Esperimento ATLAS

A Toroidal LArge Spectrometer

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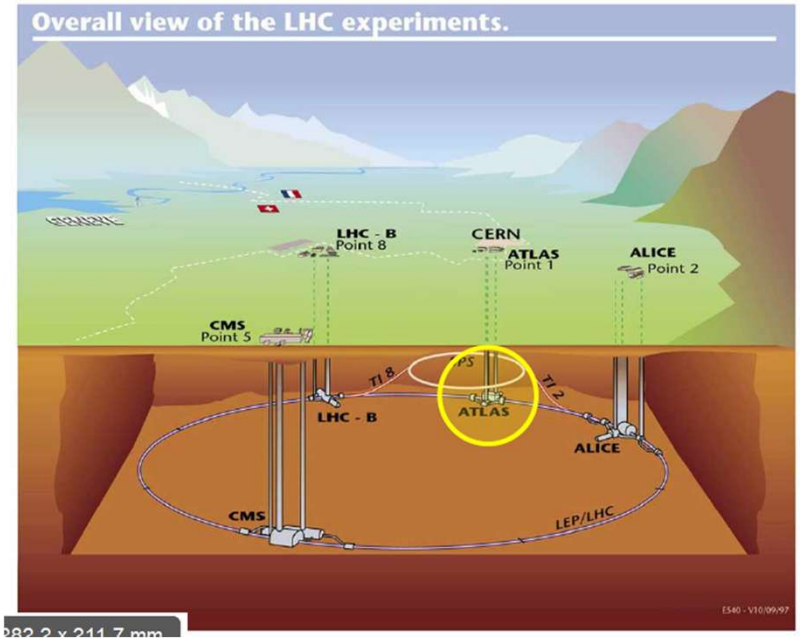
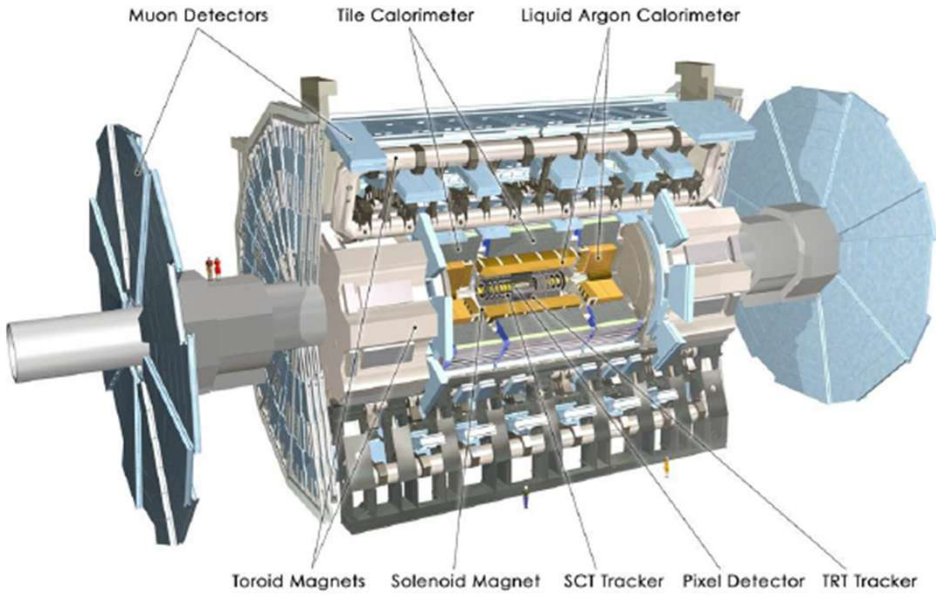
ATLAS at LHC

LHC: World's largest and most powerful collider

- Currently collides protons at 7 TeV per beam
- 27 km in circumference
- Located 100 m underground





ATLAS Experiment

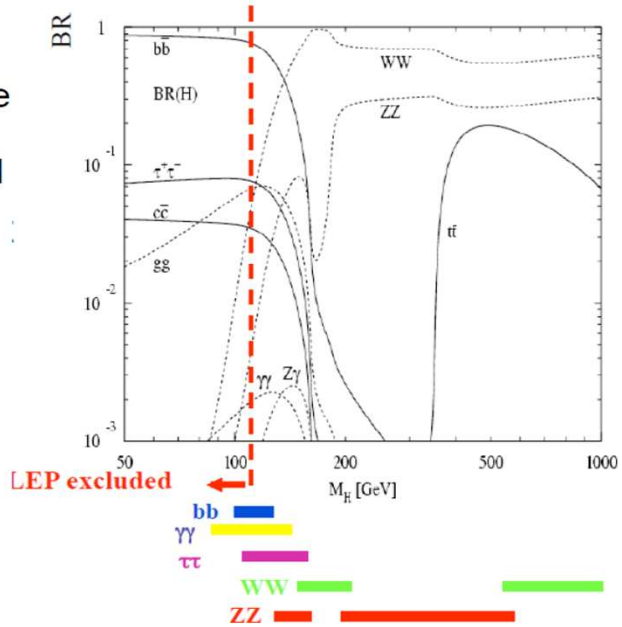
- Diameter 25 m -- Length : 46 m
- Overall weight 7 000 tonnes
- ~ 100 million electronic channels
- ~ 3 000 km of cables

Esperimento di Scoperta -> General Purpose Detector

- Esperimento così come la macchina acceleratrice aveva come obiettivo **la scoperta del Bosone di Higgs**

Known during design phase of ATLAS and CMS:

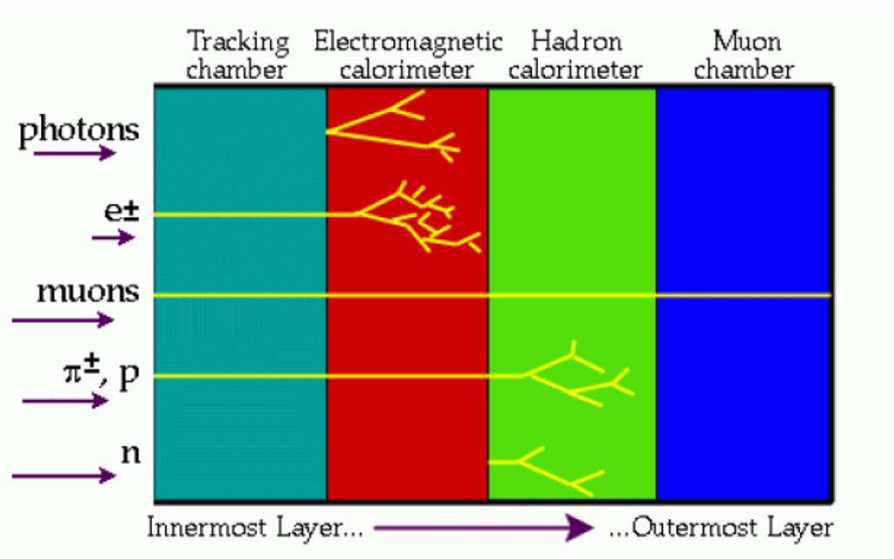
- Decay channels depend on mass:
  - M_H < 130 GeV
    - bbar dominant
    - ττ subdominant
    - γγ Small but very clean
  - M_H > 130 GeV
    - WW dominant
    - ZZ large and clean

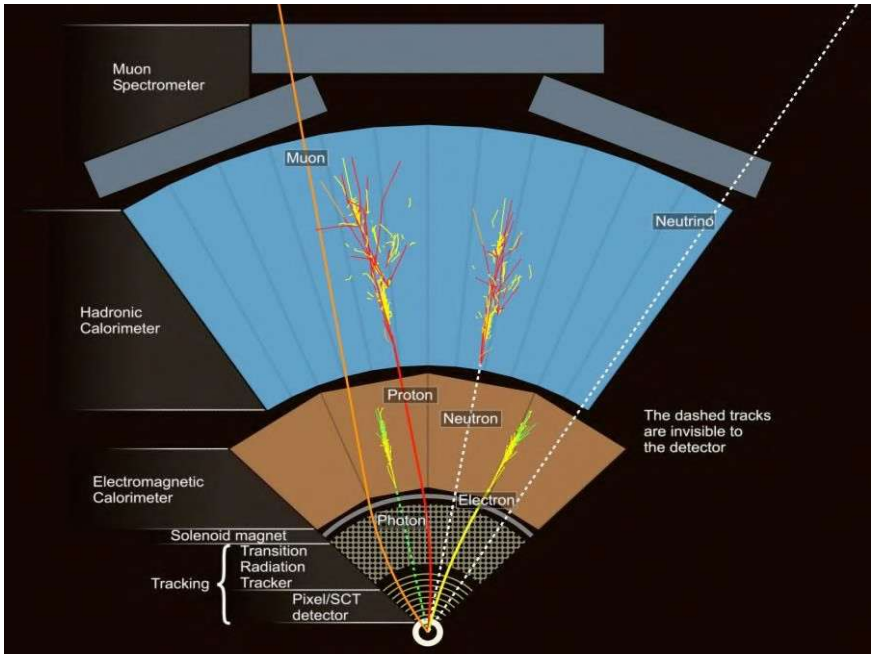


- Non conoscendo la massa della particella, non conosco i prodotti in cui decadrà né con quale frequenza decadrà in quei prodotti
- Devo poter identificare e ricostruire tutte le particelle prodotte nei possibili decadimenti
- Devo riconoscere, acquisire e ricostruire il maggior numero possibile di eventi generati dalle collisioni

General Purpose Detector -> Specialized Sub-Detectors

- Misurare tutte le variabili identificative delle particelle
  - **Identificare il numero ed il tipo di particelle prodotte**
  - **Misurare la traiettoria, la carica, l'energia e quantità di moto**





Il Rivelatore ATLAS

Supports

Shielding

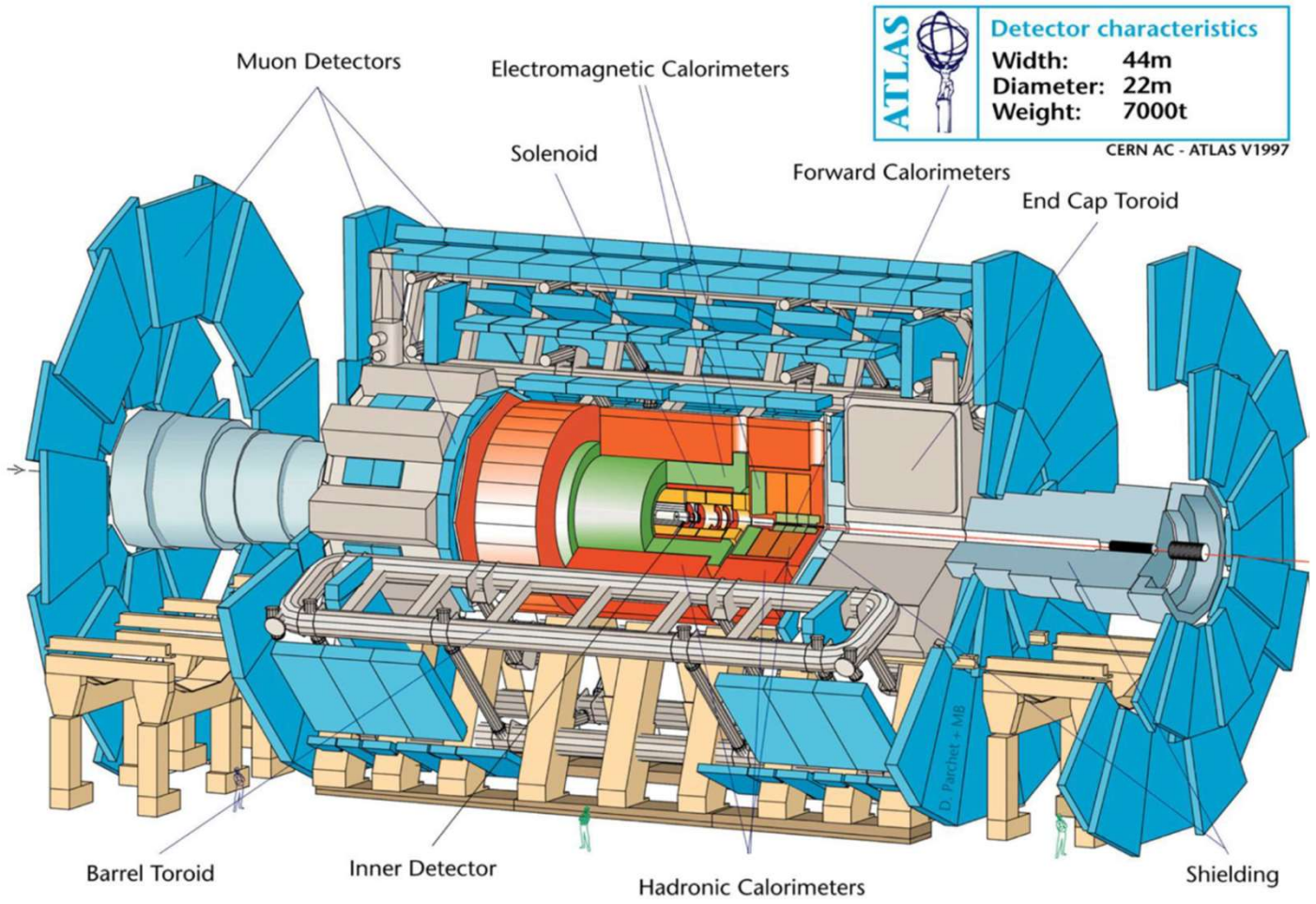
Toroids

Inner Detector

Electromagnetic Calorimeters

Hadron Calorimeters

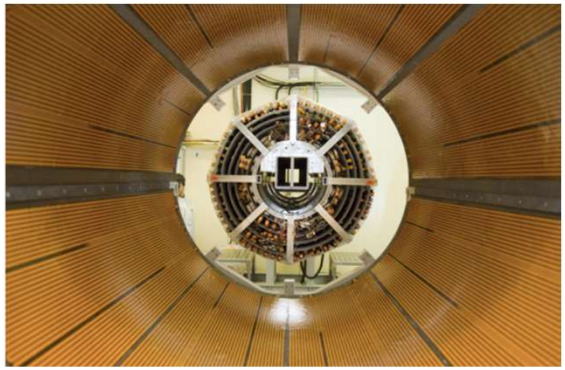
Muon Detectors



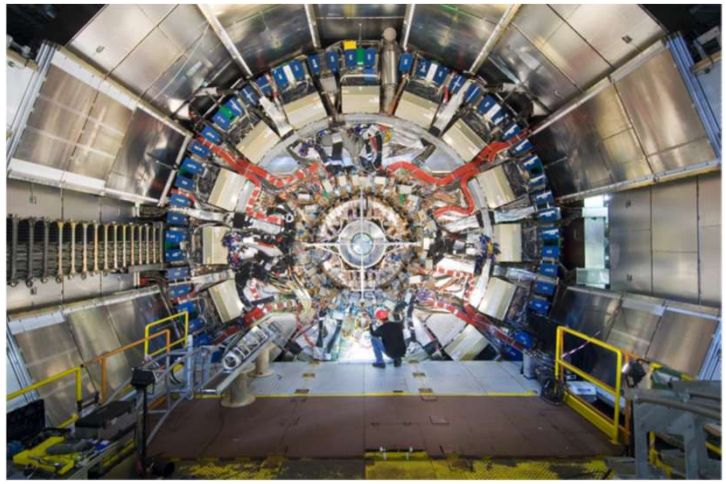
Atlas- Inner Tracker

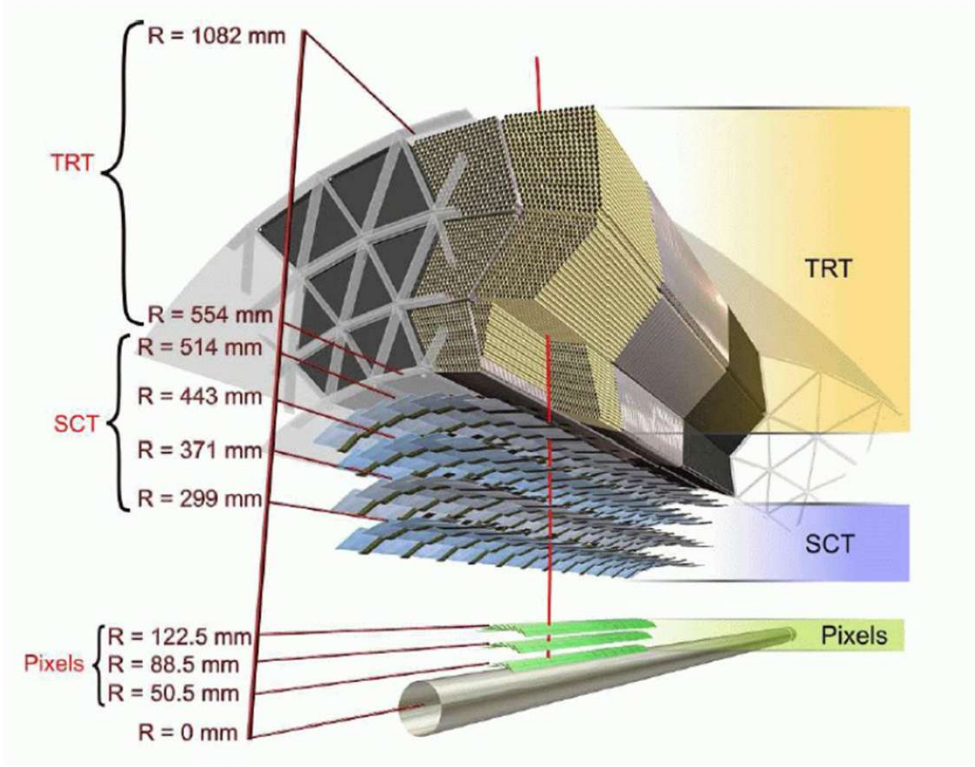
Pixel detector

Semiconductor tracker



Tracciatore interno

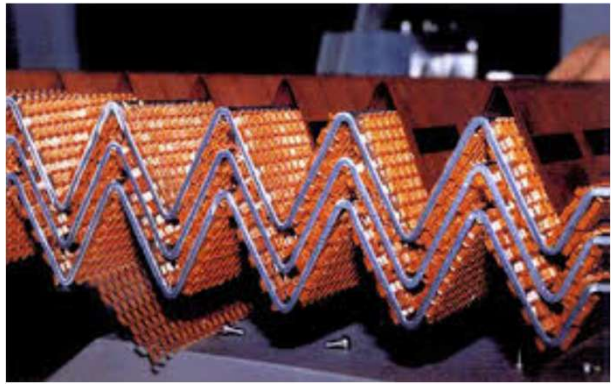




Semiconductor Detector Based
High Tracking Resolution 100 micron

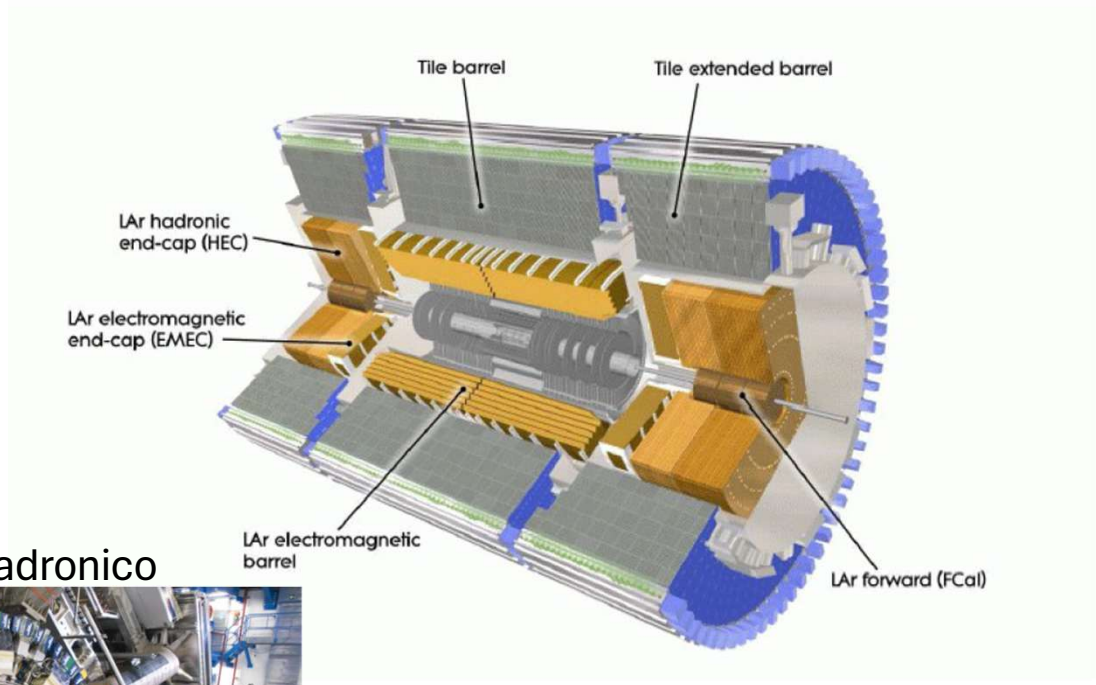
Atlas- Calorimeters

Il calorimetro elettromagnetico

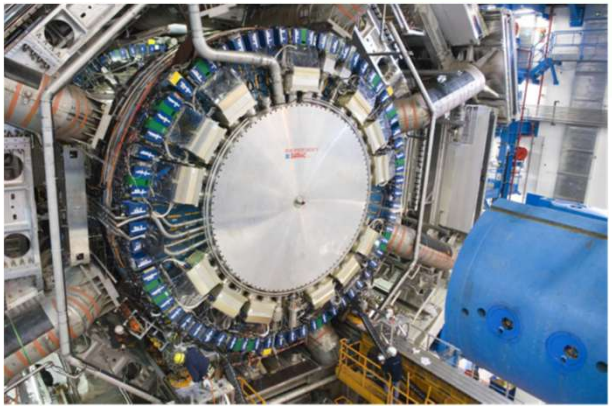


- Argon Liquido (rivelatore)

+ Piombo(assorbitore)



Il calorimetro adronico



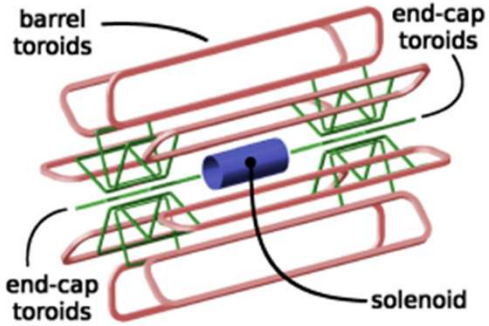
Scintillation Detector Based
Energy Resolution 10%/sqrt(E)

- Scintillatori plastici a mattonelle (rivelatore)

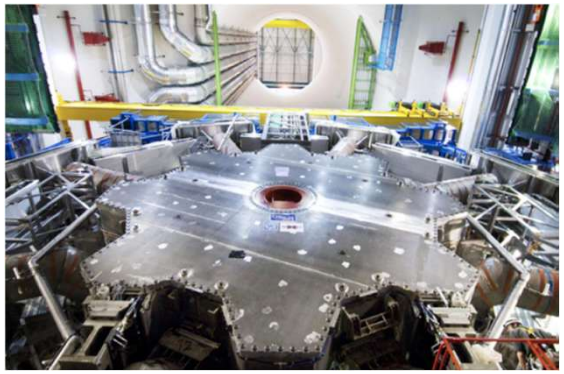
+ Ferro (assorbitore)

Atlas - Toroid Magnet

Outside of the solenoid are large air-core toroids with bending field of 1T over adistance of ~6m, BL^2=36 Tm^2



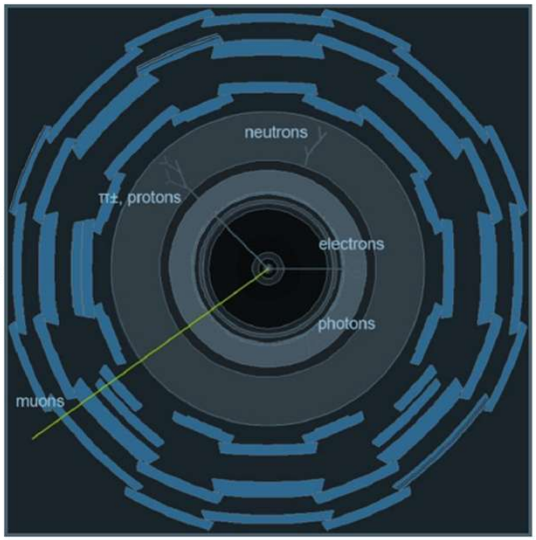
Additional end-cap toroid in forward and backward direction

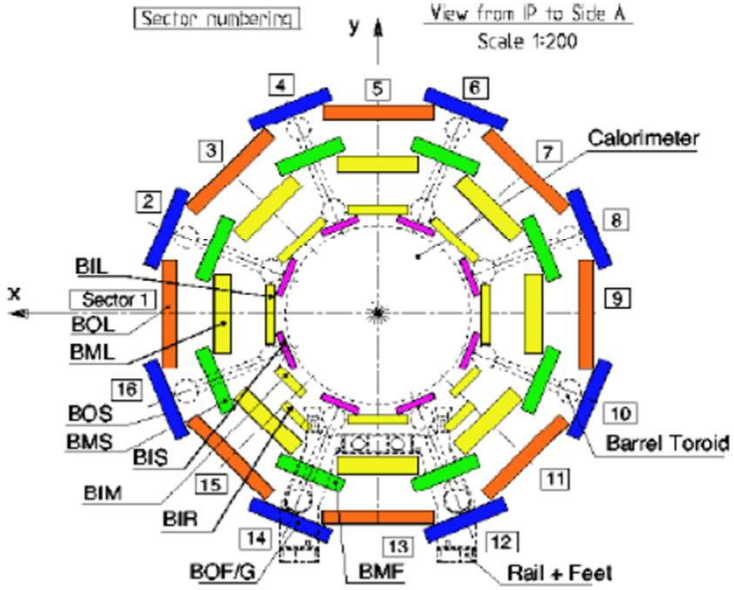


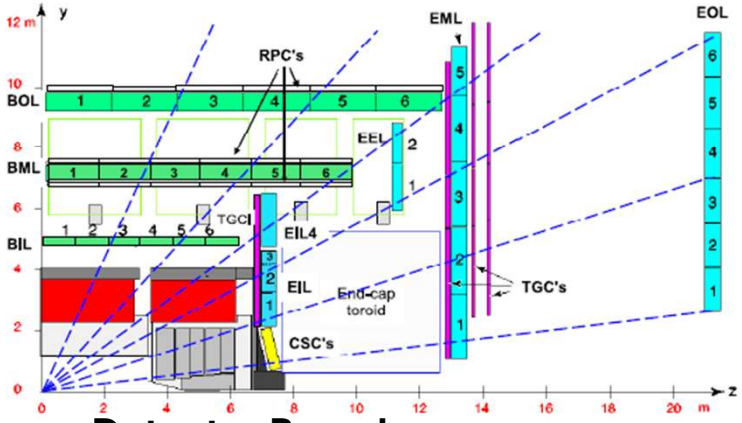
Central solenoid: L=1m in 2T bending field, BL^2=2 Tm^2

Atlas- Muon Spectrometer

- Only Muons pass through the entire detector, they can be detected separately from other particles
- **Useful for fast analysis of events**
- If muons with high transverse momentum (pT) are detected there is higher chance of interesting process







Gaseous Detector Based
Time Resolution 1 ns / Space Resolution 200 micron
Momentum Resolution order 1-10% at highest momenta

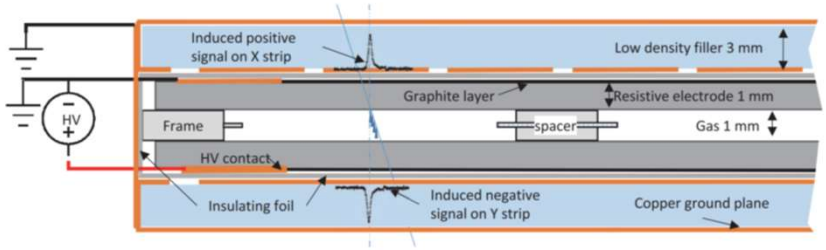
I rivelatori per Muoni di ATLAS

Monitored Drift Tubes (MDT)

- Tubo riempito di Ar+ con al centro un filo per raccogliere il segnale
- Il campo elettrico radiale è più intenso sul filo
- **Migliore risoluzione spaziale**

Resistive Plate Chambers (RPC)

Inventati qui a Tor Vergata da
Rinaldo Santonico e Roberto Cardarelli



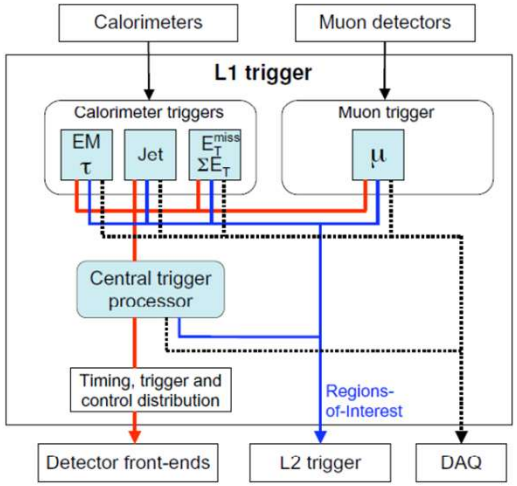
- Due elettrodi piani paralleli resistivi contengono di una miscela gassosa
- Il campo elettrico intenso è uniforme, perpendicolare agli elettrodi
- **Molto veloci e con una ottima risoluzione temporale, sono utilizzati come trigger**

Atlas- Trigger Selection

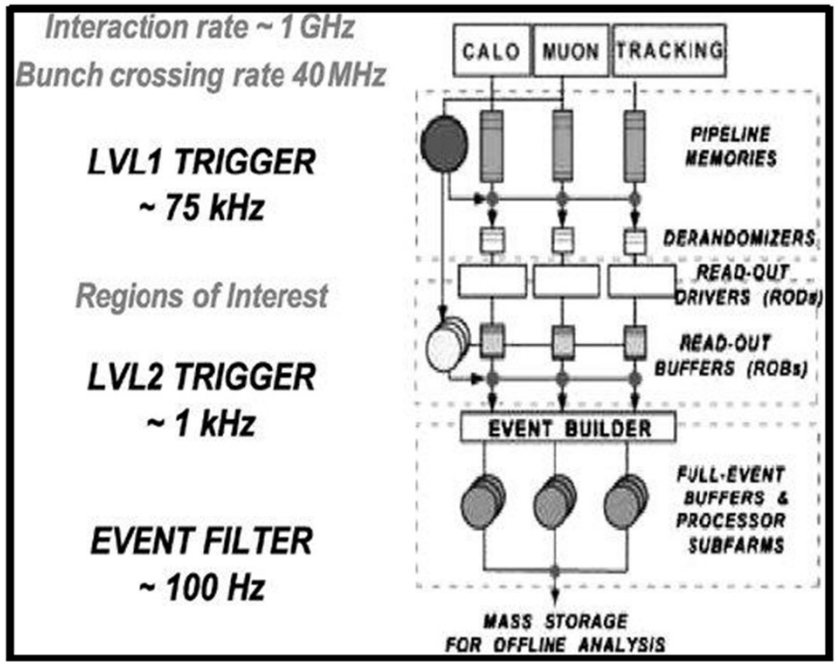
ATLAS collides protons at a rate of ~1GHz
- Raw data size for each event is ~1.6MB

Would require data flow capacity of 1.6PB/s to record everything
- Actual capacity is several 100MB/s

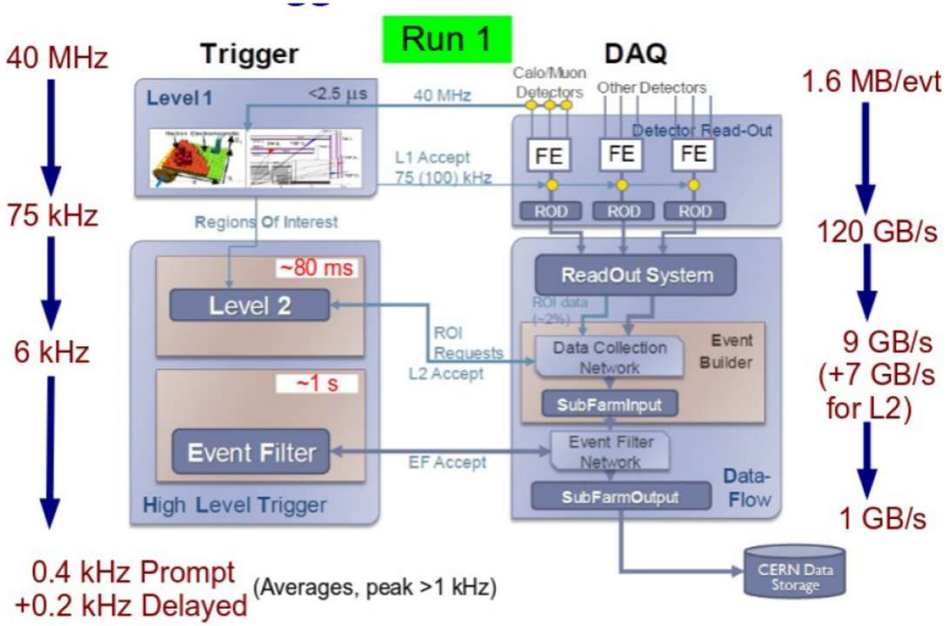
Require events to be filtered to ~100Hz
- Done using 3trigger levels

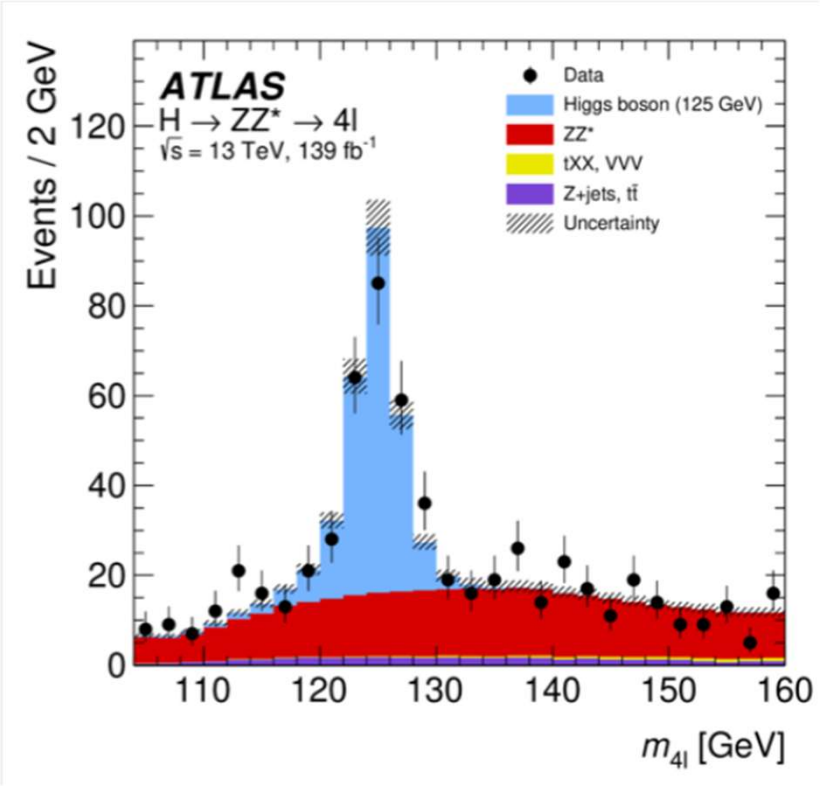


First of these is the Hardware LVL1 trigger
Needs to reduce events from ~1GHz to ~75kHz,
Requires very low latency (~2μs)



Atlas- Data Collection & Data Analisys





Upgrade Muon Detector: RPC BI

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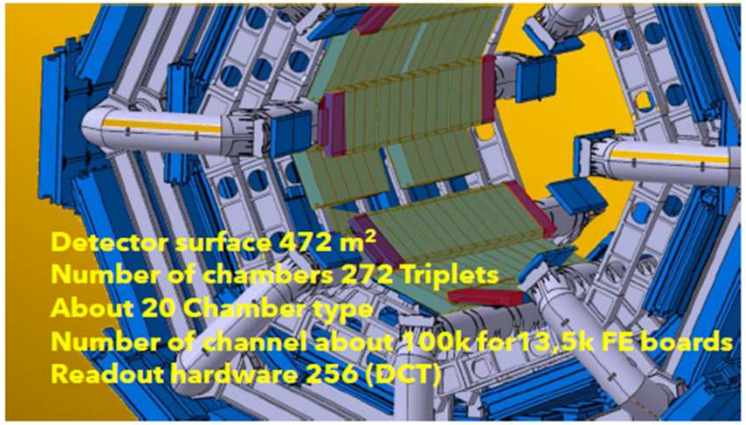
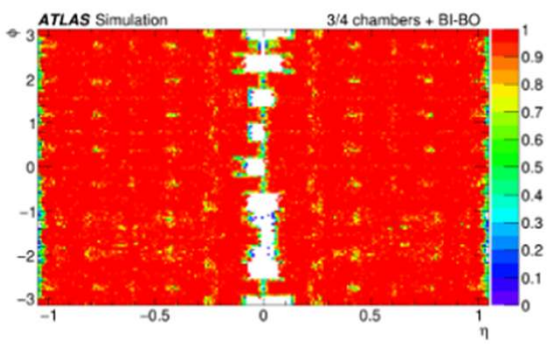
INTRODUCTION

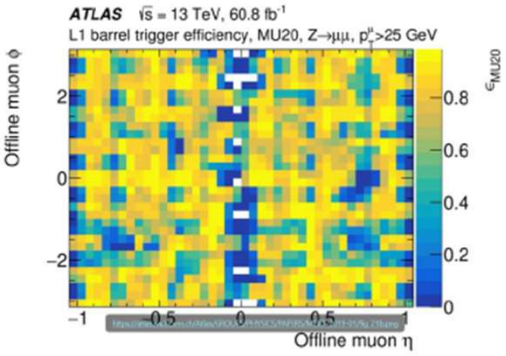
In view of the HL-LHC luminosity increase (7×10^{34} cm^{-2}s^{-1} @ 14 TeV p-p, <μ> =200) the Atlas Muon-Trigger needs major upgrades. The RPC system will be upgraded adding 272 new generation RPC detectors in the Barrel Inner and replacing the old on detector trigger PADs with new DCTs.

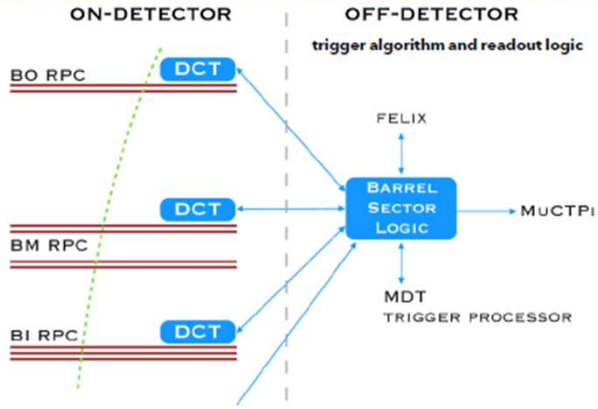
Improvement:

- **Trigger Redundancy (6 → 9 layers)**
- **Acceptance (78% → 92%, 96% with BI-BO coincidence)**
- Spectrometer lever arm (2.3 m → 4.5 m)
- Improved tracking and trigger capability
- Improved time resolution for TOF measurements









Upgrade Muon Detector: RPC BI

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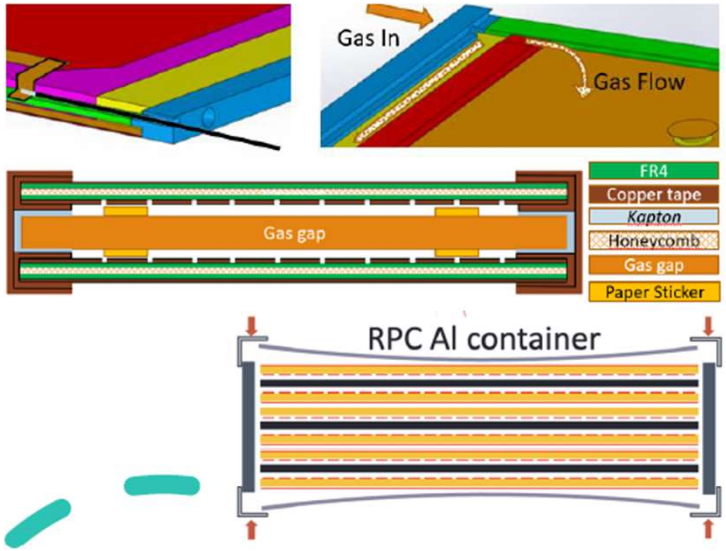
DESIGN OF THE NEW BI-RPC

Detector requirements

- **rate capability: → 7 kHz/cm²**
- **longevity: >10 years @ HL-LHC**
- **spatial resolution: <1 cm**
- **reduced envelope to be installed in the BI**



- **NEW GAS VOLUME DESIGN**
  - Gas-gap thickness 1 mm for 0.35 ns time resolution (WP = 5800 V)
  - Bakelite electrode thickness 1.4 mm
  - New HV connection on gas volume side Gas distributors on the short sides with 2 inlet and 2 outlet
  - New inlet pipe connection
- **NEW READOUT PANELS DESIGN**
  - Eta-Eta readout with ϕ coordinate reconstruction by leading time difference between two panels (1 cm)
  - Sandwich of aramid paper honeycomb between copper glade halogen free FR4 photoengraved plates for a total thickness of 3.8 mm
- **NEW FE ELECTRONICS**
  - 100 ps resolution TDC embedded,
  - minimum threshold 0.3 mV (min. detectable signal 1 ÷ 2 fC)

    → rate capability about 10 kHz/cm²
- **NEW CHAMBER STRUCTURE**
  - Three independent detectors with eta-eta read-out instead of two independent detector with eta-phi read-out

Atlas - Resistive Plate Chamber – R&D for Future

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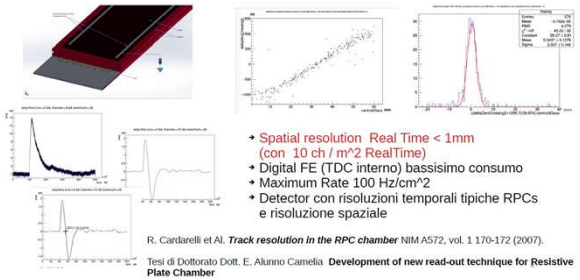
L' R&D : improved time resolution, rate capability, space resolution -> change in layout, in materials, in read-out strategy, in Front-End amplification capability, new gases mixtures

RPC - Spatial Resolution with Induced ionic signal



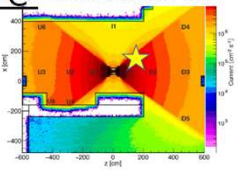
- Spatial resolution Real Time < 1mm (con 10 ch / m^2 RealTime)
- Digital FE (TDC interno) bassisimo consumo
- Maximum Rate 100 Hz/cm^2
- Detector con risoluzioni temporali tipiche RPCs e risoluzione spaziale

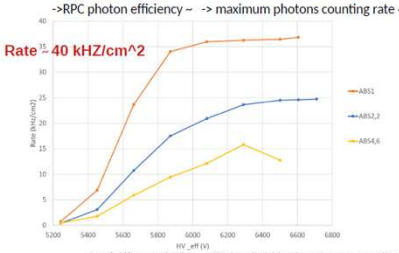
R. Cardarelli et Al. ***Track resolution in the RPC chamber*** NIM A572, vol. 1 170-172 (2007).

Tesi di Dottorato Dott. E. Alunno Camelia **Development of new read-out technique for Resistive Plate Chamber**

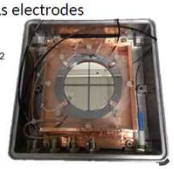
Rate capability performance of RPC with SI-GaAs electrodes

- **Hz/cm² in uniform high energy photons field**
- Equivalent discrimination threshold about 5 fC
- No photon converter on the electrode surface
  ->RPC photon efficiency ~ -> maximum photons counting rate ~/cm²





- Gas gap thickness 1 mm
- Semi Insulating GaAs electrodes
  Thickness 0.6 mm
  Resistivity 1.4×10^8 Ωcm
- Active area 6.25 cm²
- Four readout pads

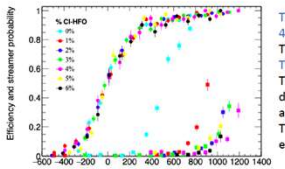


D. Pfeiffer et al, The radiation field in the Gamma Irradiation Facility GIF++ at CERN
A. Rocchi, R. Cardarelli, B. Liberti et al. *JINST* 15 (2020) 12, C12004. 10.1088/1748-0221/15/12/C12004

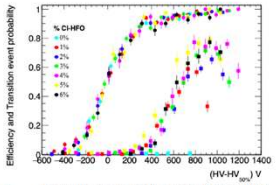
3/16/21

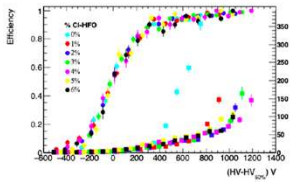
- Gas mixtures tested: HFO/CO2/i-C4H10/HFO-Cl

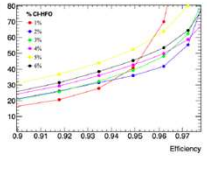
HFO/i-C_4H_{10} at a fixed ratio of (15/7) %+
variable ratio of CO_2/ Cl-HFO in the range (78/72) %/(0-6) %



The WP voltage increases at the rate ~ 400 V/1% Cl-HFO;
The WP efficiency is at least 93%;
The avalanche/streamer is ~ 400 V.
The transition event probability decreases when streamers start to appear, and is less than 20% at;
The time over threshold of transition events is less than 25 ns.



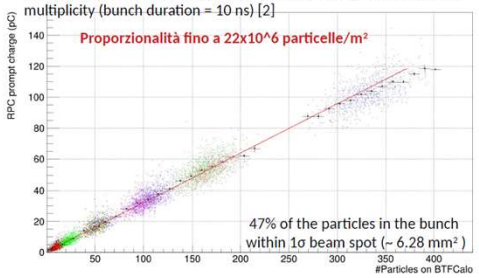




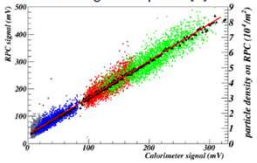
The ionic charge of the mixture 0% Cl-HFO reaches very high values (~ 75 pC) at low efficiency
The mixture with 5% and 6% Cl-HFO have an ionic charge more than 30 pC at the first plateau value
The mixture with 1% Cl-HFO shows the lowest ionic charge for $\epsilon < 94\%$
The mixture with 2% Cl-HFO shows the lowest ionic charge for $\epsilon > 94\%$

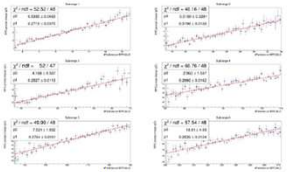
Analog calorimetry with RPC operated in saturated avalanche regime

RPC (1 mm gas gap thickness) electronic signal charge vs beam bunch multiplicity (bunch duration = 10 ns) [2]



Streamer regime response [1]



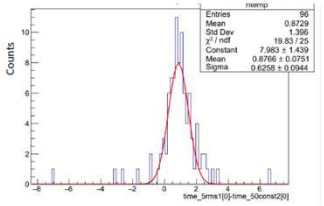


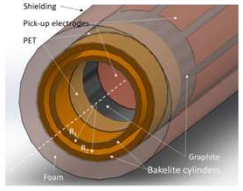
R. Bartoli et al. *Intrinsic linearity of bakelite Resistive Plate Chambers operated in streamer mode*. NIM Section A, 2019.
A. Rocchi, R. Cardarelli, B. Liberti et al. *JINST* 15 (2020) 12, C12004. 10.1088/1748-0221/15/12/C12004

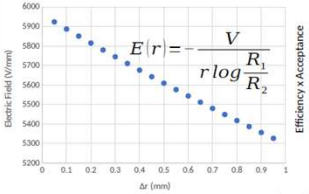
Resistive Cylindrical Chambers

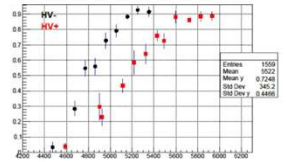
A cylindrical geometry consisting of two concentric pipes spaced by a gas gap allows to determine a very different evolution of the gas discharge development depending on the ratio of the facing surfaces radii

- The cylindrical geometry is resistant to the gas over-pressures. It can be argued that a gap working at a higher pressure is equivalent to a thicker gap, solving the lack of efficiency observed in the uniform field single thin gaps.
- In over pressure mode, new eco gases would be suitable for saturated working mode









R. Cardarelli "***Future RPC developments***", RPC2020 Roma 10-14 /02/2020 proceeding su JINST

Analisi Dati ATLAS

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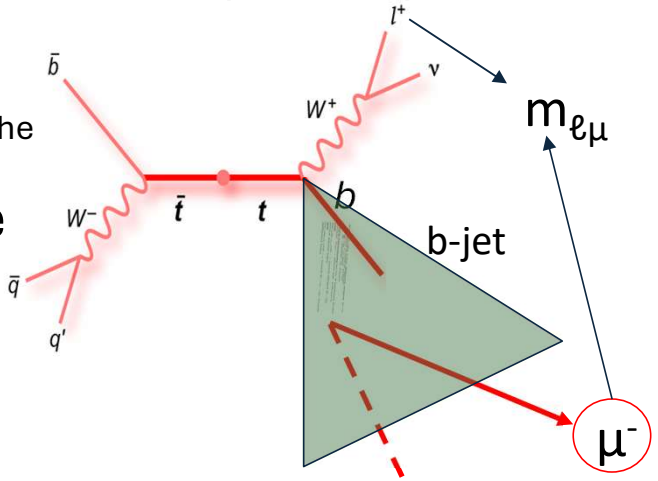
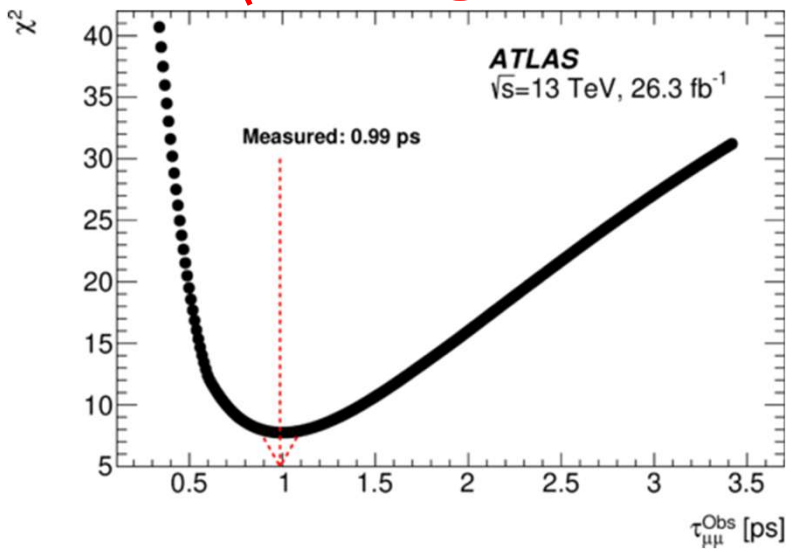
- Soft Muon Tagging algorithm development
  - PRIN project MIDDLE on this topic
  - Using top-antitop events in Run2/Run3 data
  - Usage of ML techniques to improve the identification efficiency and the fake rejection
- BR($B^0_{(s)} \rightarrow \mu\mu$) and $B^0_s \rightarrow \mu\mu$ effective lifetime
  - First ATLAS measurement in 2023
  - Compatible with CMS, LHCb measurements
  - Both measurements sensitive to BSM physics in a complementary way
  - Publication using full Run2 data by Fall
- W+ charm cross section
  - Test of pQCD, measurement of strange PDF;
  - work ongoing on data-driven background estimation, EB request in the Fall
- Muon detector performance in Run 2 and Run 3
  - 1 paper in preparation (Run 3) on muon performance, EB request in early Fall
  - 1 paper in preparation on Machine Learning based muon isolation, EB request before the end of the year (Run 2 + Run 3)





Atlas- have a good trip!