Proposal for Cosmic Rays with ALICE and P2

- Plans for Cosmic Ray studies at CERN
- Combining:
- Surface array at P2
- ALICE TPC detector at UX2
- Underground array at UX2

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CERN; Penn State;
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U. de Michoacan

QCD at Cosmic Energies - II

The Highest Energy Cosmic Rays and QCD

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Skopelos, Greece

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Participants

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The aims of the study (1)

- Our primary goal of studies of muons accompanying extensive air showers initiated by primary CRs interacting in the upper atmosphere, is to study high multiplicity muon bundles which might signify:

- High energy physics effects in the primary interaction that are not included in current Monte Carlo programs simulating UHECR:

- Coherent effects in nucleus-nucleus interactions

- Coherent pion production

- Disordered chiral condensate (DCC) states ......

- Primarily at energies above 10^{16} eV

The aims of the study (2)

- It seems highly desirable to employ a multi-100 million $ detector and its infrastructure for multiple purposes

- Hence, to use one of the large LHC detectors to help elucidate some of the UHECR puzzles is a "highly beneficial" activity, involving a relatively small additional effort:

- We are proposing to use ALICE

High Energy Cosmic Rays

Cosmic ray showers:
Dynamics of the high energy particle spectrum is crucial
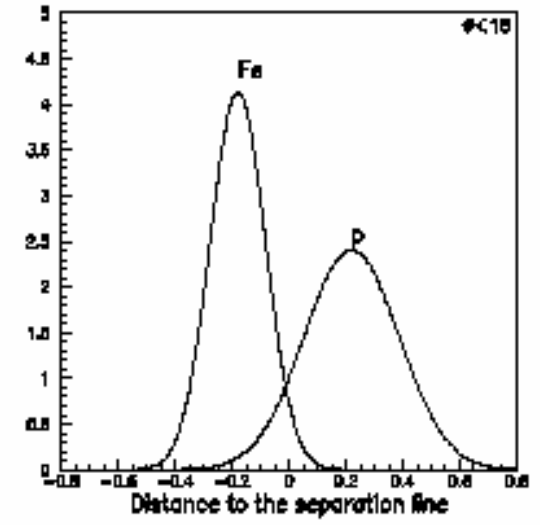
The aims of the study (3)

- A secondary goal of our muon studies is to better understand the mass composition and energy spectrum of primary CR nuclei
- Observing, simultaneously, the muonic content and the EM component, via surface arrays, provides a handle on the composition,
- primarily for 1-100 PeV

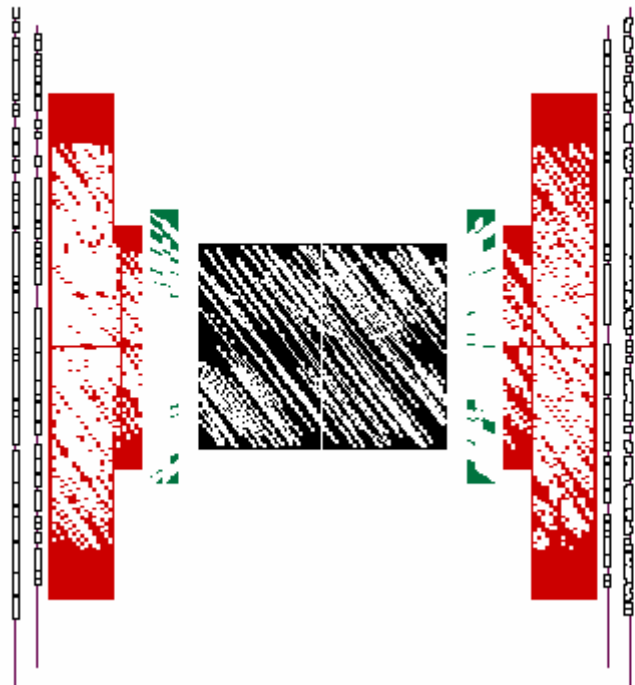# Studies from QGSJET CORSIKA MC

No. of muons
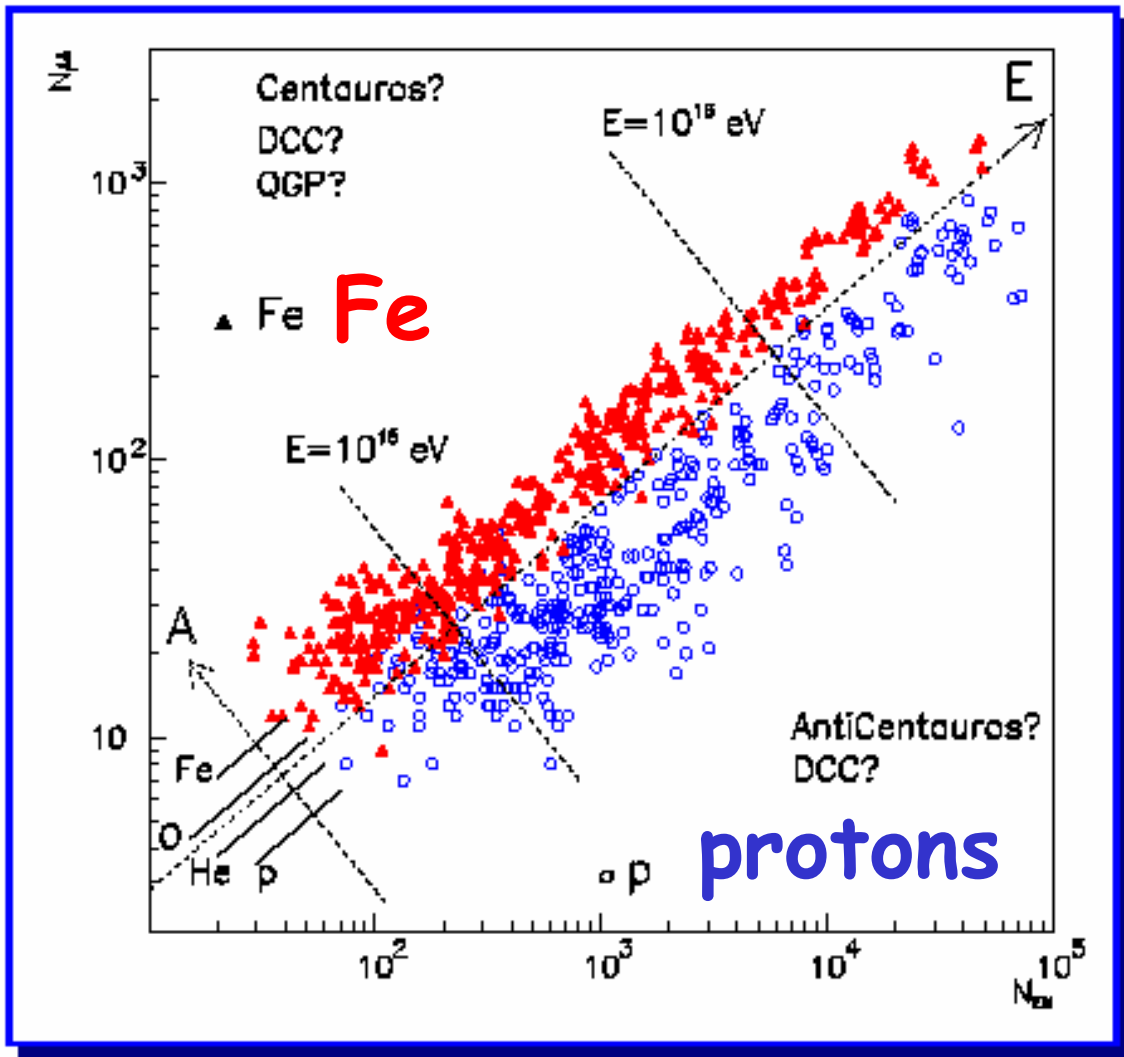
No. EM showers

Separation

$(E_\mu > 70\ GeV)$

Reminder of Results from ALEPH:

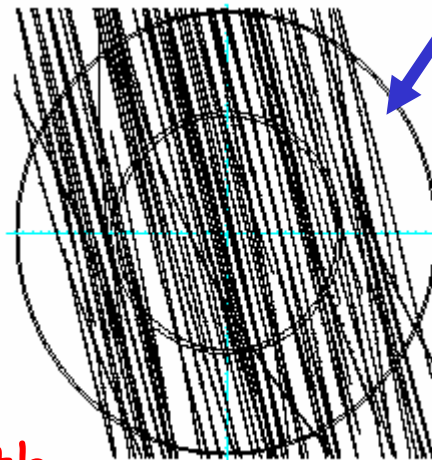(V. Avati et al, Astroparticle Physics <u>19</u> (2003) 513-523)

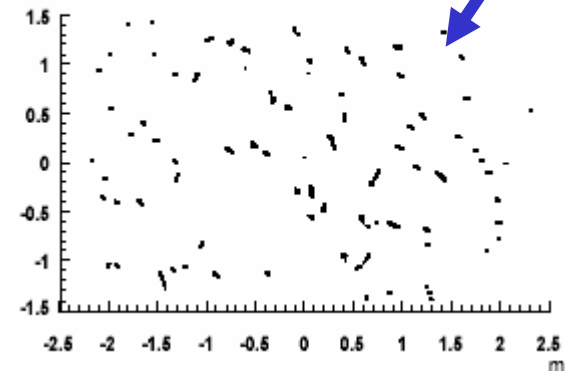A high multiplicity event in the ALEPH detector

Tracks in TPC = 76

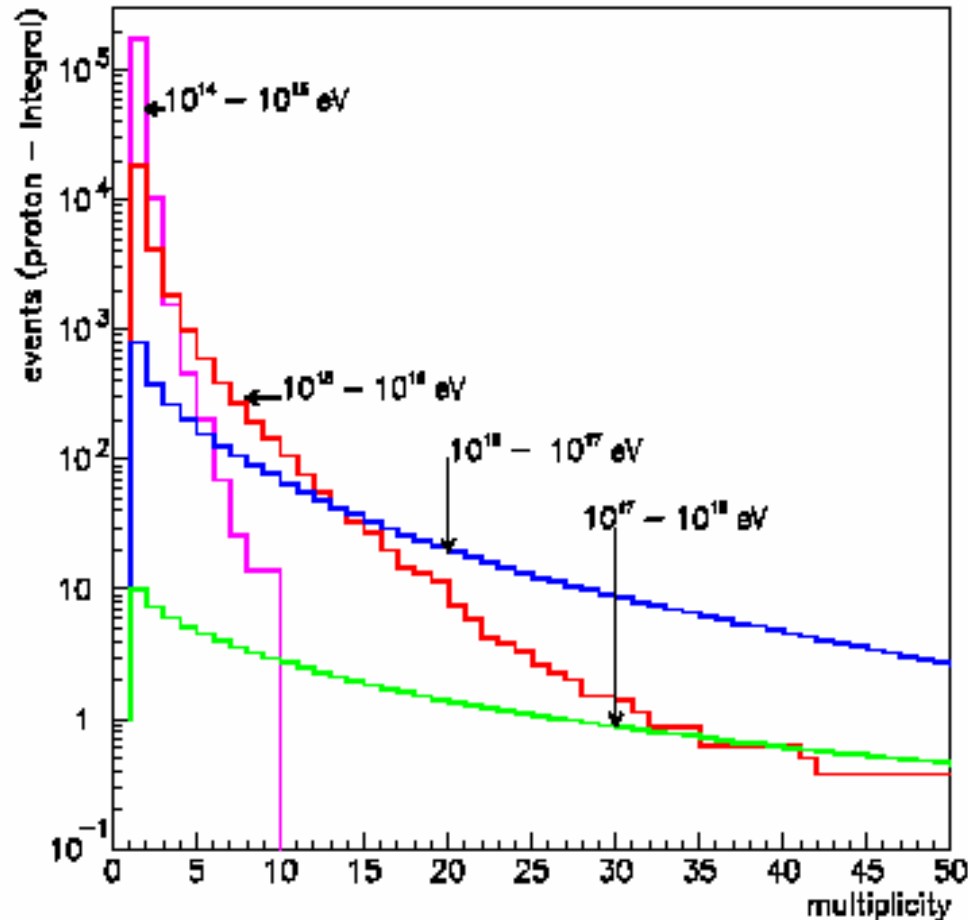140 m underground:
Vertical E_μ > 70 GeV

~parallel

~uniform

Example of an event with
76 tracks in the TPC
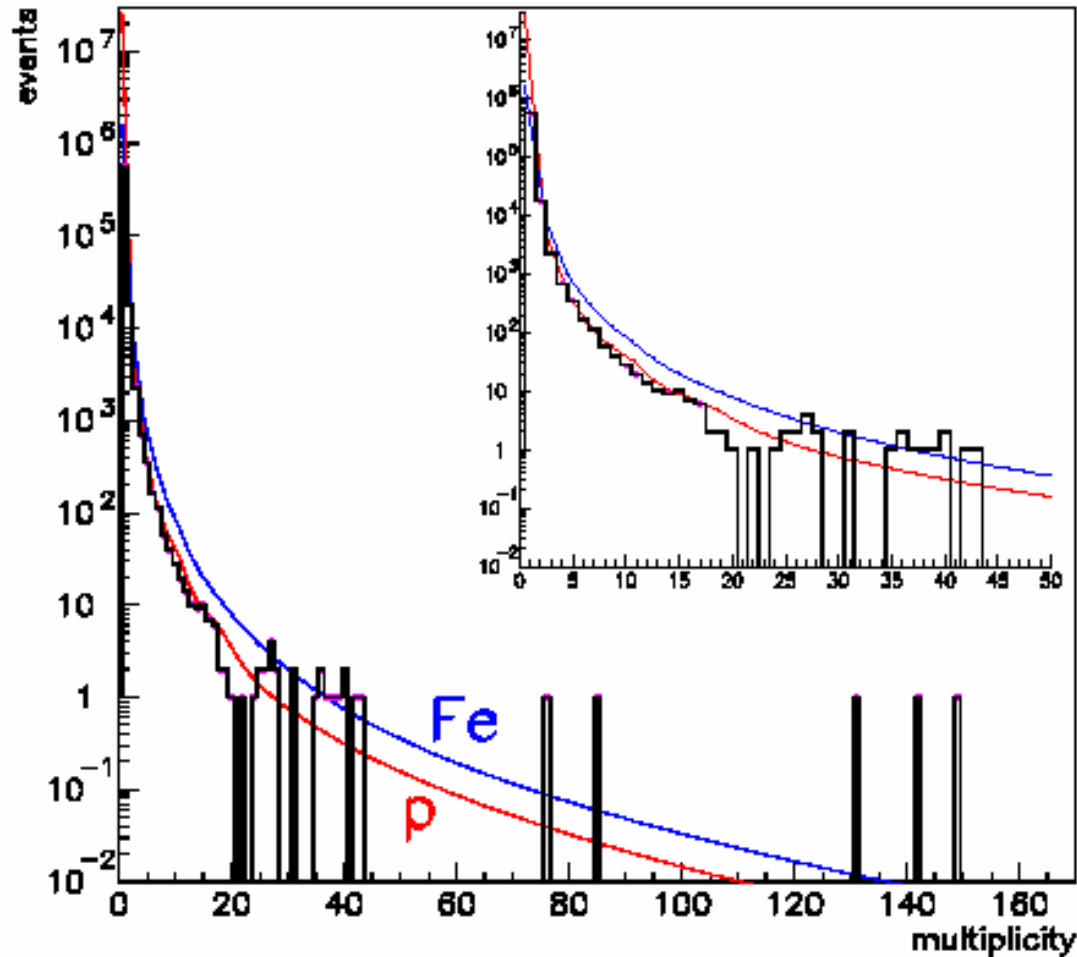
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Reminder of Results from ALEPH:

Muon density grows almost linearly with primary energy

Multiplicity bins are equivalent to energy bins:
$N_\mu = 5\text{-}20 \Rightarrow E \sim 10^{15\text{-}16}$ eV and
$N_\mu > 30 \Rightarrow E > 10^{16}$ eV

Reminder of Results from ALEPH:

Effective data-taking time was 1.7×10^6 s
# events after cuts = 584

Reminder of Results from ALEPH:

- **Conclusions (1) on <u>frequency</u>:**
- The bulk of the data could be successfully described by standard production phenomena
- The muon multiplicity distribution favors a composition that changes from light to heavier elements with increasing energy around the "knee" at $10^{15-15.5}$ eV
- The five highest multiplicity events occur with a frequency which is almost an order of magnitude above the simulation

Reminder of Results from ALEPH:

- **Conclusions (2) on <u>properties</u>:**
- High multiplicity muon bundles are almost parallel, with the muons distributed uniformly over the ALEPH area 4x3 m^2
- The interaction characteristics of forward particle production at energies beyond the current accelerator range ($E_{prim} > 3x10^{15}$ eV) cannot be explored
- Even in the accelerator range, forward particle production that is relevant for CR studies is poorly understood
- **Similar results found by DELPHI and L3**
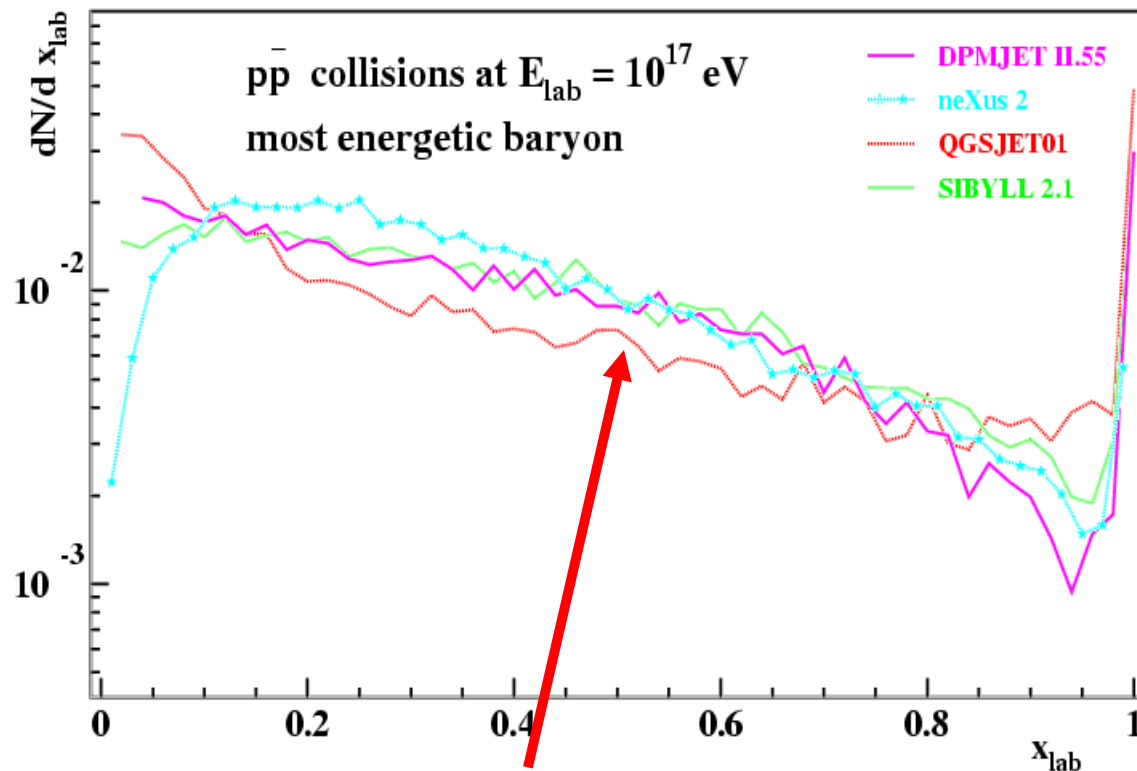
Integral flux of high energy cosmic rays
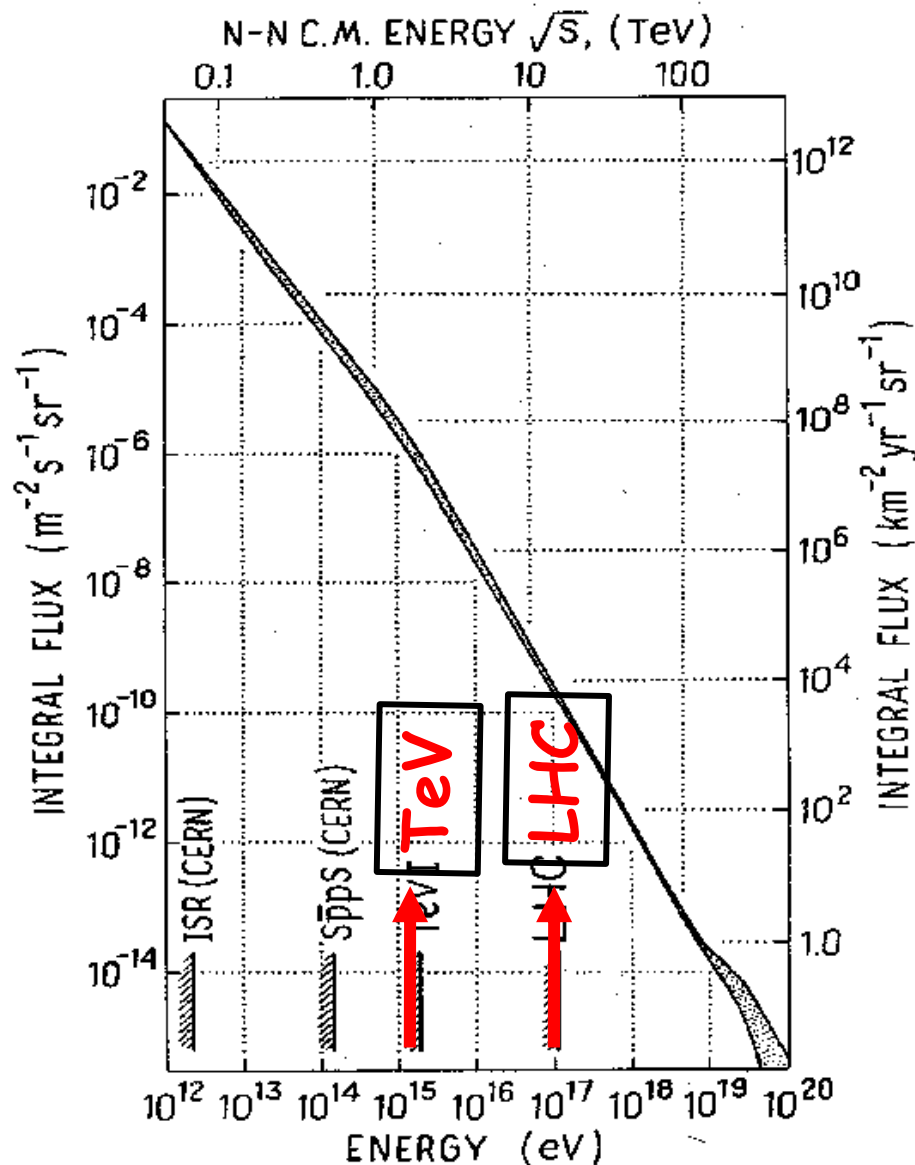
Measurements of the **very forward energy flux** (including diffraction) and of the **total cross section** are essential for the understanding of cosmic ray events

At LHC *pp* energy:

  10^4 cosmic events km^{-2} year^{-1} sr^{-1}

> 10^7 events at the LHC in one day

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High Energy Cosmic Rays

pp̄ collisions at $E_{lab} = 10^{17}$ eV

most energetic baryon

Legend: DPMJET II.55, neXus 2, QGSJET01, SIBYLL 2.1

Interpreting cosmic ray data depends on hadronic simulation programs
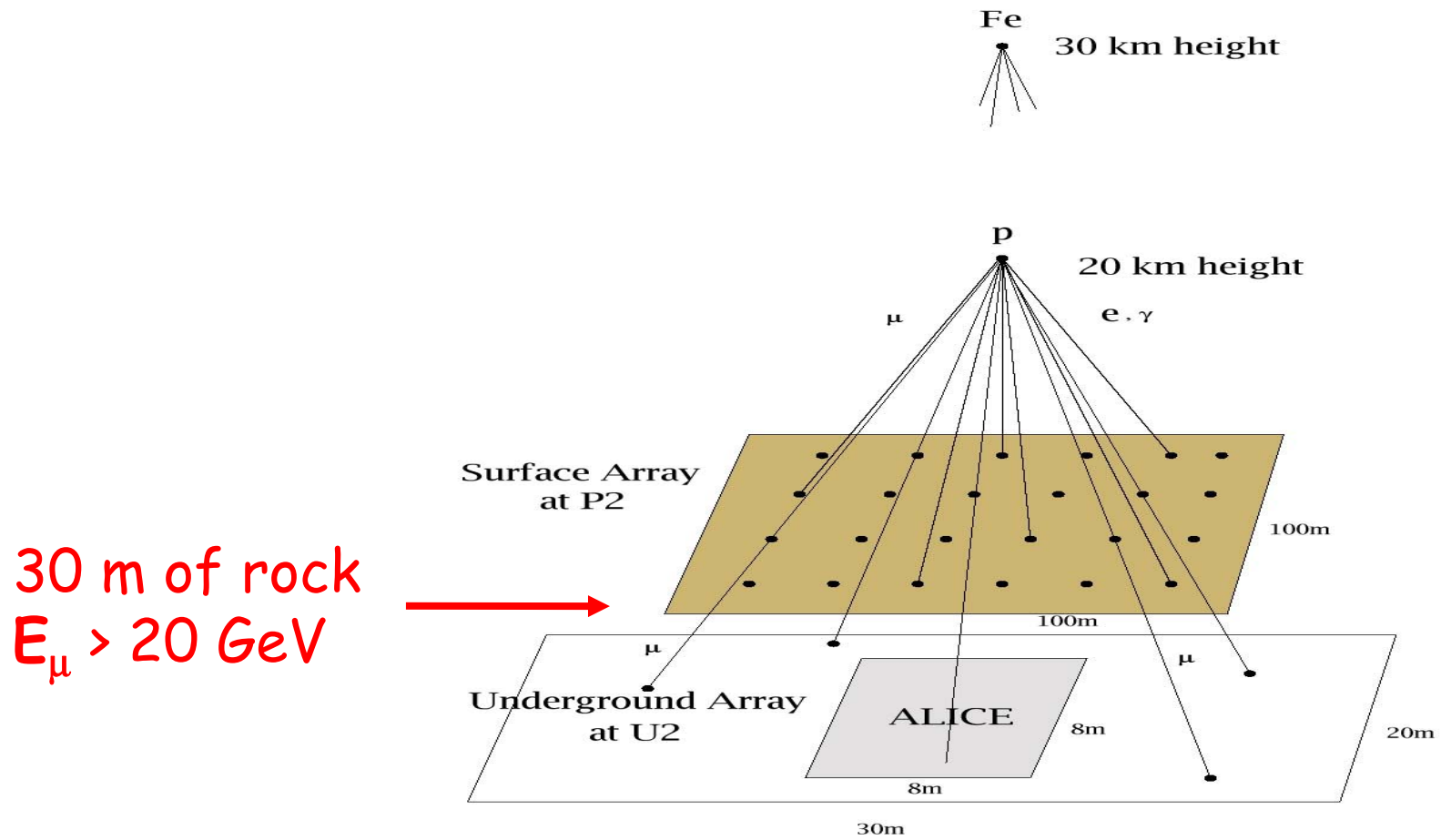The forward region is poorly known/constrained
Models differ by factor 2 or more
Need forward particle/energy measurements: e.g. dE/dη…

The next step:

- V. Avati et al: "a larger underground array (typically 400 m^2) with precise muon chambers complemented by a surface array …. to study further with much larger statistics the properties of the outstanding highest multiplicity events."
- We propose to use the ALICE TPC and TRD (~50 m^2), with a smaller overburden (E_μ > 20 GeV) and a much longer data taking time
- Combined with the existing CR shower array above ALICE at P2 to measure EM content, and
- Combined with additional counters underground both above and around the ALICE detector
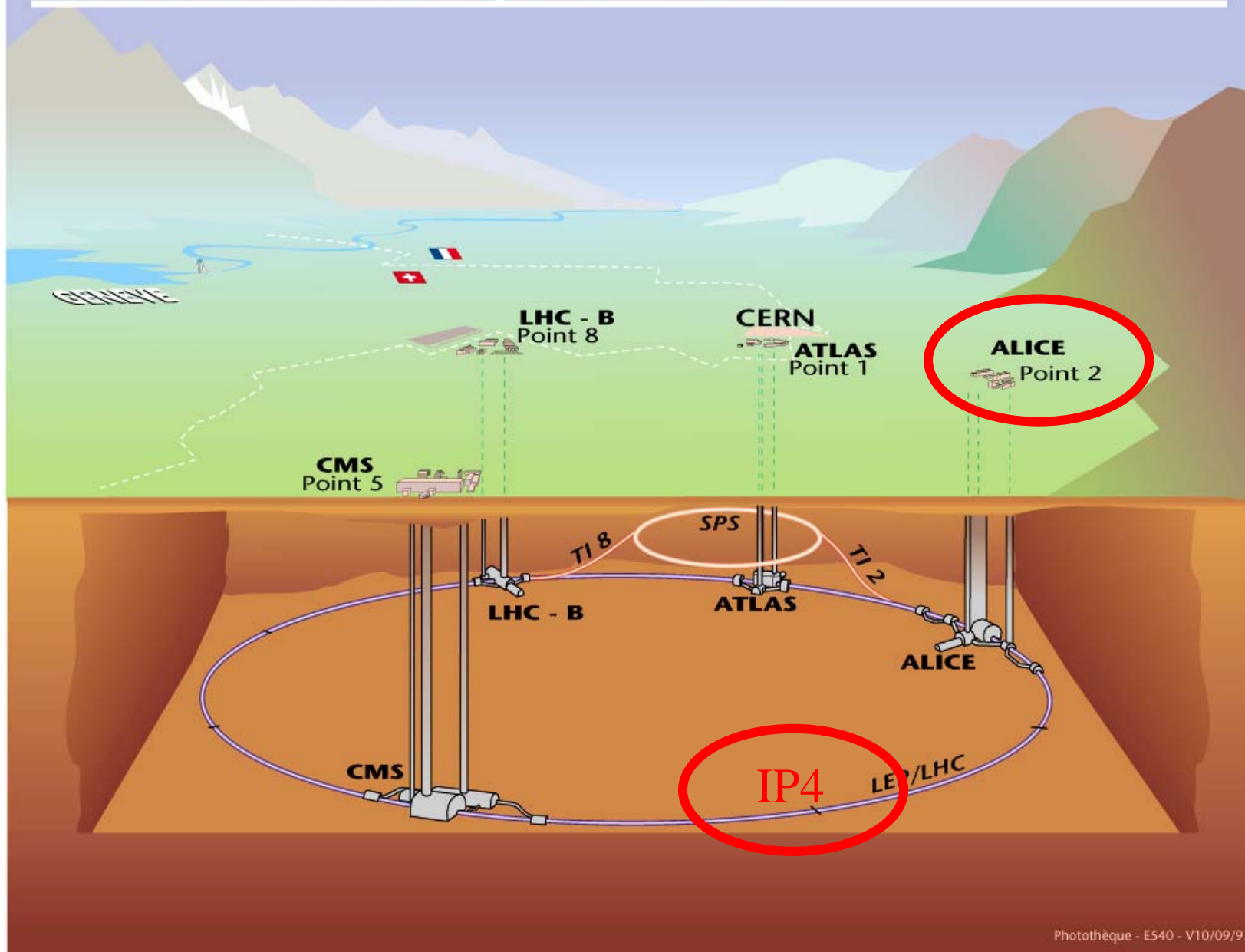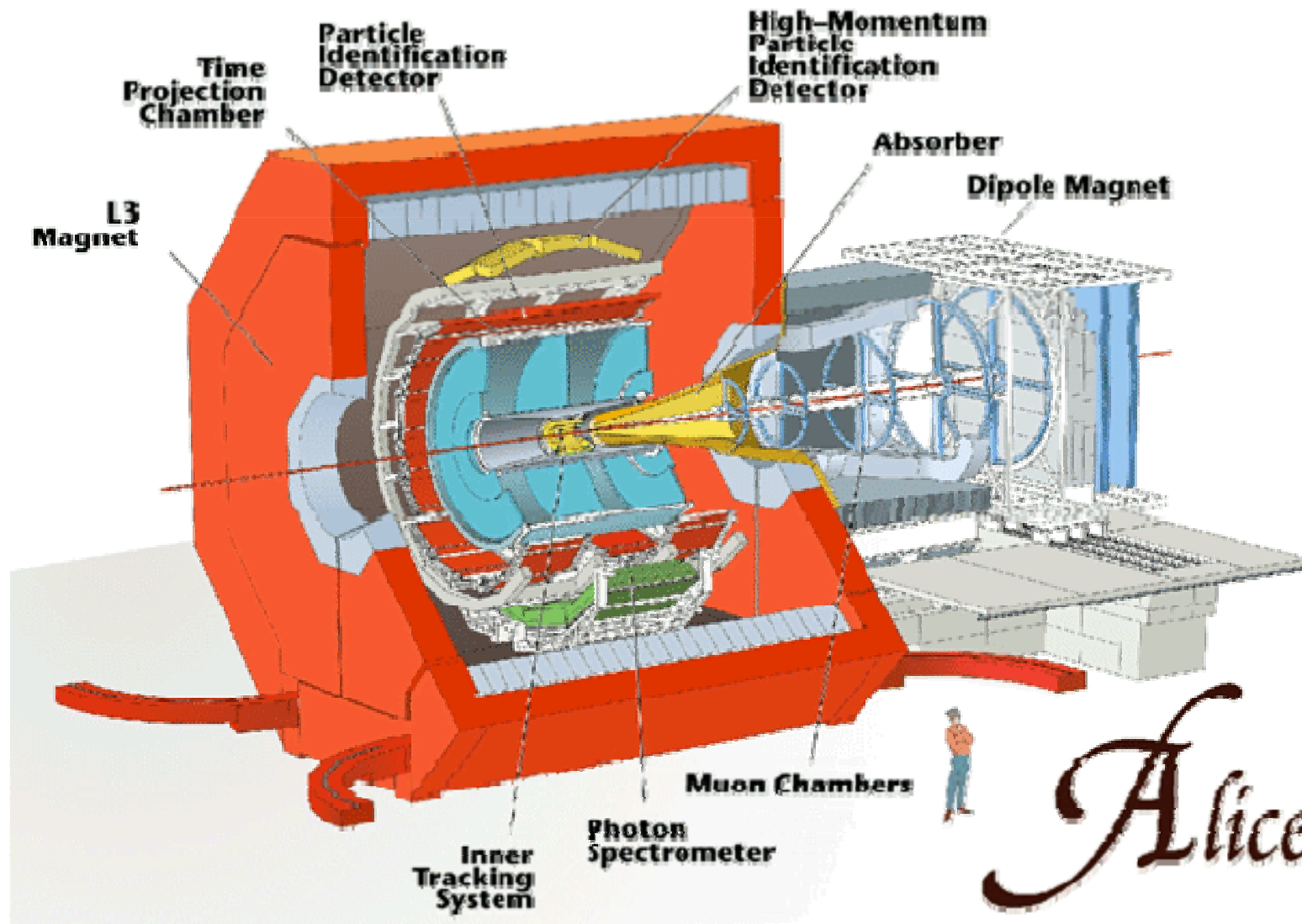
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Concept:

Fe — 30 km height

p — 20 km height

μ   e , γ

Surface Array at P2

100m

100m

30 m of rock
E_μ > 20 GeV

μ   μ

Underground Array at U2   ALICE   8m
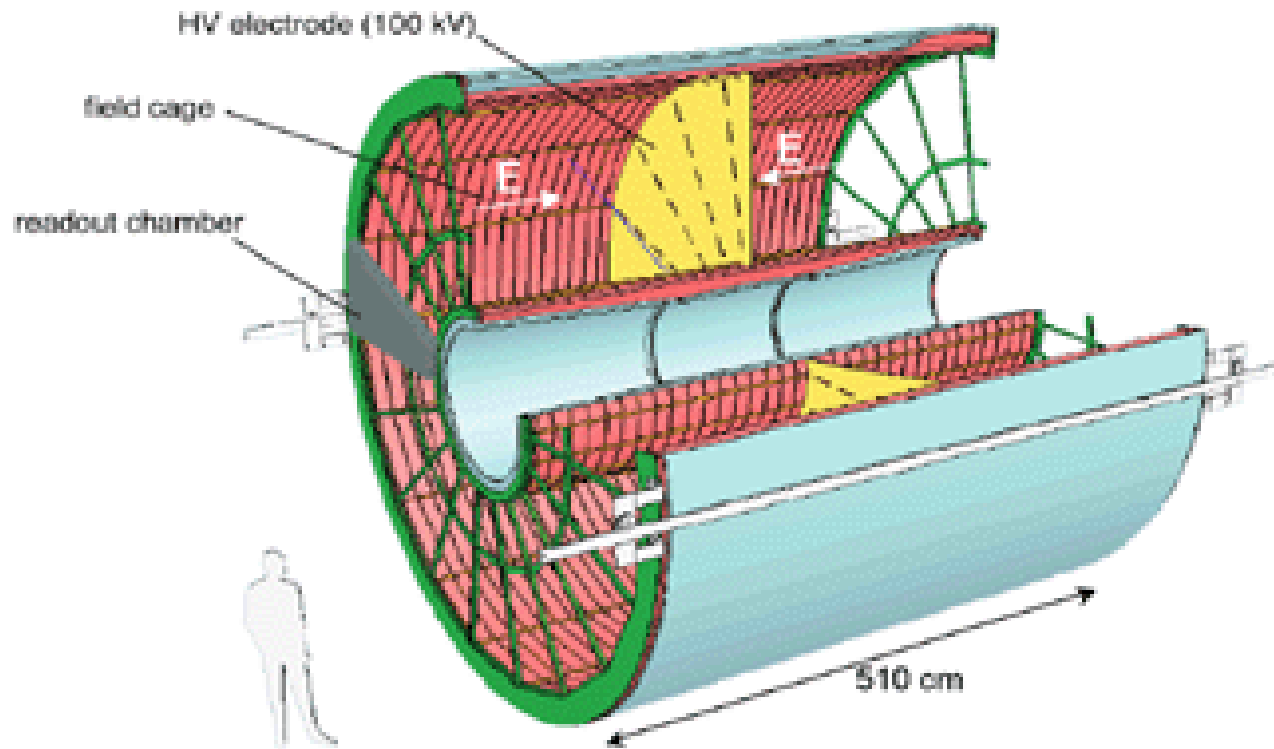
8m

20m

30m

NOT TO SCALE

Vue d'ensemble des expériences LHC.

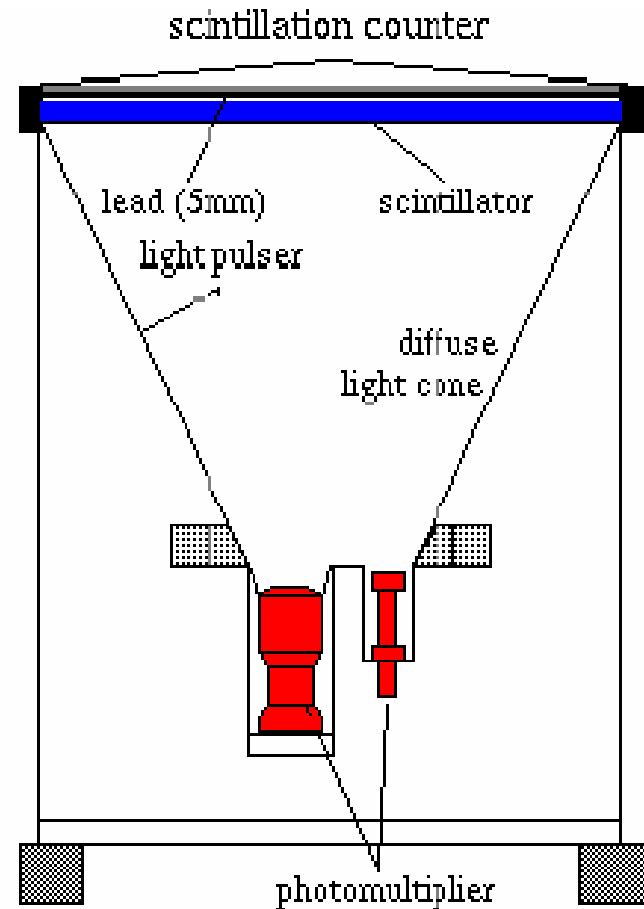# ALICE TPC at point P2

ALICE TPC/TRD at point P2

The TPC diameter is 5 m and it is 5.1 m long

Outside the TPC at 2.9 < r < 3.7 m is a TRD 7 m long

The next step:

- We have two existing surface arrays now taking data at P2 and P4:

- At P4: there are 3 rows of 7, 6 and 7 $1m^2$ counters in an area 10 x 60 m^2 (since Fall 2001)

scintillation counter

lead (5mm)   scintillator
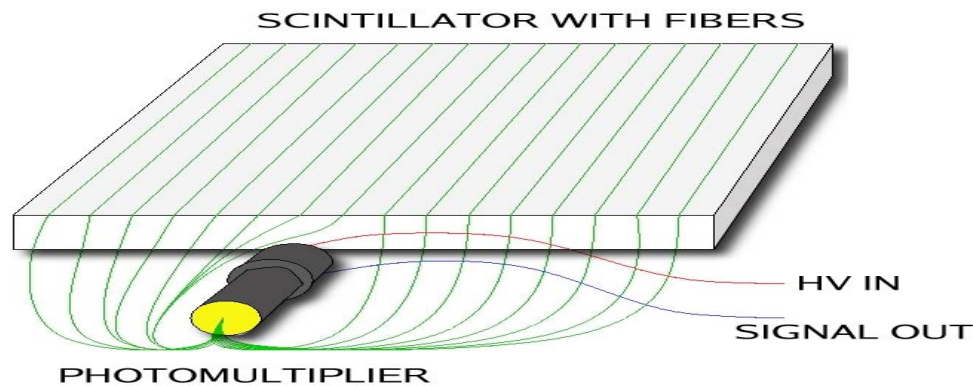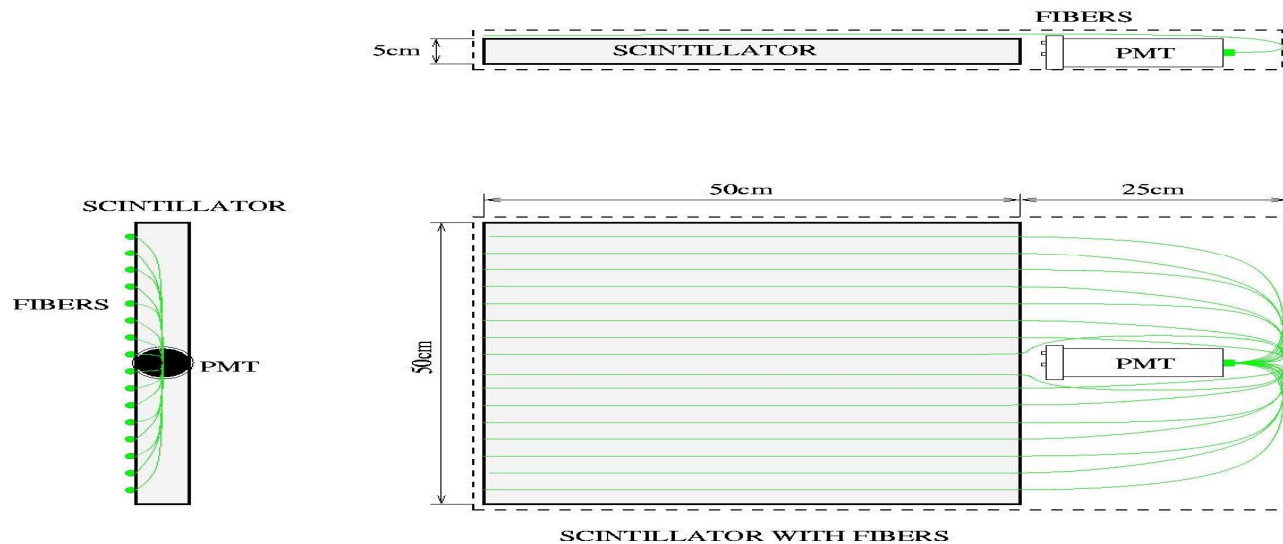light pulser

diffuse
light cone

photomultiplier

At P4:

The next step:

- At P2: there are 40 $0.5m^2$ counters in 6 rows covering an area 50 x 70 m^2 (since 2000)

- The two sets of arrays have been running consistently since April 2005

- The goal here is to look for coincidences over a range of about 8 km

At P2:

Plans for counter design

FIBERS

5cm | SCINTILLATOR | PMT

SCINTILLATOR

FIBERS

PMT

50cm

25cm

50cm

PMT

SCINTILLATOR WITH FIBERS

SCINTILLATOR WITH FIBERS

HV IN

SIGNAL OUT

PHOTOMULTIPLIER

Working on:

Design of the Sc/fiber/box

Base design

HV setup

Readout TDC/ADC

Prototype:

PULSE HEIGHT from prototype:

2005/09/11 22.02

Test Detector with 16 Fibers, Voltage = 2kV

ID	10
Entries	198309
Mean	107.4
RMS	33.65
UDFLW	0.000
OVFLW	0.000

27 ch.

Max to pedestal = 26
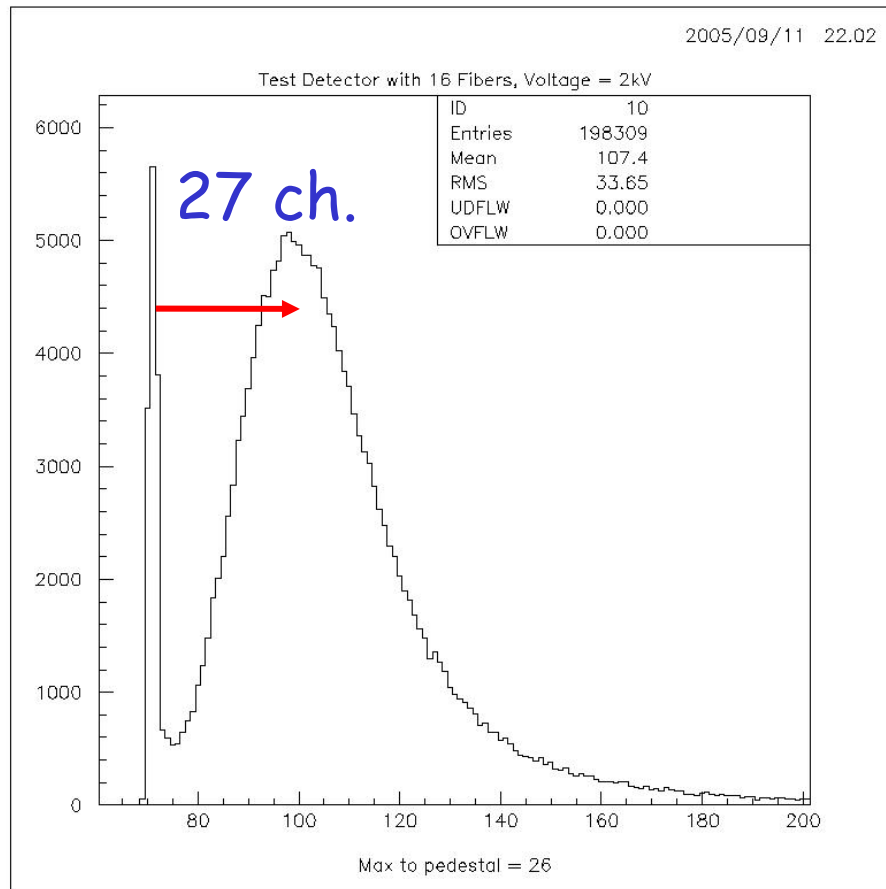
With 16 fibers
- MIP = 27
- FWHM = 31
- HV = 2000 V
- Allow for up to 20 mips

Proposal:

- To put about 100 additional counters above ground at P2,
- 5-10 (?) counters above ALICE, with
- Another 100 counters underground around ALICE
- Trigger: on counters above and around ALICE; readout ALICE and all P2 counters
- Schedule:
- Aim to have h/w ready by end of 2006(?)
- Discussions with ALICE are underway and there was already interest from ALICE (TDR)