The Muon Spectrometer of the ATLAS detector:
progress report on construction and
physics studies at the University of Athens.

Stefanides Stathis
University of Athens

Speech Flow

A) CONSTRUCTION

1. The ATLAS Detector: An overview
2. The Muon Spectrometer.
    a. basics
    b. greek contribution
3. MDT Assembly line at the University of Athens.
4. Data Acquisition for the MDT.
    a. Motivations
    b. Features
    c. Operations
    b. Results

Speech Flow

B) PHYSICS STUDIES

1. The decay channel $H \rightarrow ZZ \rightarrow 2\mu^- 2\mu^+$: main features.

2. How the study is done.

3. Effect of the misalignment on the measured muon momentum.

4. Effect of the misalignment on the search for the Higgs.

   a. Generation Level

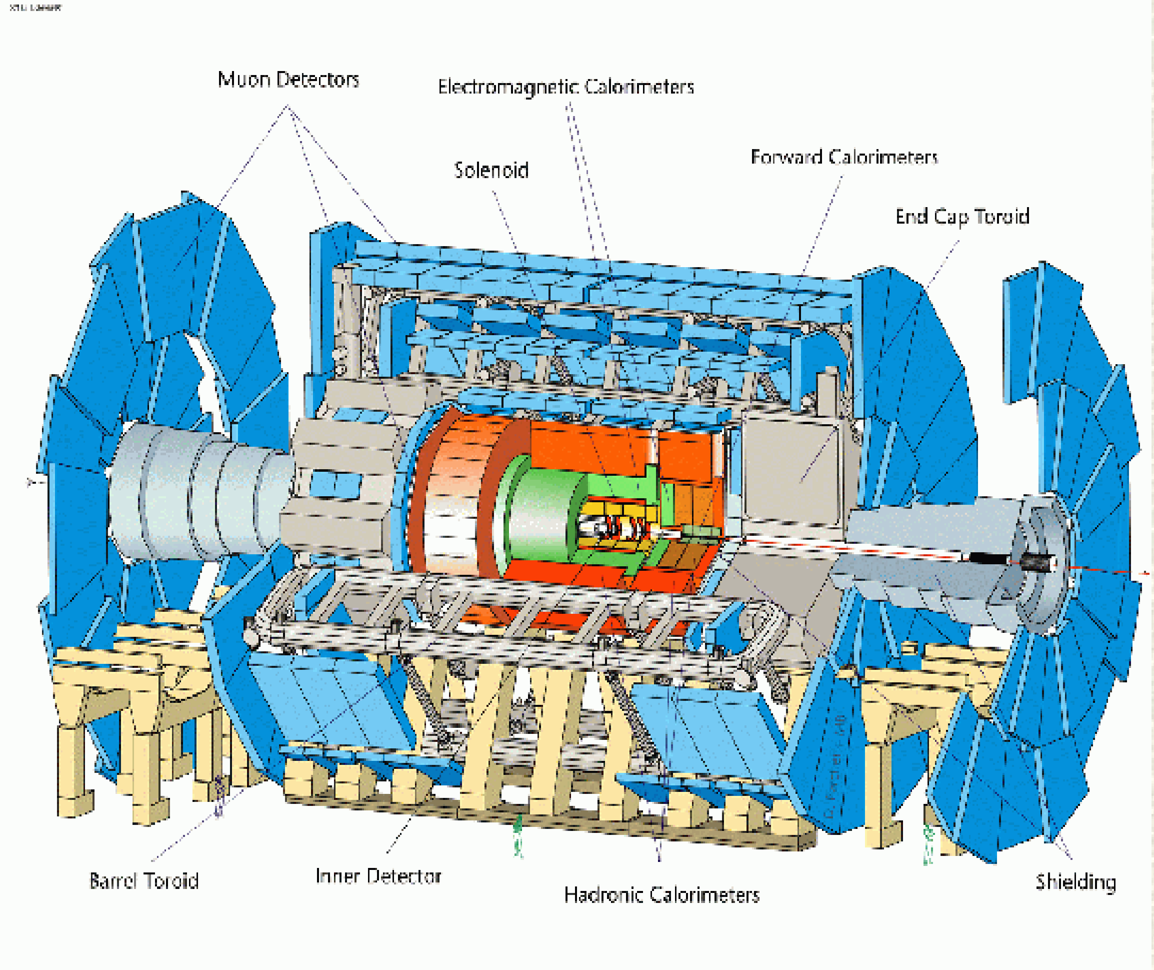
   b. Energy loss

   c. Reconstruction Level

5. Constraint Fitting: A way to improve the reconstructed info.

A) CONSTRUCTION

1 / 4. The ATLAS Detector: An overview

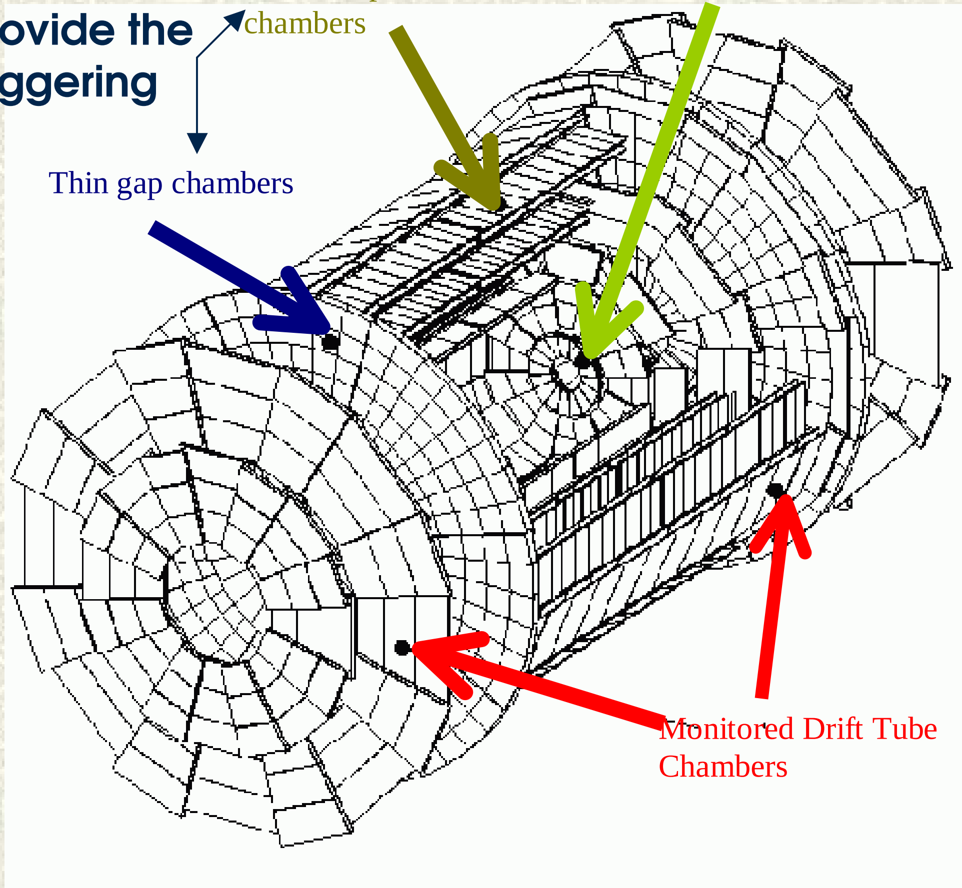


1. **pp colliding beams**
   14 TeV c.m. energy.
2. **Designed luminosity:**
   $L = 10^{34}\ cm^{-2} sec^{-1}$.
3. **Three Parts :**
   a) **Inner Detector**
   b) **Calorimeter (E/M-H/D)**
   c) **Muon Spectrometer**
4. **Magnet System:**
   a) **Solenoid : ~2 Tesla**
   b) **Toroid : ~0.4 Tesla**

A) CONSTRUCTION

2 / 4. The Muon Spectrometer. basics

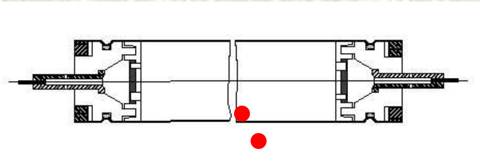
Provide the triggering

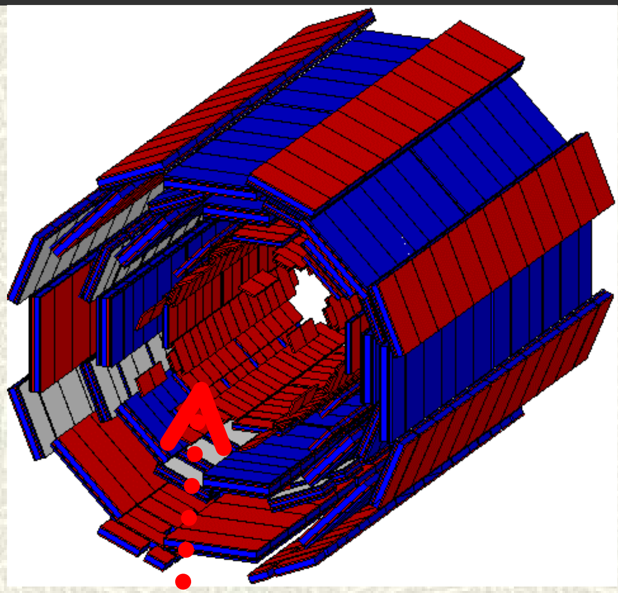


1. Based on the magnetic deflection of muon tracks.
2. Uses four chamber technologies:
   - a. Monitored Drift Tubes (MDT)
   - b. Cathode Strip Chambers (CSC)
   - c. Resistive Plate Chambers (RPC)
   - d. Thin Gap Chambers (TGC)
3. Particles from the IP travel through 3 stations of chambers.

A) CONSTRUCTION

2 / 4. **The Muon Spectrometer.-**greek contribution



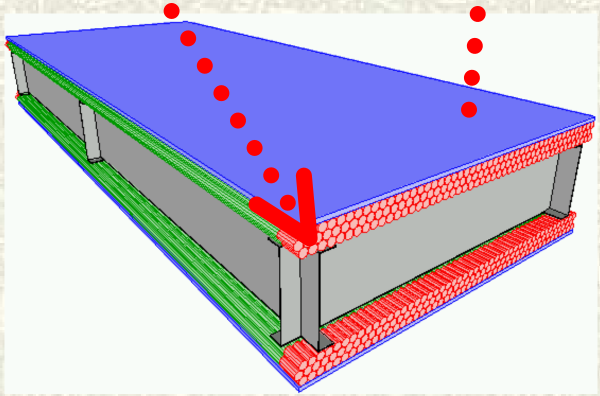


1. Construction of the ***B**(arrel)**I**(nner)**S**(mall)* chambers.
2. 3 Collaborating Institutes:

a. University of Athens (MDT assembly)

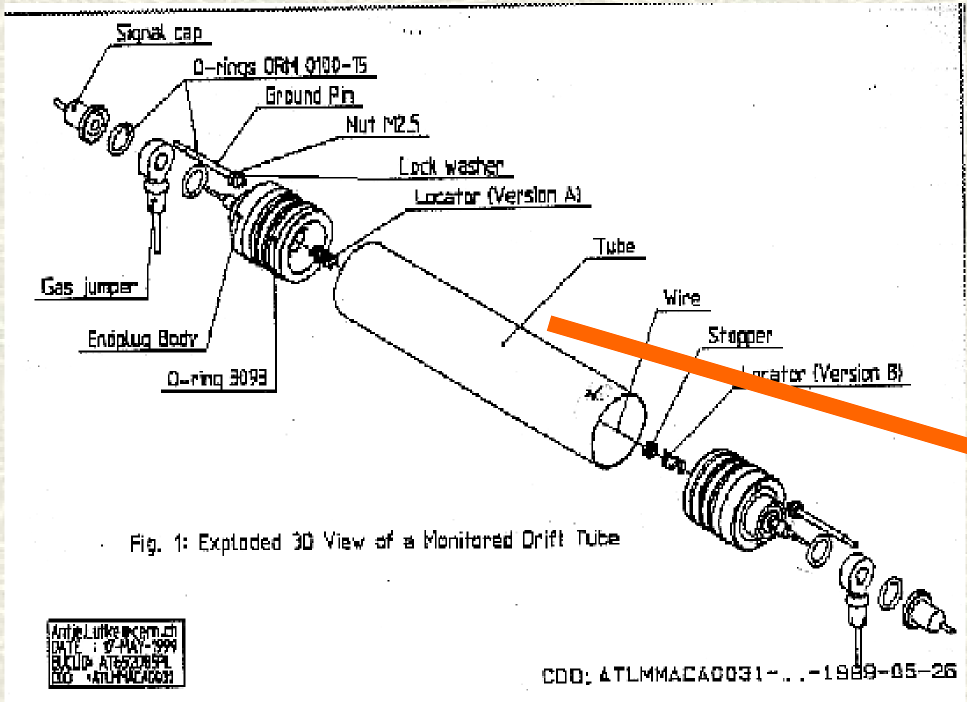
b. National and Technical University (Quality Check and Quality Assurance)

c. Aristotle University of Thessaloniki (Chamber Assembly)



A) CONSTRUCTION

3 / 4. **MDT Assembly line in the University of Athens.**



A) CONSTRUCTION

4 / 4. **Data Acquisition for the MDT :** MOTIVATIONS

A. **Requirement for satisfying construction specifications:**

.**<u>wire's mechanical tension:</u>** 350±15 gr at 20 ±1 °C

.**<u>finished tube's length:</u>** 1671,5 ±0.25 mm

B. High Production Rate

C. Reliable Operation

D. Automatic recording the features of each individual tube:

Quick and automatic filling of the Data Base.

A) CONSTRUCTION

4 / 4. **Data Acquisition for the MDT :** FEATURES

1. **Written in Lab-View.**

2. **Mean construction time reduced by 40%.**

   Allows parallel tasks.

3. **User- friendly environment .**

Questions- Constant Commu-nication.

Classification in clusters (colors).

Ability for intervention.

A) CONSTRUCTION

4 / 4. Data Acquisition for the MDT : OPERATIONS

1. Entering a set of parameters.

2. Entering the Bar Code.

3. Performing pre-tensioning and tensioning.

4. Recording the finished tube's length.

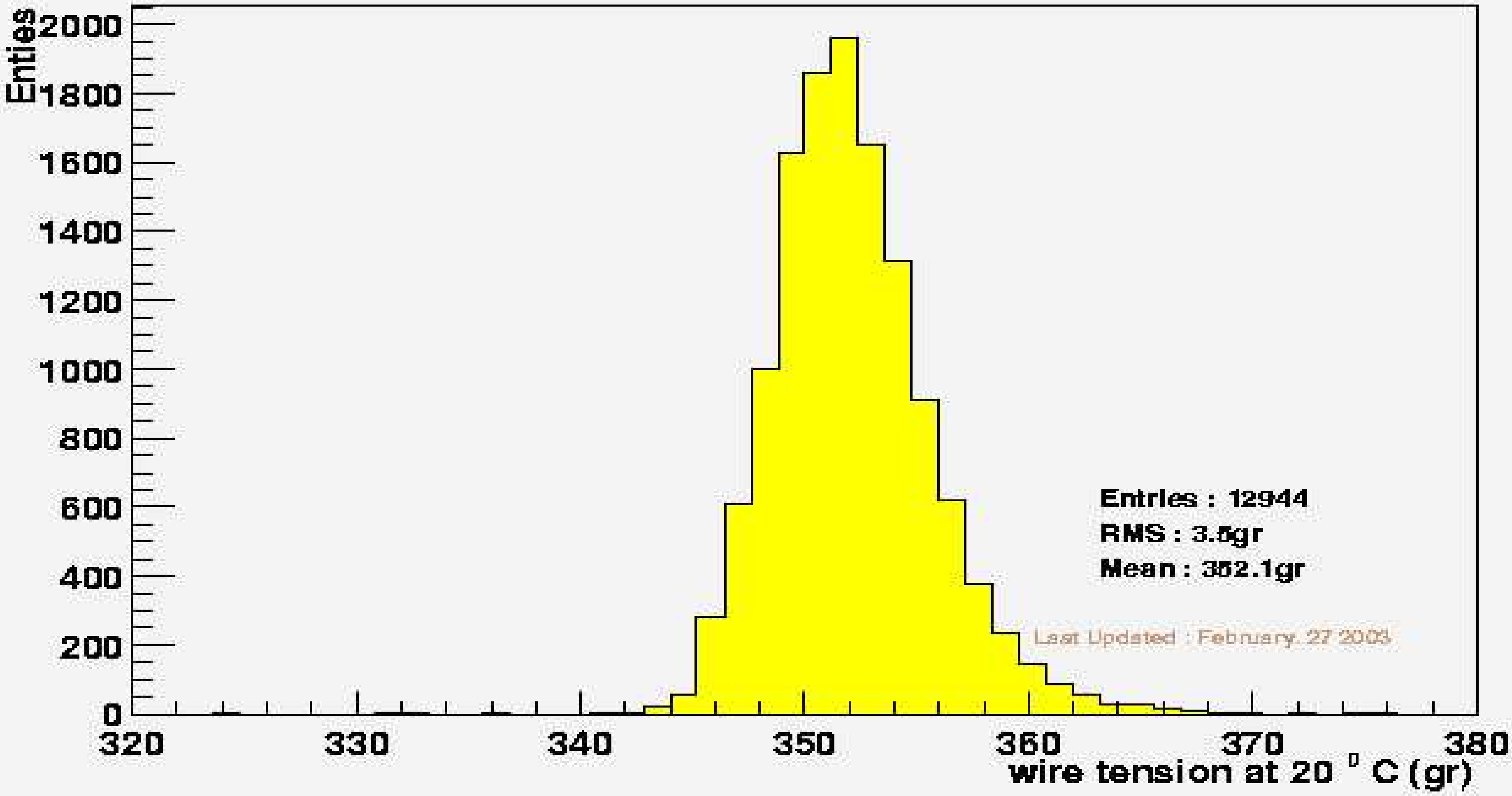
5. Recording the wire's mechanical tension.

6. Recording the date and time.

7. Storage.

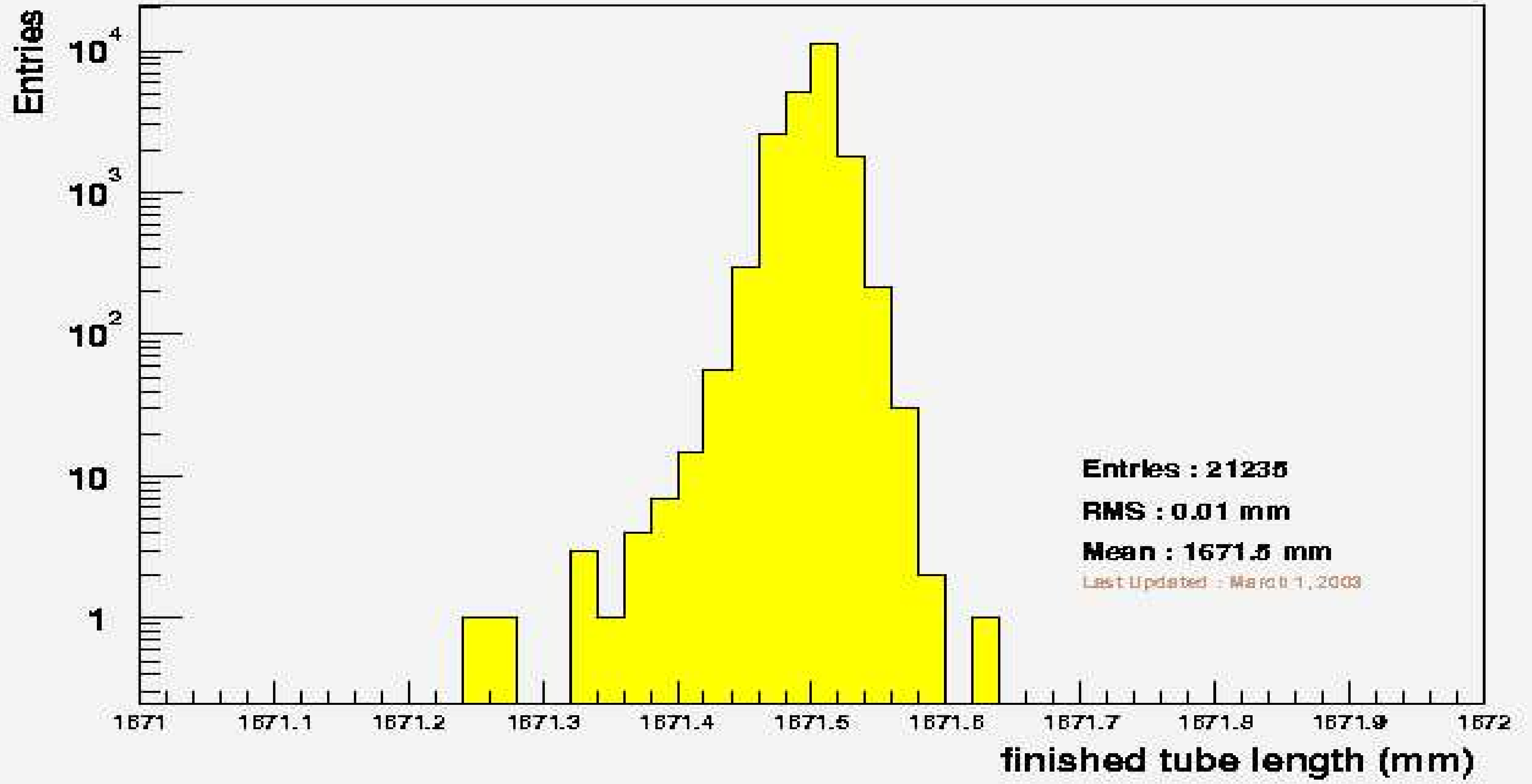
A) CONSTRUCTION

4 / 4. Data Acquisition for the MDT : RESULTS



A) CONSTRUCTION

4 / 4. Data Acquisition for the MDT : RESULTS



B) PHYSICS STUDIES

1/5. The decay channel $H \rightarrow ZZ \rightarrow 2\mu^- 2\mu^+$

- The most reliable channel in the mass range :
  $180\ GeV/c^2 < m_H < \sim 700\ GeV/c^2$

- Expected Background : continuum production of Z boson pairs:
  $Z(\gamma^*)Z(\gamma^*) \rightarrow 4l$

- For $m_H > 300\ GeV/c^2$, Γ_H increases rapidly and overlaps the experimental mass resolution.

- High-momenta of the final-state leptons.

- $\sigma_m = ((\Gamma_H/2.36)^2 + (0.02 m_H)^2)^{1/2}$.

B) PHYSICS STUDIES

2/5. How the study is done.

(i). Generation : Pythia

(ii). Simulation: LHCTOR (Ver. 6.203) $\Rightarrow$ Interface to GEANT

(iii). Reconstruction : MuonBox (Ver. 6.305)

(iv). Chamber Displacement : Code written by D.S. Levin

(v). Analysis : C/C++ Code.

- **Use the ROOT interface**
- **Apply the OO philosophy**

3/5. Effect of the misalignment on the measured muon momentum.

Production : P_T = 80 GeV/c , η = 0.5, all φ's
Displacement : along z-axis, randomly at 0, 100, 150, 200, 250, 300 microns

$\Delta P/P$

Displacement	0 µm	100 µm	150 µm	200 µm	250 µm	300 µm
Gaussian Mean	1.616×10^{-3}	1.748×10^{-3}	1.681×10^{-3}	2.191×10^{-3}	2.622×10^{-3}	2.602×10^{-3}
Gaussian Sigma	1.952×10^{-2}	2.021×10^{-2}	2.154×10^{-2}	2.352×10^{-2}	2.597×10^{-2}	2.882×10^{-2}
% events out of 2 sigma	17.10%	16.90%	17.78%	18.94%	20.99%	23.11%

$\Delta P_T/P_T$

Displacement	0 µm	100 µm	150 µm	200 µm	250 µm	300 µm
Gaussian Mean	1.797×10^{-3}	1.782×10^{-3}	1.840×10^{-3}	2.297×10^{-3}	2.564×10^{-3}	2.787×10^{-3}
Gaussian Sigma	1.952×10^{-2}	2.030×10^{-2}	2.105×10^{-2}	2.353×10^{-2}	2.588×10^{-2}	2.877×10^{-2}
% events out of 2 sigma	16.92%	16.70%	17.50%	18.74%	20.74%	23.03%

4/5. Effect of the misalignment on the search for the Higgs: Generation Level.

- Generated Higgs:

$m_H = 300 \pm 0$ GeV/c^2 , $\Gamma_H = 8.45 \pm 0.10$ GeV/c^2

- BUT AFTER γ-Radiation (Bremsstruhlung Radiation)

$m_H = 299.1 \pm 0.1$ GeV/c^2 , $\Gamma_H = 9.95 \pm 0.14$ GeV/c^2

- We loss (8.61 ± 0.20) % of the events because one at least muon has

P<5 GeV/c or P_T<3 GeV/c or η >3

4/5. Effect of the misalignment on the search for the Higgs: Energy Loss.

- Muons' mean energy loss at Calorimeter: ~4.5 GeV
- Parametrization of the energy loss in the EM Calorimeter:

$$\text{Energy\_Loss} = a_o + a_1 \cdot p + a_2 \cdot p^2$$

$$\text{Error} = b_o + b_1 \cdot p$$

where the coefficients a and b depend on η and p is the reconstructed momentum for each muon.

4/5. Effect of the misalignment on the search for the Higgs: Reconstruction Level.

- Require 4 final-state muons (generated AND reconstructed)
- Efficiency: (73.4 ± 0. 4) %
- No background is used (yet!!!)
- Correct muon pairing selection: (91.5 ± 0.4) %

4/5. Effect of the misalignment on the search for the Higgs: Reconstruction Level.

$\Delta M_H / M_{H\text{-GENERATED}}$

M_H = 200 GeV/c^2

Displacement	0 μm	100 μm	150 μm	200 μm	250 μm	300 μm
Gaussian Mean	6.496×10^{-3}	6.232×10^{-3}	6.449×10^{-3}	6.471×10^{-3}	6.505×10^{-3}	6.442×10^{-3}
Gaussian Sigma	2.387×10^{-2}	2.404×10^{-2}	2.406×10^{-2}	2.487×10^{-2}	2.545×10^{-2}	2.638×10^{-2}
% events out of 2 sigma	12.49 %	12.02 %	12.54 %	12.79 %	13.18 %	14.06 %

M_H = 300 GeV/c^2

Displacement	0 μm	100 μm	150 μm	200 μm	250 μm	300 μm
Gaussian Mean	4.882×10^{-3}	5.133×10^{-3}	5.382×10^{-3}	5.349×10^{-3}	5.593×10^{-3}	5.533×10^{-3}
Gaussian Sigma	2.349×10^{-2}	2.414×10^{-2}	2.502×10^{-2}	2.621×10^{-2}	2.790×10^{-2}	2.930×10^{-2}
% events out of 2 sigma	13.66 %	13.37 %	14.05 %	14.62 %	15.10 %	16.4 %

5/5. Constraint Fitting: A way to improve the reconstructed information: Introduction.

- Uses the Lagrange Multipliers to minimize the quantity:

$$\chi^2 = \sum_{i=1}^{2} \left(\frac{P^i{}_r - P^i{}_f}{\sigma_{P^i}} \right)^2 + \left(\frac{\theta^i{}_r - \theta^i{}_f}{\sigma_{\theta^i}} \right)^2 + \left(\frac{\phi^i{}_r - \phi^i{}_f}{\sigma_{\phi^i}} \right)^2$$

- Impose the constraint on the Z mass, i.e force the invariant mass of the 2 muons be the Z mass.

- For the 2 possible combinations :

  INPUT : P_r, θ_r, φ_r and σ_P , σ_θ, σ_φ for each muon.

  OUTPUT: P_f, θ_f, φ_f and χ^2 of the fit.

- Choose finally the combination with the least χ^2.

- Code written in C++.

5/5. Constraint Fitting: A way to improve the reconstructed information: Results.

Study done for: zero displacement

constraint value on Z-mass = 91.2 GeV/c^2

Breit-Wigner Fit at range : $M_H \pm 50$

M_H= 300 GeV/c^2

	Reconstructed	Fitted
Mass	*295.9* ± 0.3	300.5 ± 0.2
Width	20.71 ± 0.55	19.41 ± 0.51
% events out of 2 sigma	*31.29 %*	*33.92 %*

M_H= 200 GeV/c^2

	Reconstructed	Fitted
Mass	197.2 ± 0.1	200.6 ± 0.1
Width	8.57 ± 0.19	7.83 ± 0.21
% events out of 2 sigma	*33.82 %*	*30.39 %*

THE CONSTRAINT FITTING DOESN'T HELP US MUCH. BUT……

…..WHY DO WE FORCE ALL Z's BE BORN AT 91.2 GeV/c^2 ???

NEXT STEP : Let Z's be born following a B-W distribution.

STAY TUNED….