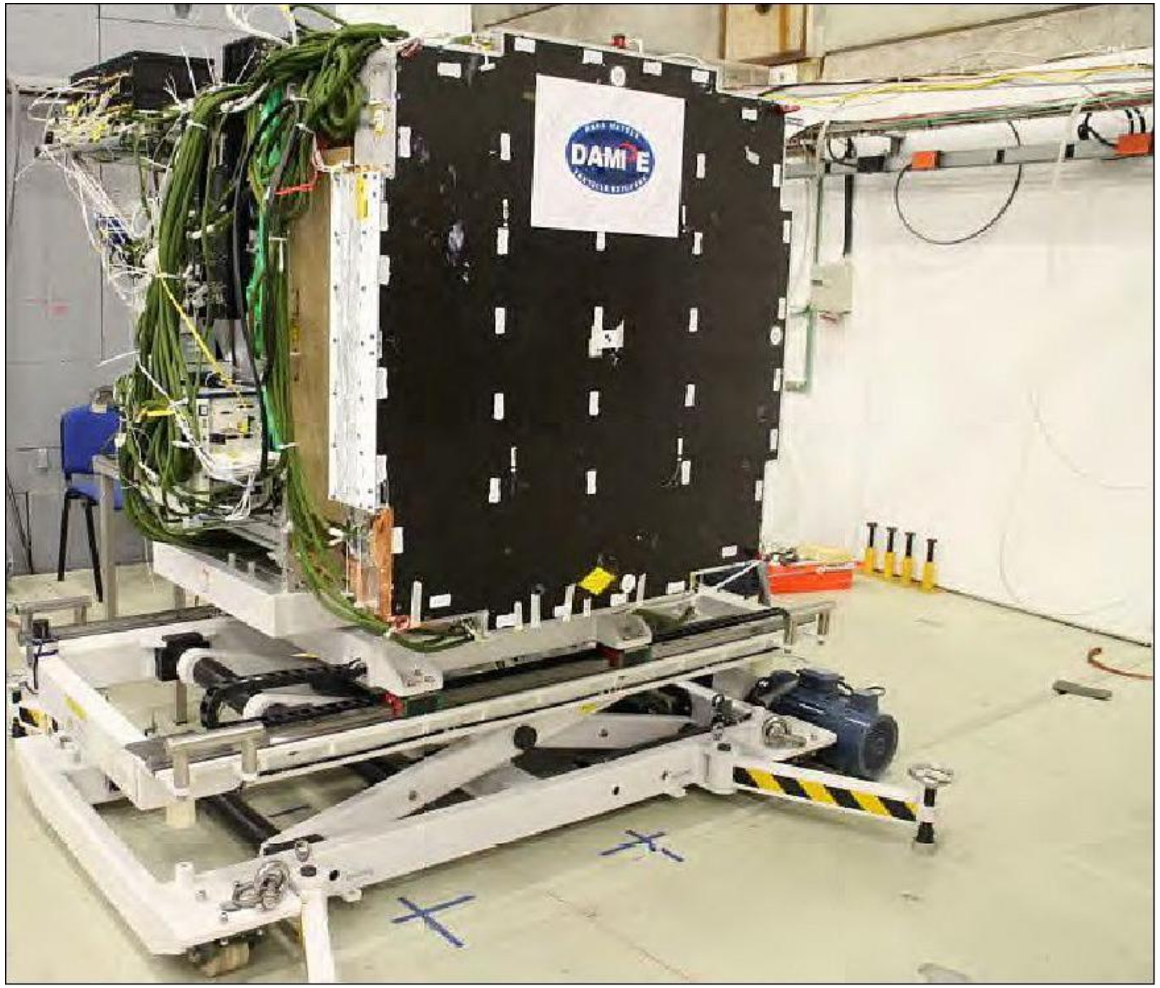
IHEP – INFN Partnerships: DAMPE

- **DArk Matter Particle Explorer**
  - CAS Strategic Pioneer Program on Space Science
  - DAMPE satellite (500 km orbit): dark matter study in cosmic rays
  - e/γ 5 GeV-10 TeV
  - nuclei 100 GeV-100 TeV

INFN: 3 Sections (~20 researchers)
Bari, Lecce, Perugia

INFN-Perugia leader of the Si tracker detector:
- PAMELA, AMS1/2 and FERMI know-how
- CERN test beam in 2014

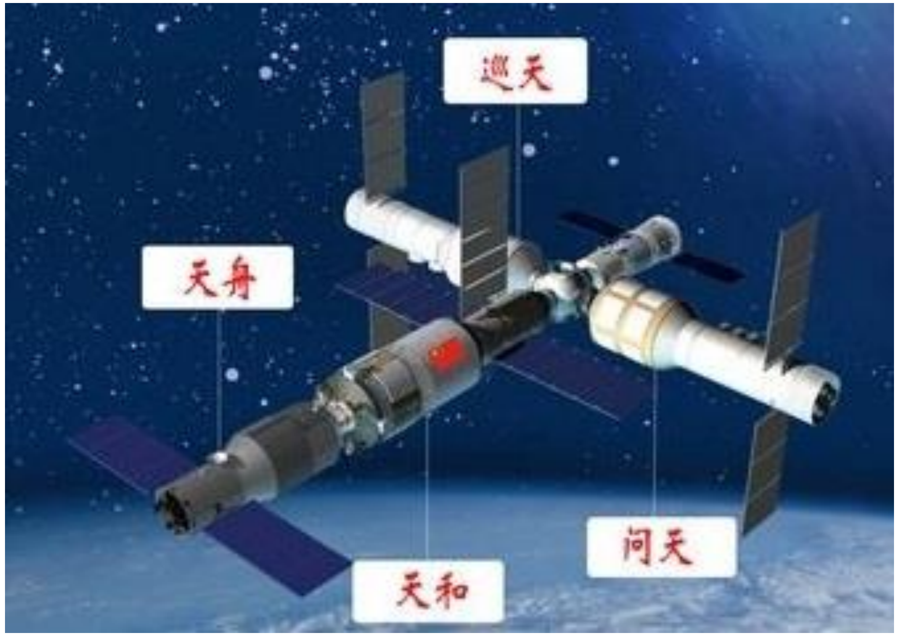
Dec. 17th 2015: Jiuquan Satellite Launch Center, Gobi desert



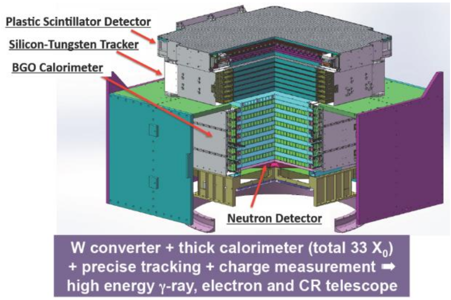
IHEP – INFN Partnerships: HERD

- **High Energy cosmic-Radiation Detection**
  - evolution of DAMPE
  - Dark Matter indirect search with unprecedented sensitivity
  - precision measurement of cosmic rays spectrum and of the knee energy
  - γ-rays experimental measurement
  - INFN leading the 3D-calorimeter construction
  - flagship experiment on the China's Space Station

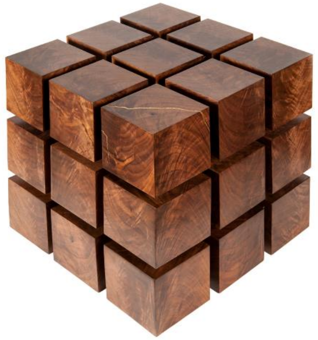
INFN: proposal phase



Roadmap:
- 09-14/04/2018: joint ASI-CSU Review Board appointed (11 members, 2 INFN, 2 ASI) for proposal evaluation
- 24/04/2018: proposal submission
- 11/05/2018: Review Board meeting for proposal evaluation
- launch and installation on CSS: if approved on 2025



DAMPE

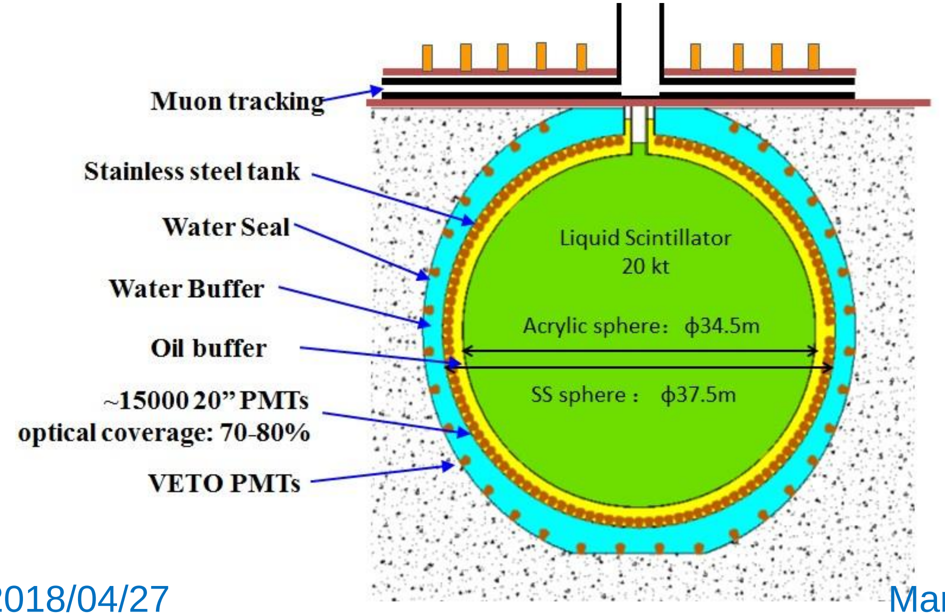


HERD

IHEP – INFN Partnerships: JUNO

INFN: 8 Institutions (~65 researchers)
Catania, Ferrara, Frascati, Milano, MilanoB, Padova, Perugia, Roma3

- **Jiangmen Underground Neutrino Observatory**
  - 53 km away from both Yangjiang and Taishan Nuclear Power Plants in Guangdong
  - designed to determine the neutrino mass hierarchy
  - underground liquid scintillator detector
  - experimental hall, spanning more than 50 meters, under a granite mountain of over 700 m overburden
  - six years of data taking data foreseen
  - the detection of reactor antineutrinos can resolve neutrino mass hierarchy with a 3-4σ precision



INFN contributes:
- purification system (exploiting distillation)
- part of the muon tracker and its front end electronics
- distributed intelligence for the readout of photo-tubes and their trigger
- monitoring technologies for nuclear reactors

INFN R&D Activities: large impact on CepC/SppC

INFN: 15 Sections (~84 researchers)
Bari, Bologna, Catania, Ferrara, Firenze, Frascati, Lecce, Milano, Padova, Pavia, Pisa, Roma, Roma3, Torino, Trieste

- **R&D on detectors for/and next generation accelerators (CEPC, FCC, …):**
  - expected impact on next generation experiments on next generation accelerators: CepC, FCC, HE-LHC, ILC, Muon Collider, SppC, …
  - effort needed for the new Higgs Factories
  - activities as well on Physics and Simulations of the new experimental scenarios
  - involved in the CepC CDR redaction

R&D INFN:

- Micro Pattern Gas Detector (MPGD) with μRwell and μTPC technologies
- dual readout calorimetry with SiPM sensors
- next generation Drift Chambers

Thank you!