Experiment ATLAS/LHC and participation of Slovakia

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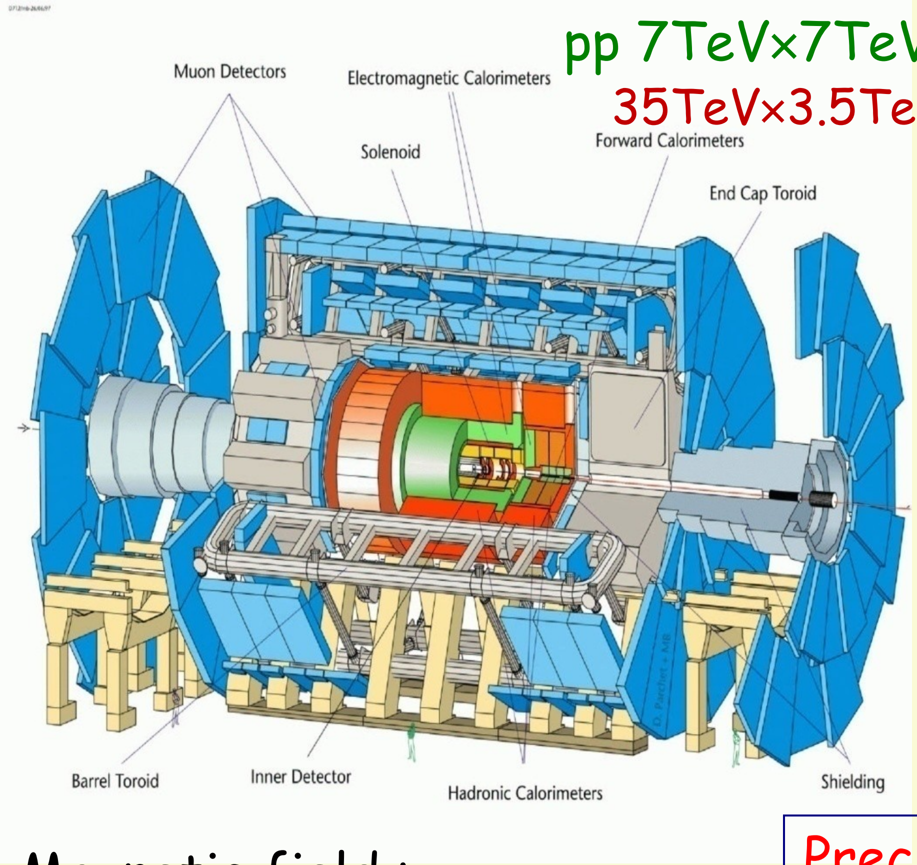
Outline

- Experiment ATLAS - basic facts
- Why we need LHC
- Participation of Slovak teams in building of ATLAS
- On Kosice team ATLAS activities
- On Bratislava team ATLAS activities
- Outreach
- Conclusions

Detektor experimentu ATLAS

Multipurpose particle detector (coverage |η|=5, $L=10^{34}\ cm^{-2}s^{-1}$)



pp 7TeV×7TeV

35TeV×3.5TeV

- **Inner Detector**

$\sigma / p_T \approx 0.05\% \cdot p_T(GeV) \oplus 0.1\%$

Tracking range |η|< 2.5

- **EM Calorimetry**

$\sigma / E \approx 10\% / \sqrt{E(GeV)} \oplus 1\%$

Fine granularity up to $|\eta| < 2.5$

- **Hadronic Calorimetry**

$\sigma / E \approx 50\% / \sqrt{E(GeV)} \oplus 3\%$

Range: $|\eta| < 4.9$

- **Muon System**

$\sigma / p_T \approx 2 - 7\%$, range: $|\eta| < 2.7$

Magnetic field :

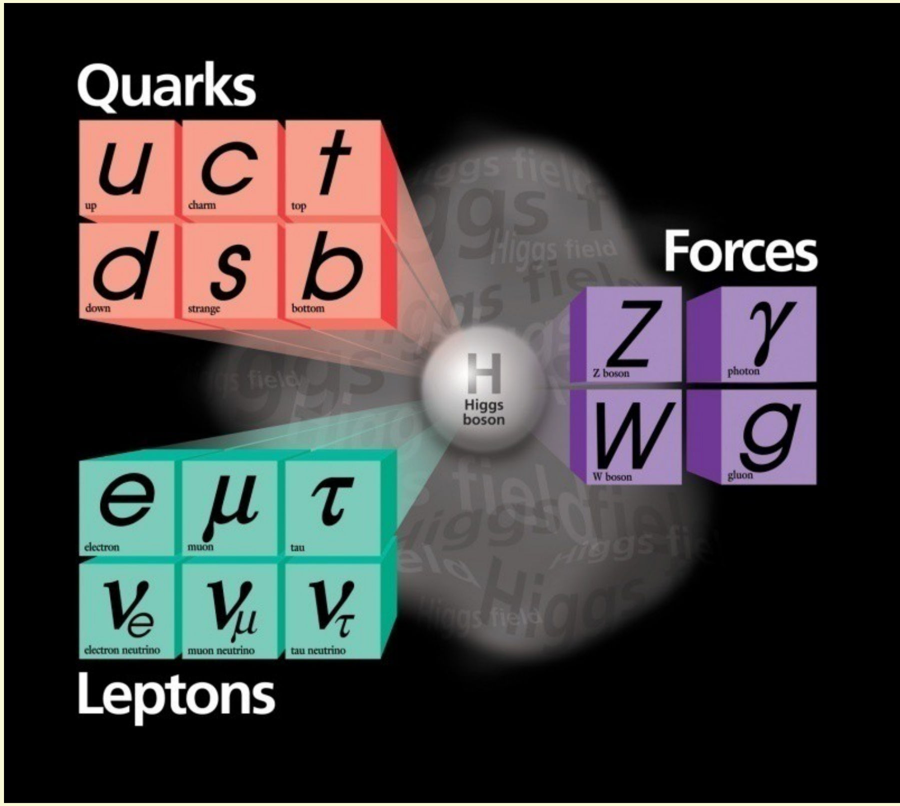
2T Solenoid + 3 air core toroids

start: autumn 2009

Precision physics in |η|<2.5
Lepton energy scale: 0.02% (Z→ll)
Jet energy scale: 1.0 % (W →jj)

Why we need LHC: present staus

SM: full version - 25 (26) parameters



EWSB(E-W symmetry breaking):

$SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$

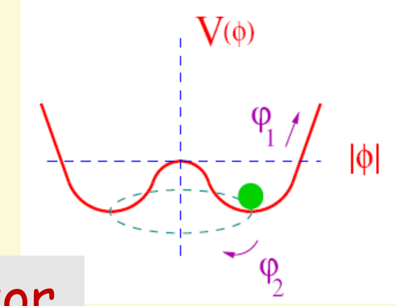
$\rightarrow SU(3)_c \otimes U(1)_{QED}$

EWSB consequences:

- ✓ $\langle\phi\rangle \neq 0$
- ✓ W, Z bosons: $M_W, M_Z \neq 0$
- ✓ leptons, and quarks: $m_{l,q} \neq 0$
- ✓ Gluons a photons: $m = 0$

Higgs sector: 1 neutral Higgs boson H

→Higgs field $\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$ $V(\phi) = -|\mu^2||\phi|^2 + \lambda\left(|\phi|^2\right)^2$



Moment 1: Study of the symmetry breaking in Higgs sector

LHC: need to go beyond SM

Minimal SuSy extension of SM (MSSM): 19+105 parameters

Moment 2: in SM
✓No candidate on dark matter
✓ n_B/n_γ:
Obs: 5.5×10^{-10}
SM: $< 10^{-20}$

SM		Spin	SUSY		Spin
leptons	$\ell,\ \nu_\ell$	$\frac{1}{2}$	sleptons	$\tilde{\ell},\ \tilde{\nu}_\ell$	0
quarks	q	$\frac{1}{2}$	squarks	$\tilde{q}$	0
gluons	g	1	gluinos	$\tilde{g}$	$\frac{1}{2}$
EW bosons	$\gamma,\ Z,\ W$	1	charginos	$\tilde{\chi}^{\pm}_{1,2}$	$\frac{1}{2}$
Higgs	$h,\ H,\ A,\ H^{\pm}$	0	neutralinos	$\tilde{\chi}^{0}_{1,2,3,4}$	$\frac{1}{2}$

Lightest SuSy particle is stable: LSP = $\tilde{\chi}_1$ (dark matter candidate)

→Higgs sector

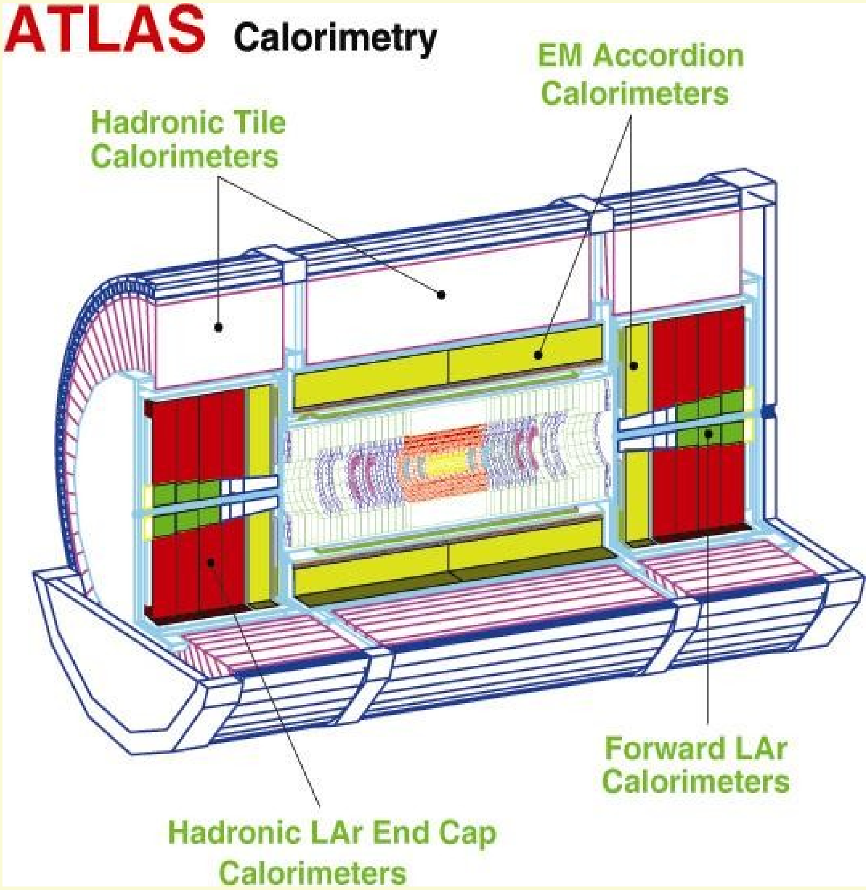
$$\phi_2 = \begin{pmatrix} \phi_2^+ \\ v_2 + \phi_2^0 \end{pmatrix}, \quad \phi_1 = \begin{pmatrix} v_1 + \phi_1^0 \\ \phi_1^- \end{pmatrix}, \quad \tan\beta = \frac{v_2}{v_1}$$

Physical Higgs bosons: h, H, A, $H^{\pm}$
2 vacuum expectation values $\neq 0$

xSec ~ $\tan^2\beta$ enhanced: fb→pb !

Construction and testing of ATLAS detector

- Kosice team: Hadronic LAr End Cap calorimeter (HEC) based on liquid argon technology
- Bratislava team: Hadronic Tile calorimeter (Tile) – scintill. tiles +fibers
- Hardware:
  - ✓Development, production and tests of Forward readout board (with Columbia Univ.) (HEC)
  - ✓Production of so-called cold electronics (HEC)
  - ✓Iron plates for Tile calorimeter
  - ✓Angle bracket for tile modules manipulations



Both team: in assembling and commissioning of Calo's

ATLAS group in Košice

Team: 5 physicists; 2 engineers, 1 PhD student, 3 technicians

Basic topics:

In the past:

✓study of HEC properties, cosmic runs analysis,...

✓ analysis of data from the tests carried out in H6 channel in CERN

✓ analysis of data from the high luminosity runs in Protvino

✓ commissioning of LAr Endcap calorimeter.

❑ Now:

✓ on-line calibration (LAr on-line calibration convenor is from KE team)

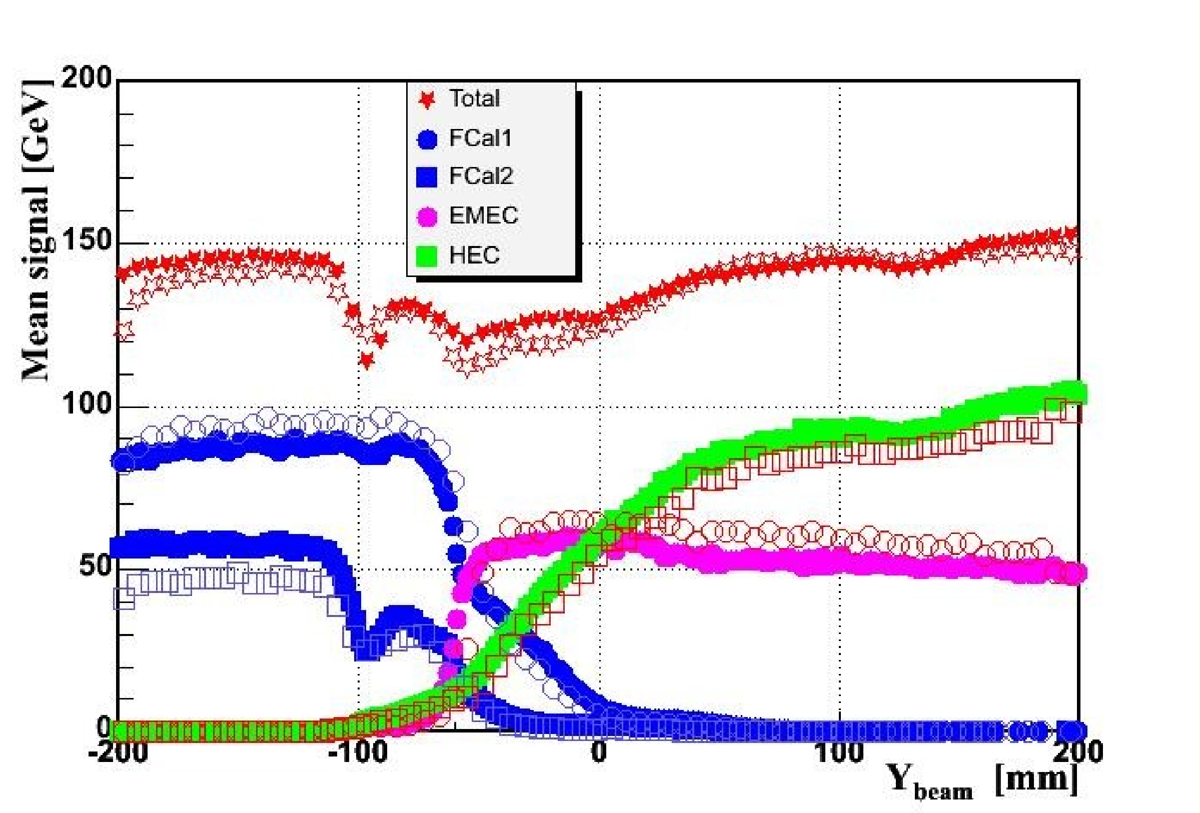
✓ATLAS shifts for data accumulation

✓ study of top/anti-top production in pp collision in dilepton channel

✓ electronics upgrade (ADC,...) for the ATLAS upgrade with a close collaboration with Columbia University.

KE team: test beam data analysis

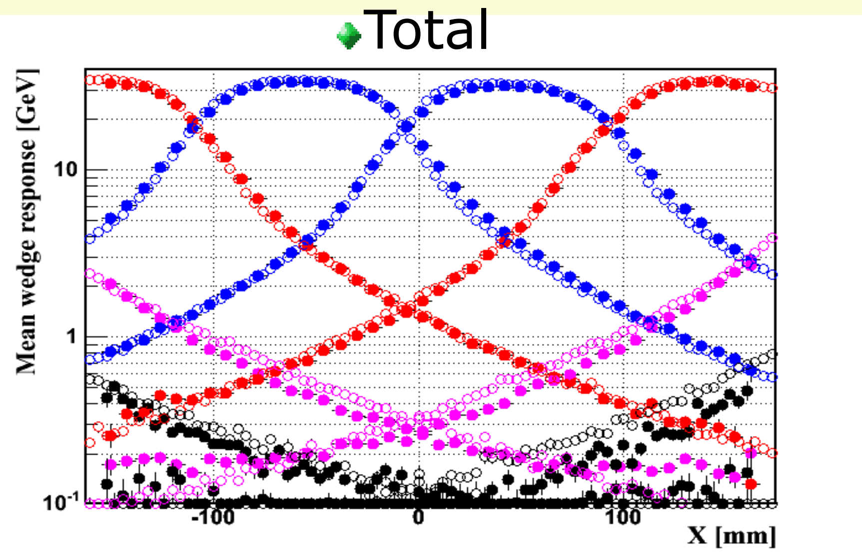
Study of the crack region using 200 GeV pions:
⇒comparing the test beam data with MC
Data: full symbols, MC: empty symbols

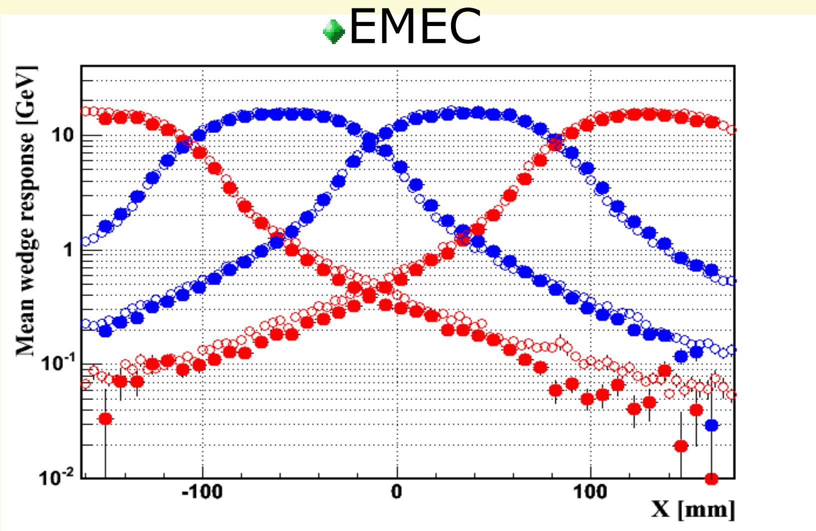


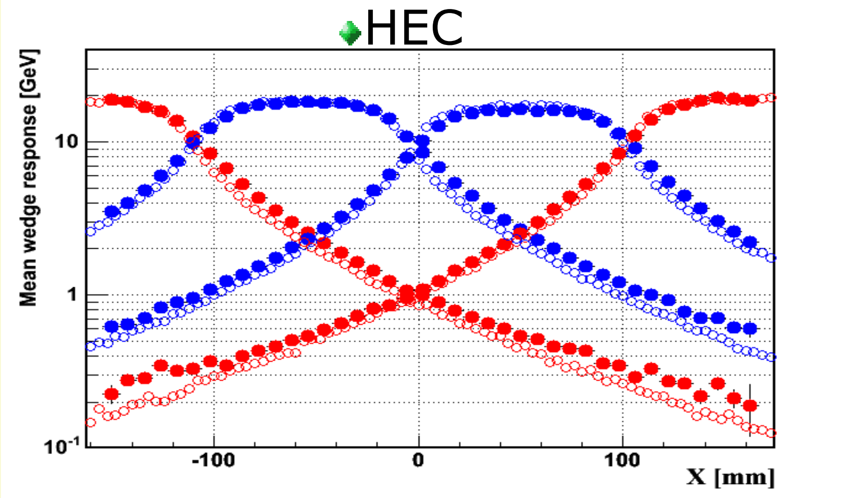
KE team: test beam data analysis

Reconstruction of HEC response:

- ✓ incident pions, 60 GeV
- ✓ X-scan: 60 GeV pions over EMEC/HEC region (data = full, MC =open symbols)
- ✓ each profile is sum of energy in one phi-bin
- ✓ MC: QGSP_BERT code used for comparison with data



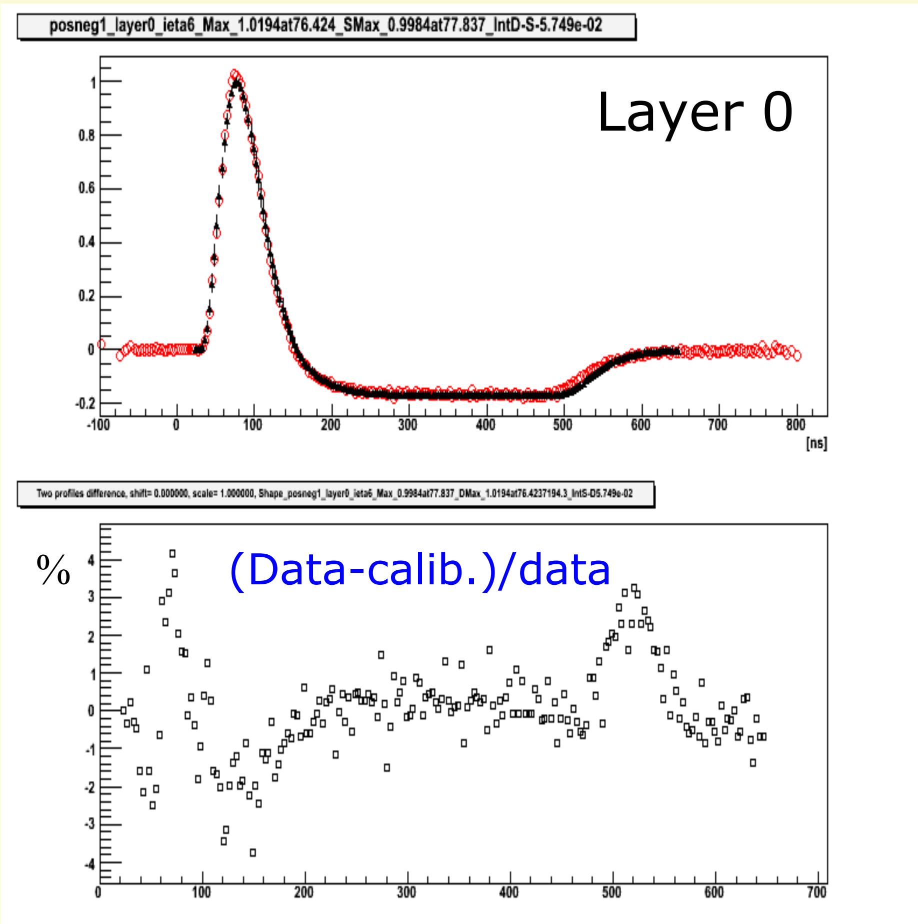


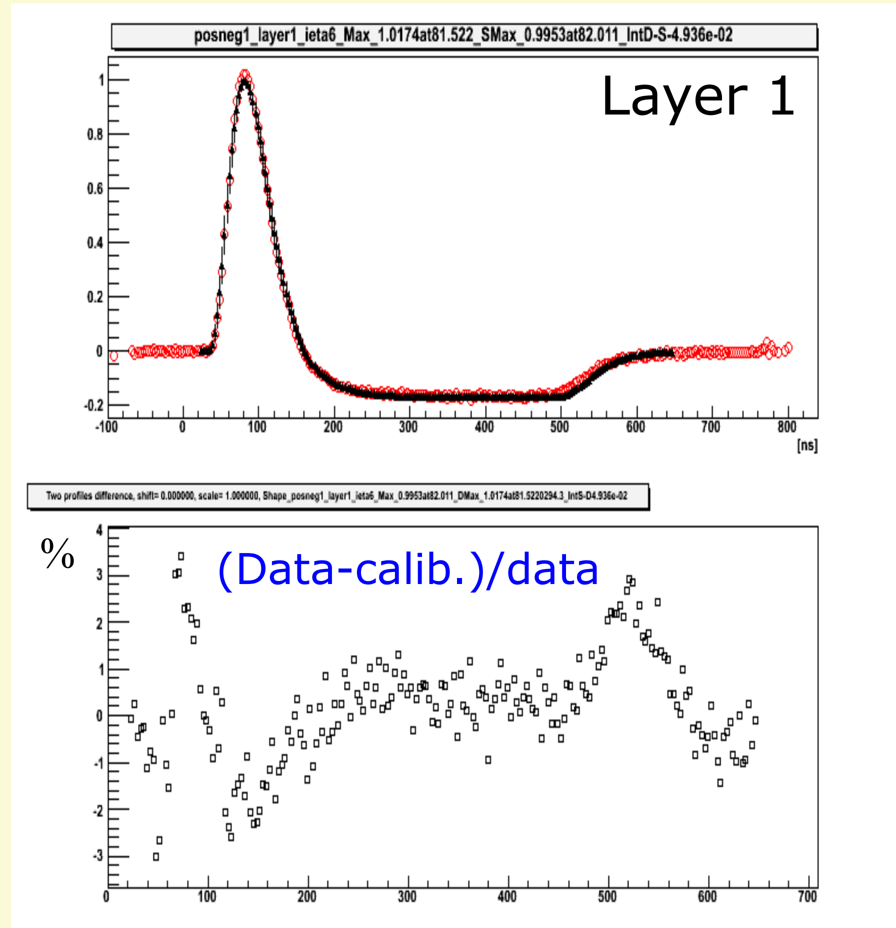


KE team: HEC signal shape

Cosmic muon tests were used to study HEC signal shape

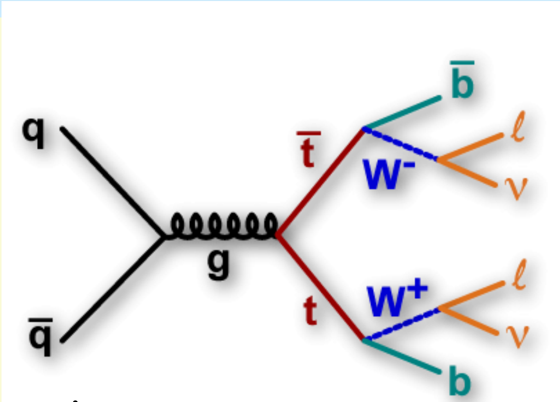
✓ Layer 0 (left) and layer 1 (right) signal; red circles ≡ data, black triangles ≡ predictions from calibration



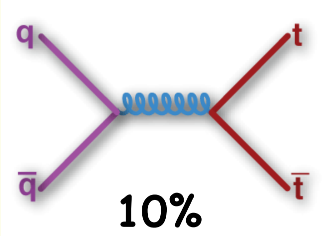


KE team: ttbar production in Dilepton channel

Dilepton channel, $qq(gg) \to t\bar{t} \to \left(bl^{+}\nu\right)\left(\bar{b}l^{-}\bar{\nu}\right)$,
of ttbar process: low BR (4.9%), high S/B



Production:
(7TeV/160pb)



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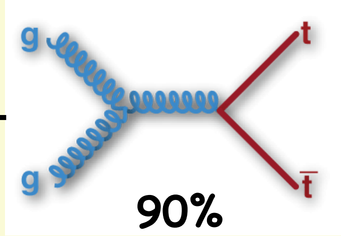


Leptons: $e\mu$

Kosice team: a lot of experience in dilepton studies from CDF

✓Top quark mass in DL channel using template approach + template method with cross section vs M_{top}

✓Ttbar spin correlations in DL channel

✓Top quark charge in DL channel

Present status:

Atlas soft handled – first ttbar dilepton distributions obtained aimed at top mass (template method) and analysis of W helicity states

Effective contribution: autumn 2011

ATLAS team in Bratislava

Team: 4 physicists, 3 PhD students, 2 und. students, 1 technician

Past activities:

✓Tests of photomultipliers using single photoelectron approach

✓ Reconstruction of calorimeter response to pions (linearity, homogenita, energy resolution)

✓Method of energy reconstruction using topology of hadronic shower

✓Method of fast simulation of hadronic calorimeter

Present activities:

✓Atlas shifts – data accumulations

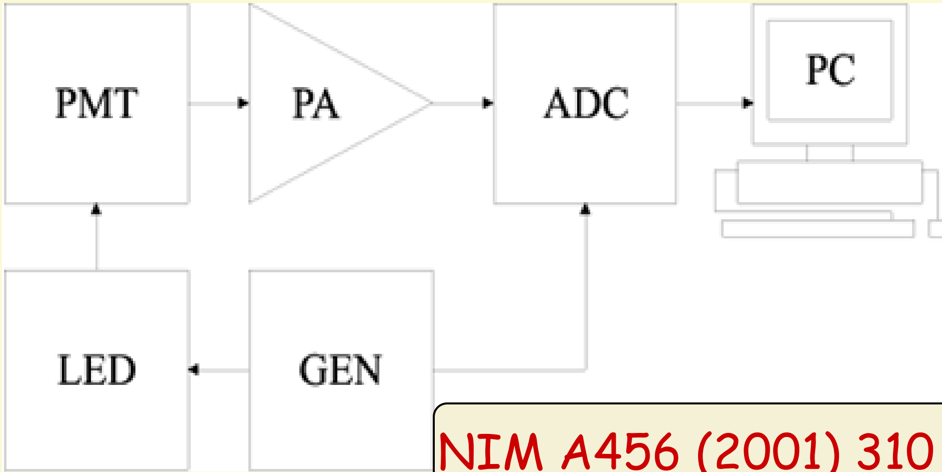
✓DQ coordinator for TileCal, development of software for TileCal DQ

Physics:

✓Top quark properties: top quark charge studies via top decay products

✓Soft QCD: Bose-Einstein correlation studies

BA team: PMT tests using single p.e. analysis



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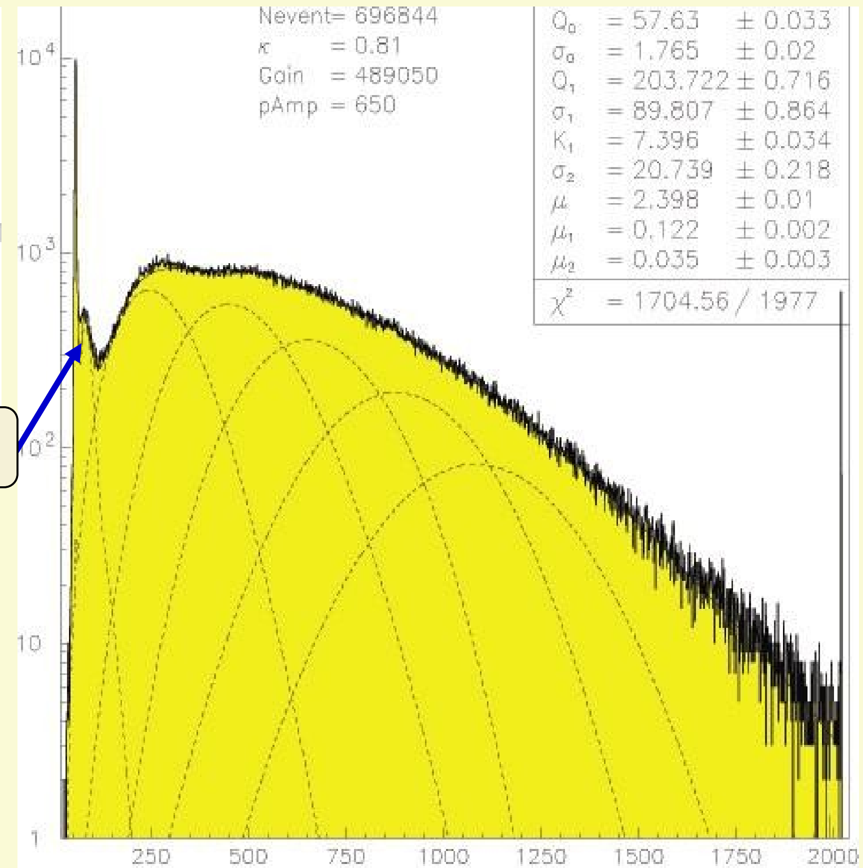


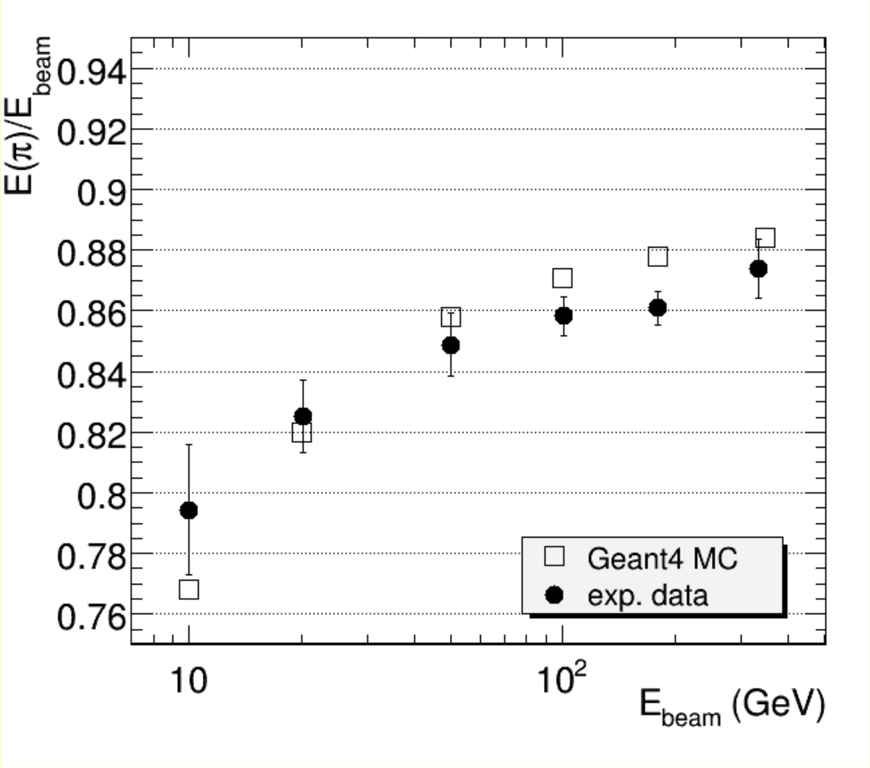
A PMT spectrum analysed by the single p.e. method

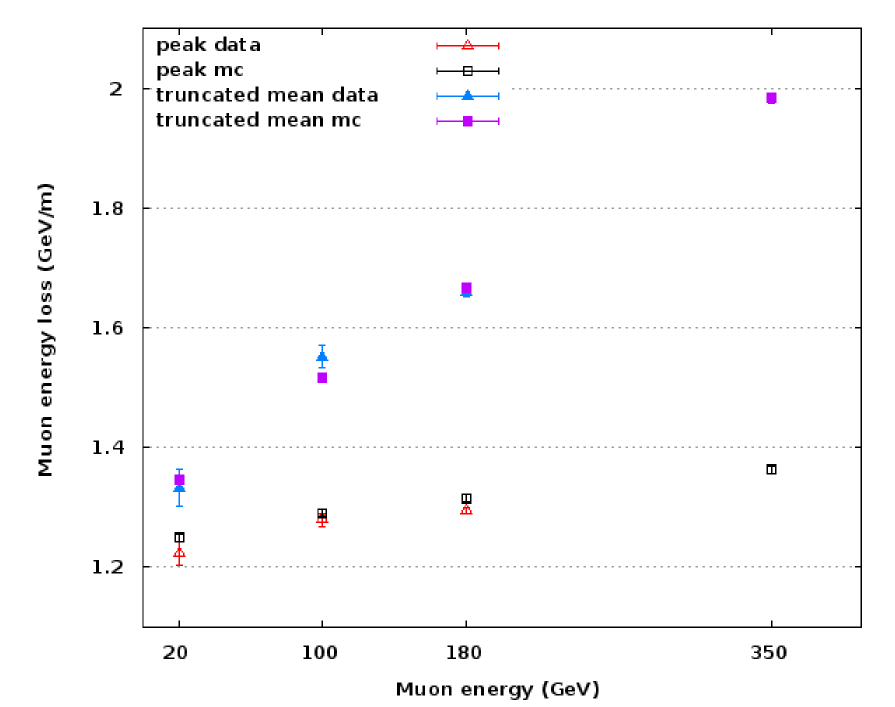
PMT excess factor found

$$\mu = f_{PMT} \cdot \frac{Q^2}{\sigma^2}, \quad f_{PMT} \approx 1 + \frac{\sigma_1^2}{Q_1^2}$$

Details of PMT structure seen (1st dynode effect)

BA-team: Some test beam results





Linearity of TileCal response to pions

- ✓data compared with MC
- ✓Non-compensation effect seen

TileCal response to muons as a function of muon energy

data compared to MC:

- ✓most probable response value
- ✓truncated mean values

BA-team: Top Quark charge

- SM (Q_{top} = 2/3): $t^{2/3} \to b^{-1/3} + W^{+1}$ → $l^{+1} + \upsilon_e$
- exotics (Q = -4/3): $\hat{t}^{-4/3} \to b^{-1/3} + W^{-1}$ → $l^{-1} + \upsilon_e$

- for top quark determination
  - -Charge of W via its lept-decay
  - -Determination of b-jet charge
  - -Correct lepton – b-jet pairing

$$Q_{b-jet} = \frac{\sum_i^N q_i \left|\vec{j} \cdot \vec{p}_i\right|}{\sum_i^N \left|\vec{j} \cdot \vec{p}_i\right|}$$

q_i ≡ i^th particle charge
$\vec{p}_i$ ≡ i^th particle momentum
$\vec{j}$ ≡ b-jet direction
κ ≡ an exponent (=0.5)

lepton+jets case (1 hi-p_T lep.)

$$m(l, b_{jet}^{(1,2)}) < m_{cr} \quad \& \quad m(l, b_{jet}^{(2,1)}) > m_{cr}$$

alternative: KLFitter tested

Needed: $\langle Q_l \times Q_{bjet} \rangle$ { <0: SM; >0: Exo }

Top quark Charge (2)

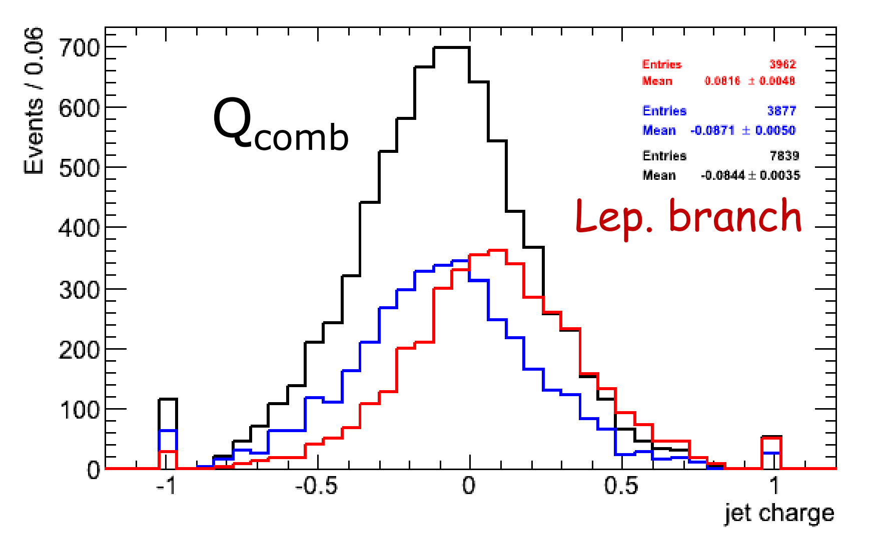
MC used: MC@NLO

Q(l+)≡ mean b-jet charge assoc. with l+

Q(l-)≡ mean b-jet charge assoc. with l-

Q_{comb}≡ mean Q_{bjet} ×Q(l) charge

Invariant mass pairing criterion tested



We analyze MC samples and real data

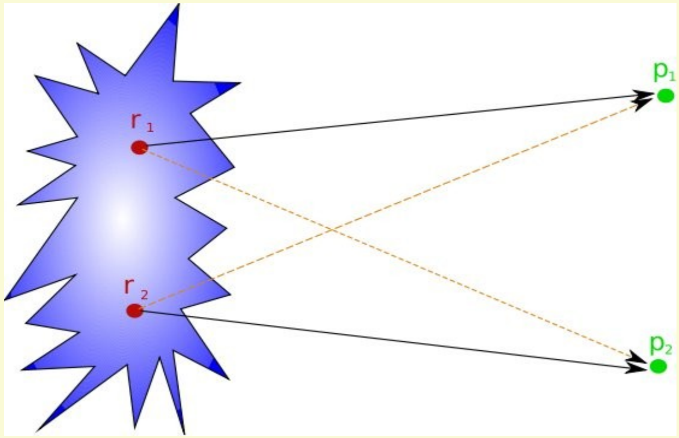
To have an interesting result 150 pb^{-1} is needed

Hopefully our results will be blessed during June 2011 !

BA-team: BEC- theoretical background

BEC effect correspond to an enhancement in two identical boson correlation function when the two particles are near in momentum space

$$C_2(q) = \frac{P(p_1, p_2)}{P(p_1)P(p_2)}$$



Plane wave approach (incoherent sum):

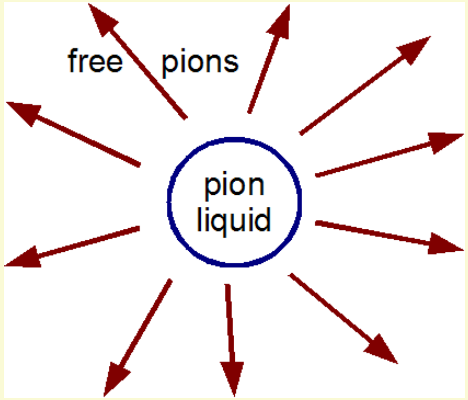
for Gaussian source emission probability

$$C_2(Q) = 1 + \lambda e^{-Q^2 R^2}$$

R is the source radius

λ is the *incoherence factor (0,1)* introduced empirically

$Q^2 = -q^2 = (p_1 - p_2)^2 \equiv$ the four momentum difference



Quantum optical approach (taken from optics):

✓ based on squeezed coherent states

✓ leads to: $C_2(Q) = 1 + 2p(1-p)e^{-R^2Q^2} + p^2 e^{-2R^2Q^2}$

p is the chaoticity: =0 (=1)" for purely coherent (chaotic) sources

BEC: experimental approach

- For each track pair we reconstruct Q ($Q^2 = -q^2 = -(E_1 - E_2)^2 + (\vec{p}_1 - \vec{p}_2)^2$)
- We reconstruct N(Q) for
  - ✓ signal sample (contains BEC)
  - ✓ reference sample (without BEC)

In experiment: we construct the C_2 correlation function as a ratio of the signal Q distribution (N(Q)) and reference Q distribution ($N^{ref}(Q)$) which is free of BEC, but should contain all other correlations.

$$C_2(Q) = \frac{N(Q)}{N^{ref}(Q)}$$

It is a problem!!!

N(Q) ≡ two particles Q distribution
- identical particles used

Fitting functions used in the analysis ➡

$$C_2(Q) = C_0\left(1 + \lambda e^{-R^2Q^2}\right) \qquad C_2(Q) = C_0\left(1 + 2p(1-p)e^{-R^2Q^2} + p^2 e^{-2R^2Q^2}\right)$$

$$C_2(Q) = C_0\left(1 + \lambda e^{-RQ}\right) \qquad C_2(Q) = C_0\left(1 + 2p(1-p)e^{-RQ} + p^2 e^{-2RQ}\right)$$

In real fit: $C_2(Q) \rightarrow C_2(Q)\times(1+\varepsilon Q)$

Results blessing: June '11

Outreach activities

- Exposition about CERN – project LHC /ATLAS and ALICE
  - ✓ at 8 places during 2009-10, 167 days
  - ✓30 popular presentations on high energy physics matter
  - ✓ 86 student –lectors
  - ✓ visited by 295 groups, 15,000 visitors

- Popular presentations for high schools and general public
  - ✓ day of CERN was organized in Bratislava and Košice when first collisions occurred
  - ✓Special presentations devoted to LHC experiments
  - ✓ created a CD with popular presentation on the present elementary particles physics for high schools in Slovakia

- Performances in Slovak TV and Radio, newspapers and journals

Conclusions

- Experiment ATLAS it is an outstanding opportunity for scientists of Slovakia, especially young people, to be in contact with frontier high energy physics.
- Our teams contributed quite a lot to the ATLAS calorimetric system in each step of its construction, testing, commissioning...
- We actively participate in physics studies (top physics, QCD) and we are ready to do our best for a success of ATLAS.
- We are optimistic and believe that ATLAS (along with other LHC experiments) will provide us with exciting discoveries that will promote particle physics to deeper understanding of Nature.
- In CERN experiments we have reached a global unification of people of different nations - hopefully this example will have a positive impact on all other mankind activities.

Thank you !