Dec 17, 2015 0:12 UTC

DAMPE → WUKONG

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microsat
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高能物理研究所

中国科学技术大学

IMP
近代物理研究所

UNIVERSITÉ DE GENÈVE
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INFN Istituto Nazionale di Fisica Nucleare
意大利国家核物理研究所

佩鲁贾大学

UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO
巴里大学

UNIVERSITÀ DEL SALENTO
萨兰托大学

IFD2015

INFN Workshop on Future Detectors

16-18 December 2015 - Torino - Italy

Large Area Detectors

Ivan De Mitri

Università del Salento and INFN Lecce

Roberto Cardarelli

INFN Roma2

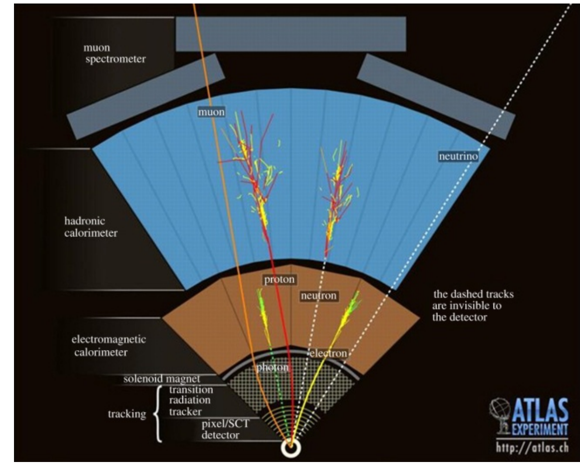
LADs: Large Area Detectors

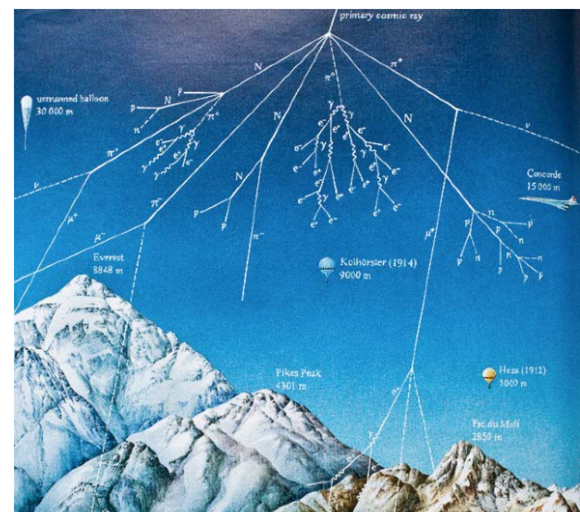
- "Large" .. a relative concept…

- The case of Physics at Accelerators
  (R. Cardarelli , G. Aielli, L.Paolozzi, R. Santonico)

- The case(s) of Astroparticle Physics
  (I. De Mitri)

- Complementarity with other talks at this workshop





LADs at Accelerators

Large area muon systems (e.g. at FCC-hh)

Requirements:

- Very large area. → o(10000m^2).
- Provide bunch crossing identification. → Time resolution < 1 ns.
- Tracking capability. → Space resolution < 100 μm
- Operate in high background. → o(10 kHz/cm^2) barrel + o(100 kHz/cm^2) endcap
- Excellent aging performance. → Integrate 10 HL-LHC.

LADs at Accelerators

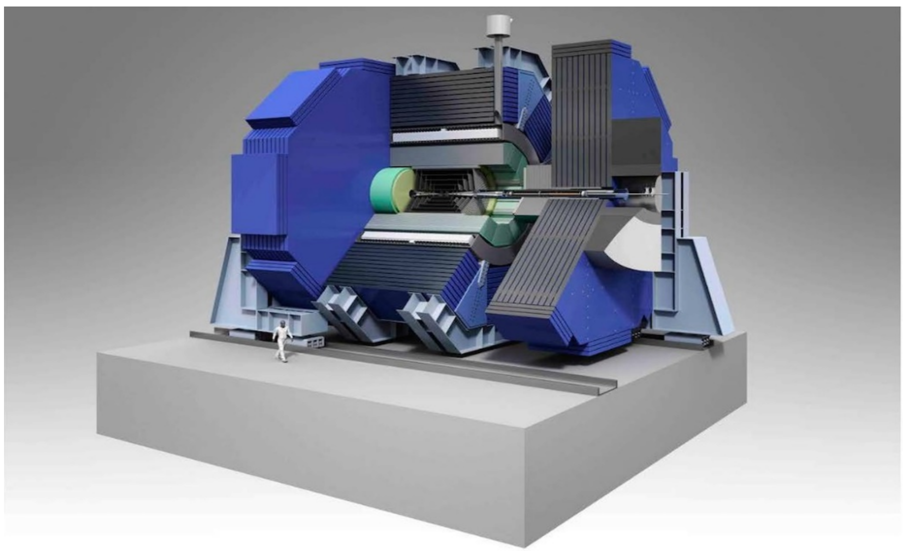
One example

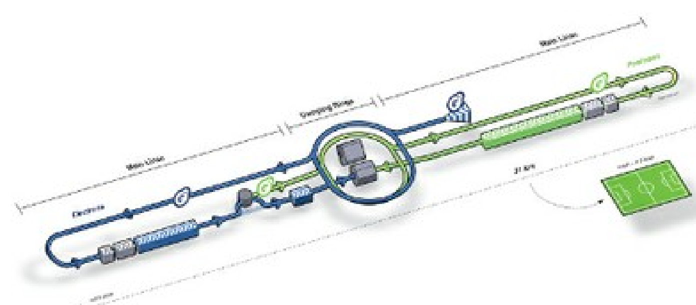
Table II-1.1
Key parameters of the baseline SiD design. (All dimension are given in cm).

SiD Barrel	Technology	Inner radius	Outer radius	z extent
Vertex detector	Silicon pixels	1.4	6.0	$\pm$ 6.25
Tracker	Silicon strips	21.7	122.1	$\pm$ 152.2
ECAL	Silicon pixels-W	126.5	140.9	$\pm$ 176.5
HCAL	RPC-steel	141.7	249.3	$\pm$ 301.8
Solenoid	5 Tesla SC	259.1	339.2	$\pm$ 298.3
Flux return	Scintillator-steel	340.2	604.2	$\pm$ 303.3

SiD Endcap	Technology	Inner z	Outer z	Outer radius
Vertex detector	Silicon pixels	7.3	83.4	16.6
Tracker	Silicon strips	77.0	164.3	125.5
ECAL	Silicon pixel-W	165.7	180.0	125.0
HCAL	RPC-steel	180.5	302.8	140.2
Flux return	Scintillator/steel	303.3	567.3	604.2
LumiCal	Silicon-W	155.7	170.0	20.0
BeamCal	Semiconductor-W	277.5	300.7	13.5

SiD - "Silicon Detector“ @ ILC





LADs at Accelerators

SiPM readout and thin gap RPCs

Figure II-5.5
SiPMs are positioned at the end of each fibre by a SiPM mounting block and fibre guide.

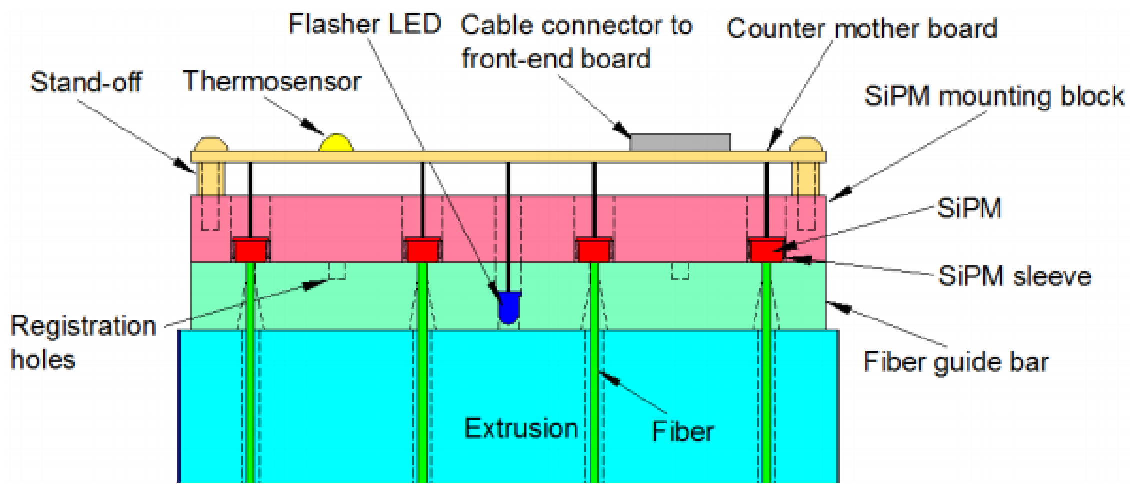
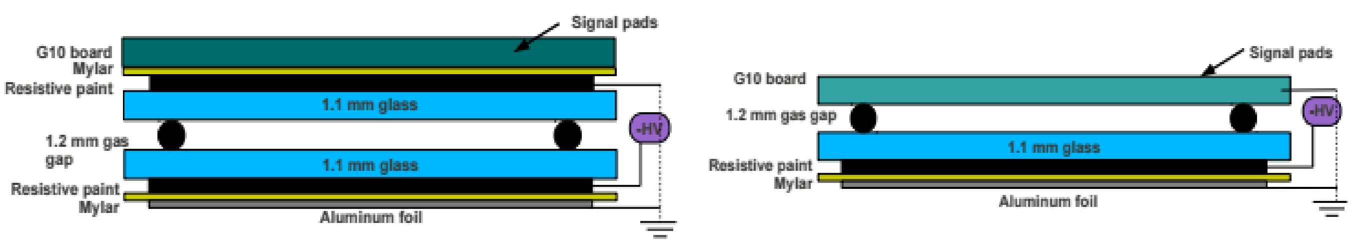


Figure II-4.8
Schematic of the RPC design with two glass plates (left) and one glass plate (right). Not to scale.



LADs at Accelerators

The progress in the **front end electronics** is mandatory for new colliders

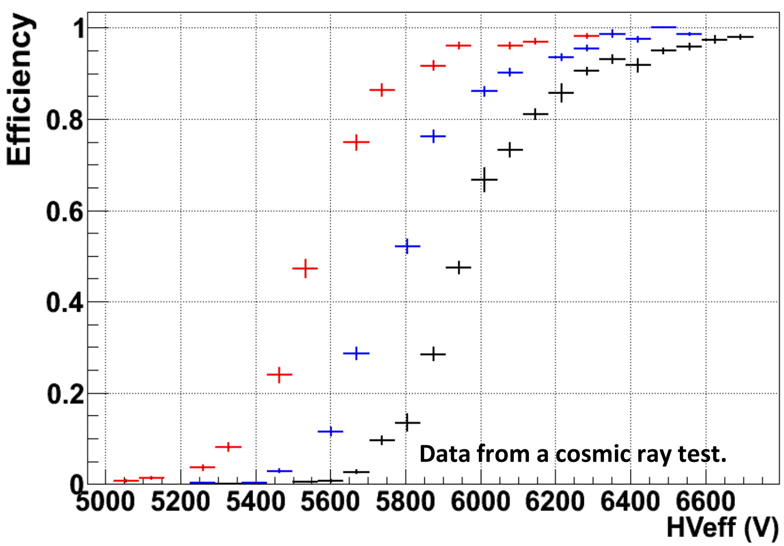
- Transfer the amplification from the detector to the front end electronics.
- Decrease the noise (down to 100 e^- RMS).
- Decrease the shaping of the pulse (10-40 ns).
- Increase the dynamic range.
- Decrease the power consumption.
- Decrease the cost.
- Increase the speed (100 GHz).

⇨ **A very promising technology is SiGe.**

LADs at Accelerators

SiGe amplifier application on Resistive Plate Chambers (1)

A 1 mm gap RPC detector read out with a ATLAS like threshold (black), the new preamplifier in silicon technology (blue) and in SiGe technology (red)

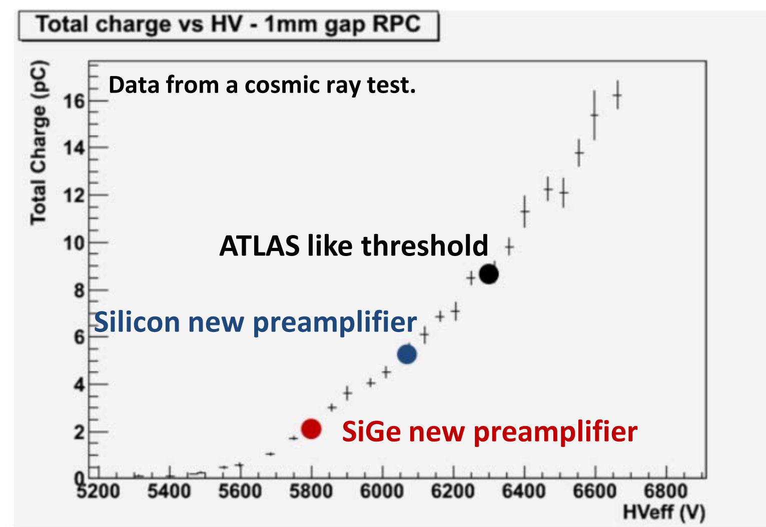


Lower gain means lower charge per count.

NOTE: the total charge reported is not the prompt charge collected in the front end.

Using a more sensitive front end allows to operate the detector at a lower gas gain.

Total delivered charge per count in the detector. The working point with different front ends is

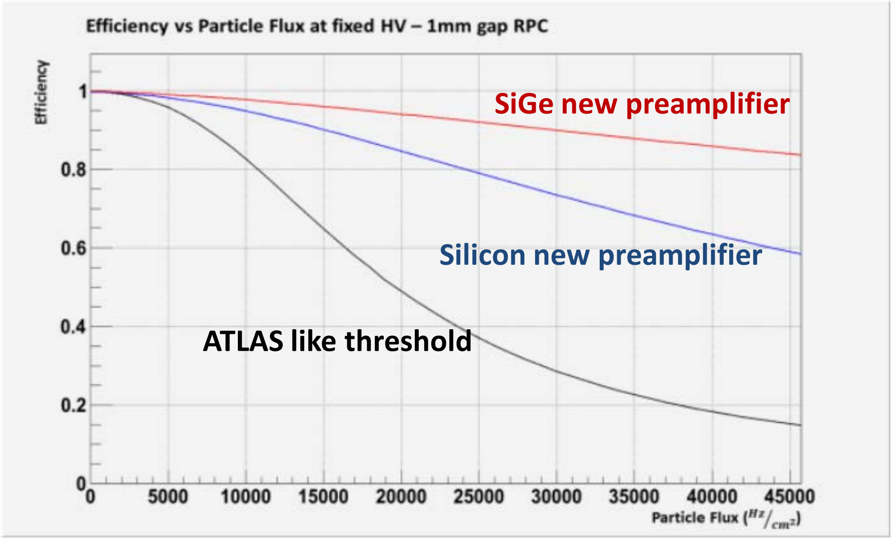


LADs at Accelerators

SiGe amplifier application on Resistive Plate Chambers (2)

- Operating the detector at a lower charge per count means improving rate and reducing the ageing of the detector.

Efficiency vs counting rate simulated for a 1mm single gap RPCs.



- Starting from experimental data at 7 KHz/cm^2 we simulated the efficiency VS counting rate for a RPCs with ATLAS standard electrode plates. The applied voltage is 200 V above the plateau knee. The results are in agreement with the experimental data collected at the CERN GIF.

LADs at Accelerators

Synchronous particle density
v.s.
amplitude signal in streamer mode in the RPC

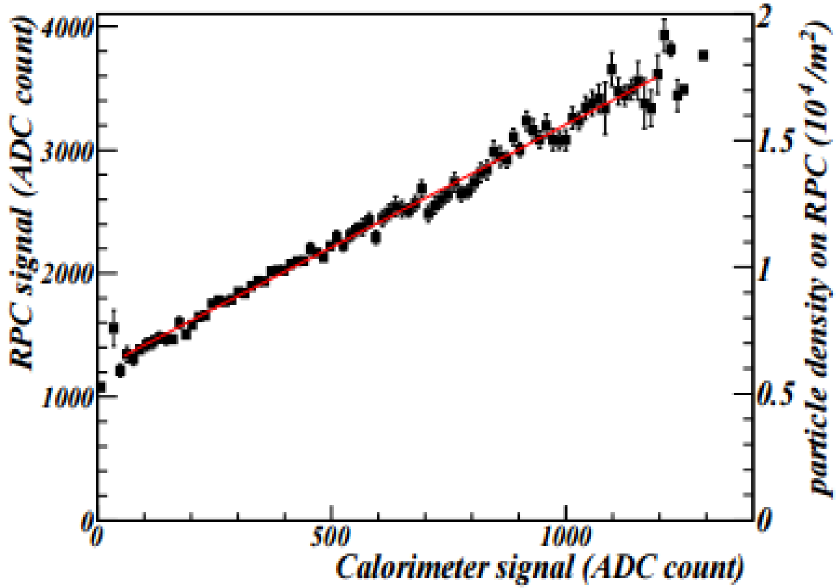


Figure 7: Result of the RPC linearity test performed at the BTF (see text for details). The fit with a straight line, in red, has been performed.

RPC Linearity up-to 2-5 particles/mm^2 density when operated in avalanche mode

LADs at Accelerators

100ps time resolution with thin silicon pixel detectors and a SiGe HBT amplifier.

Mathieu Benoit[a], Roberto Cardarelli[b], Stéphane Débieux[a], Yannick Favre[a], Giuseppe Iacobucci[a], Marzio Nessi[a,c], Lorenzo Paolozzi[a,*] and Kenji Shu[d].

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E-mail: lorenzo.paolozzi@cern.ch

ABSTRACT: A 100µm thick silicon detector with 1mm² pad readout optimized for sub-nanosecond time resolution has been developed and tested. Coupled to a purposely developed amplifier based on SiGe HBT technology, this detector was characterized at the H8 beam line at the CERN SPS. An excellent time resolution of (106±1)ps for silicon detectors was measured with minimum ionizing particles.

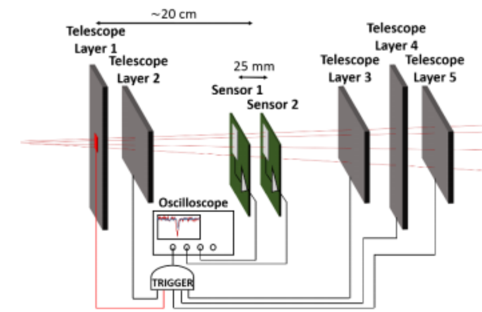


Figure 4: Schematic representation of the test beam setup. The pion beam was coming from left side of the figure. The beam divergence is exaggerated. The trigger region of interest is set on the first telescope layer.

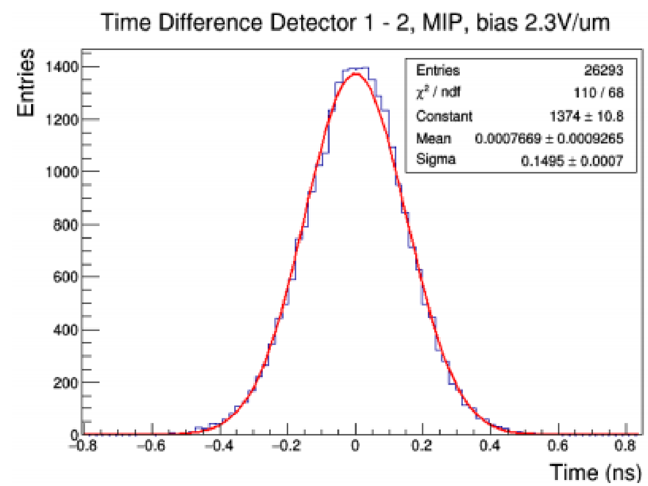


Figure 11: Pulse time difference between the two detectors corrected for time walk effect and fitted with a Gaussian function. The expected mean value was not estimated and it was set to zero in the plot.

LADs at Accelerators

Recent developments on Front End electronics played a major role in improving the performance of present generation of particle detectors:

RPC:
Very low noise,
fast shaping amplifiers.
→ Rate capability 1 kHz/cm^2 → > 10 kHz/cm^2
Space resolution 1 mm → 100 µm

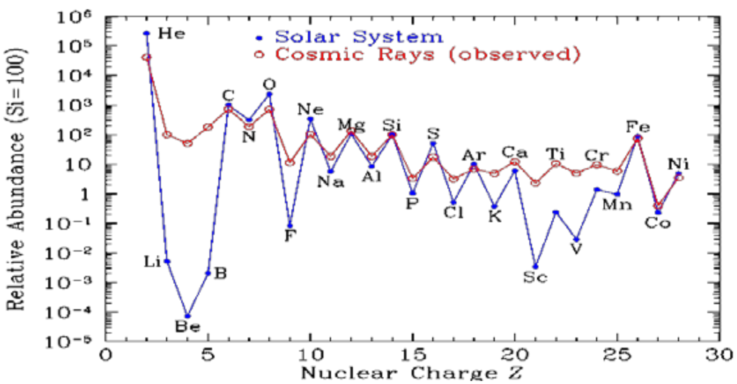
Silicon detectors:
Very low noise,
fast shaping amplifiers.
→ Time resolution 2-3 ns → 100 ps

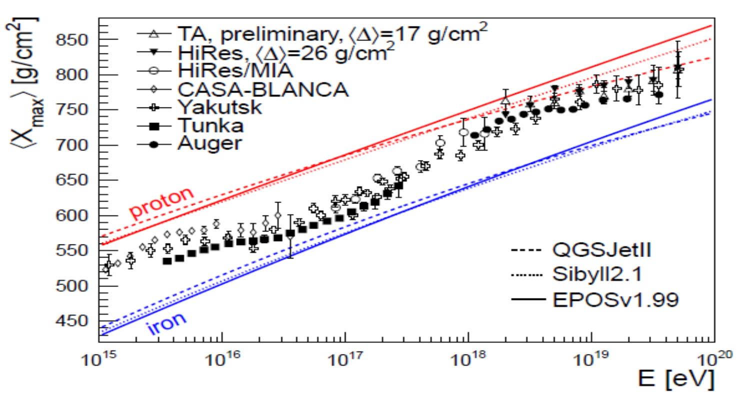
Scintillating detectors:
SiPMs and fast low noise amplifiers.
→ Operation in magnetic field is now possible.

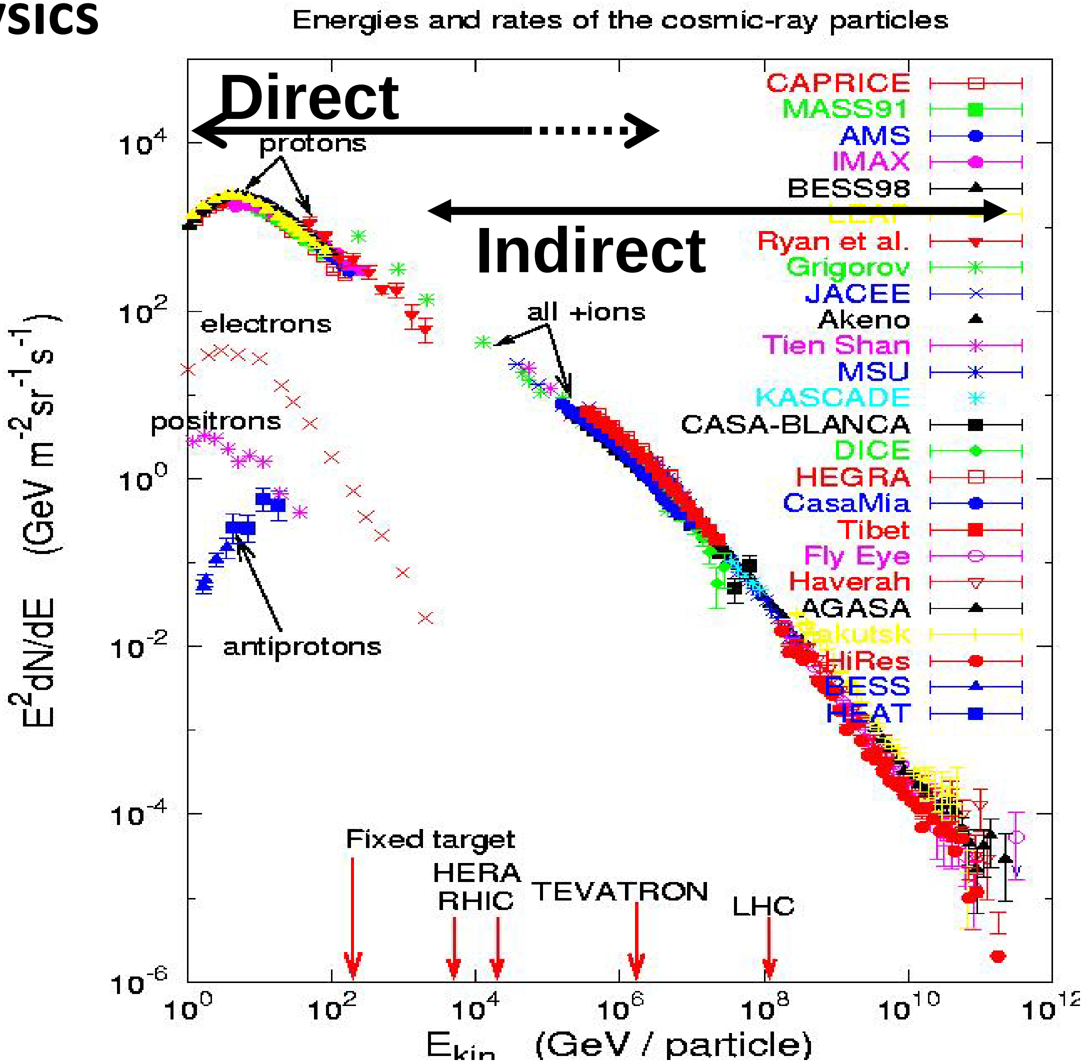
LADs for Astroparticle Physics

The case of Cosmic Ray physics

The beam :



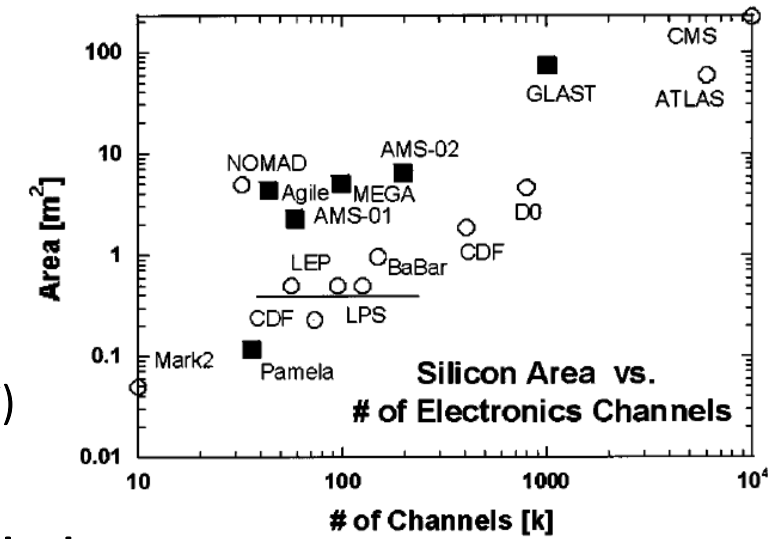




LADs for Astroparticle Physics

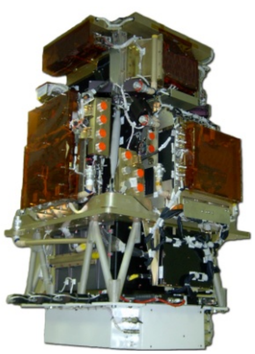
Cosmic Rays : Direct Measurements

Use ballons or satellites:
- particle ID (scintillators, silicon, TRD, ToF, …)
- tracking (silicon layers, ….)
- spectrometry (MDR limited, up to few TeV)
- calorimetry (mass/size limited, up to few hundreds TeV)

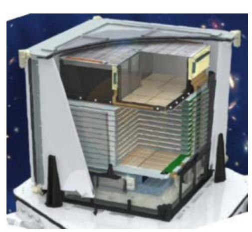


power consumption issues in space

Large Area Silicon tracking and/or charge-measuring detectors:
- 50-200 μm pitch
- analog readout



PAMELA - 0.2 m^2



AGILE - 4 m^2

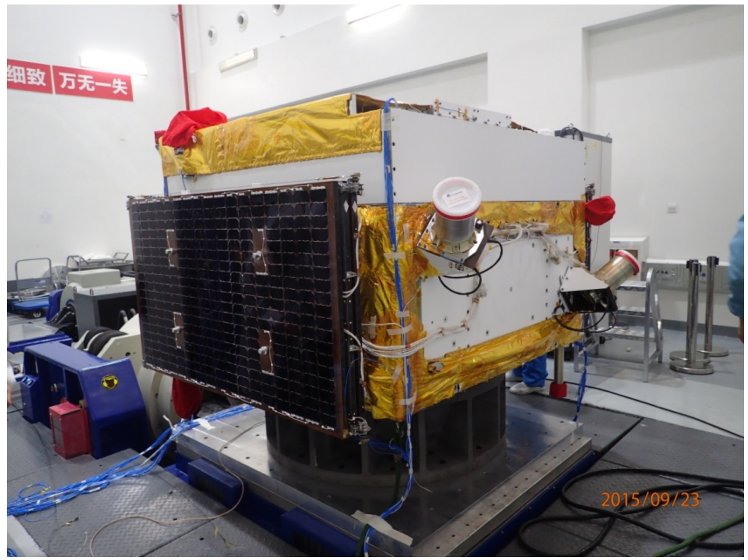
FERMI - 74 m^2

AMS - 7 m^2

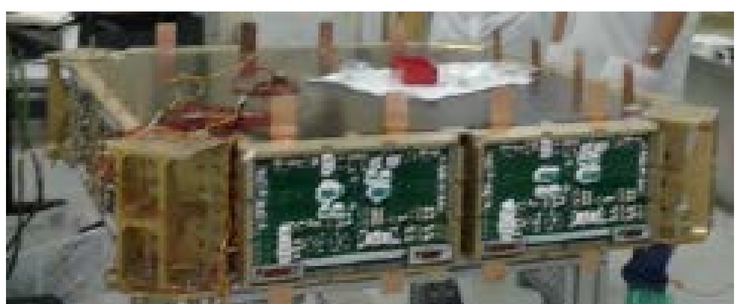
LADs for Astroparticle Physics

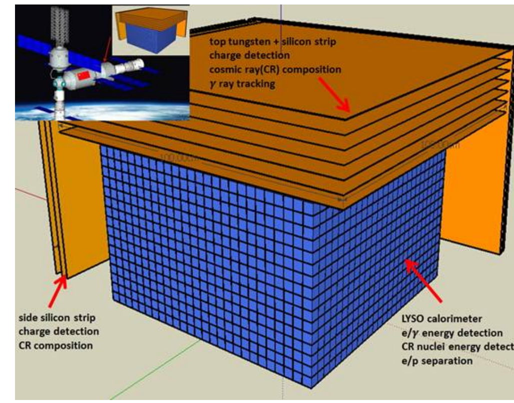
Cosmic Rays : Direct Measurements

Launched !
Dec 17, 2015 at 0:12 UTC using a Long March-2D launch vehicle from the 603 Launch Pad at the Jiuquan Satellite Launch Center's LC43 in the Gobi desert

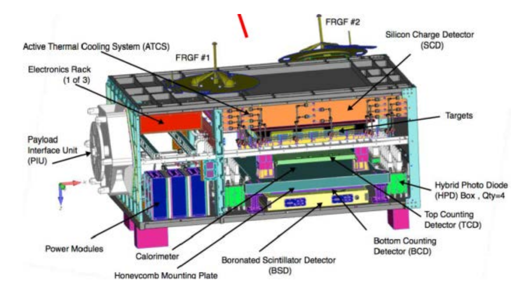


DAMPE -> WUKONG 7 m^2 / 74k ch





HERD 14 m^2



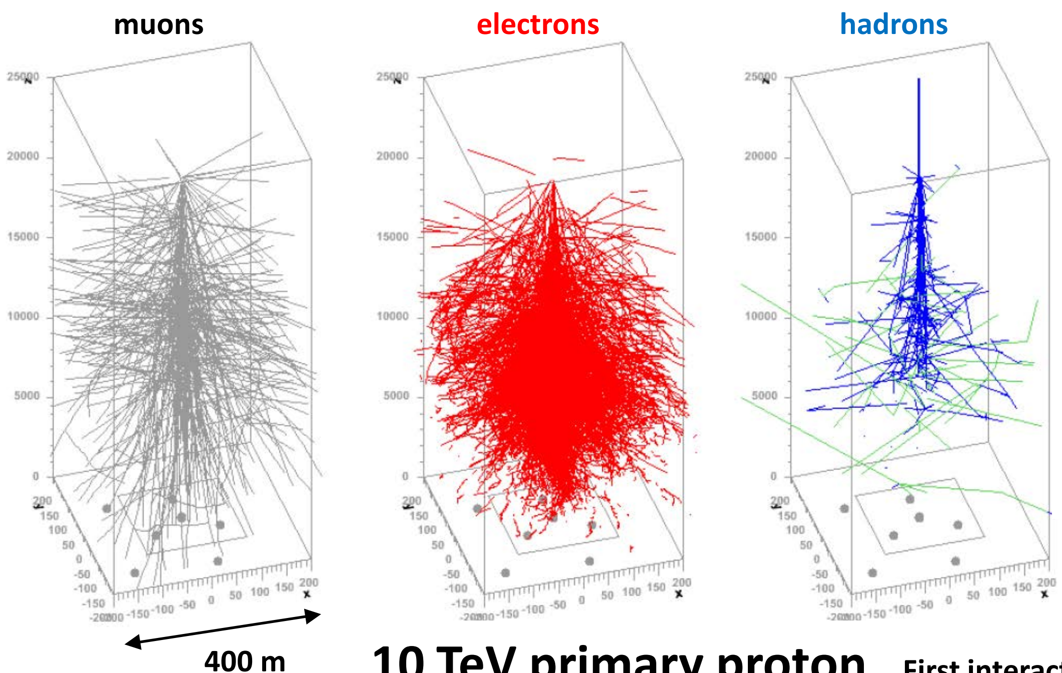
ISS-CREAM 2.5 m^2

LADs for Astroparticle Physics

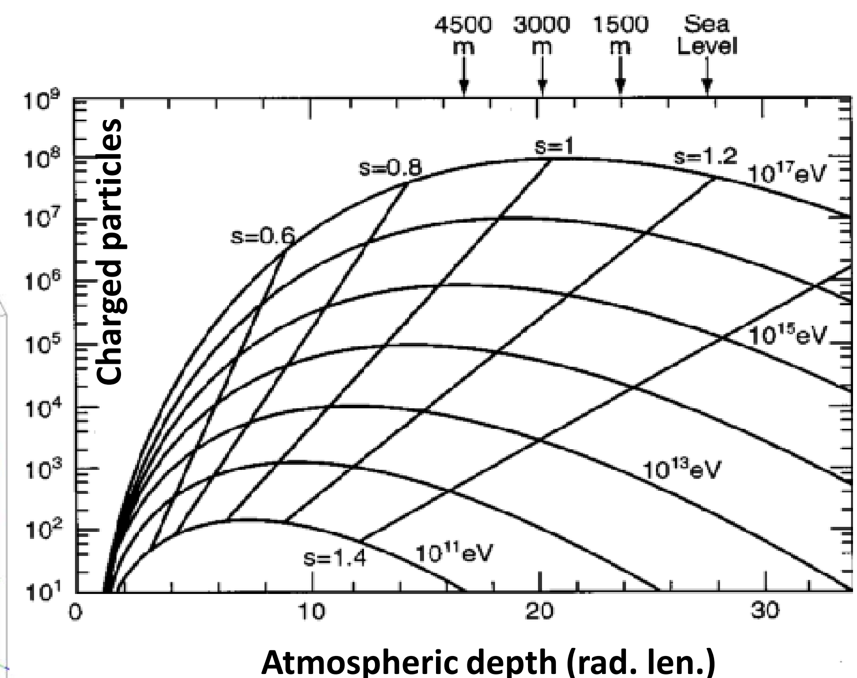
Cosmic Rays : Indirect Measurements

Use detector arrays on large surfaces and/or optical/radio signals :
- Larger systematics
- Very difficult composition measurements
- Can go to the highest energies

The vertical atmospheric depth corresponds to $28X_0$ or to 13Λ



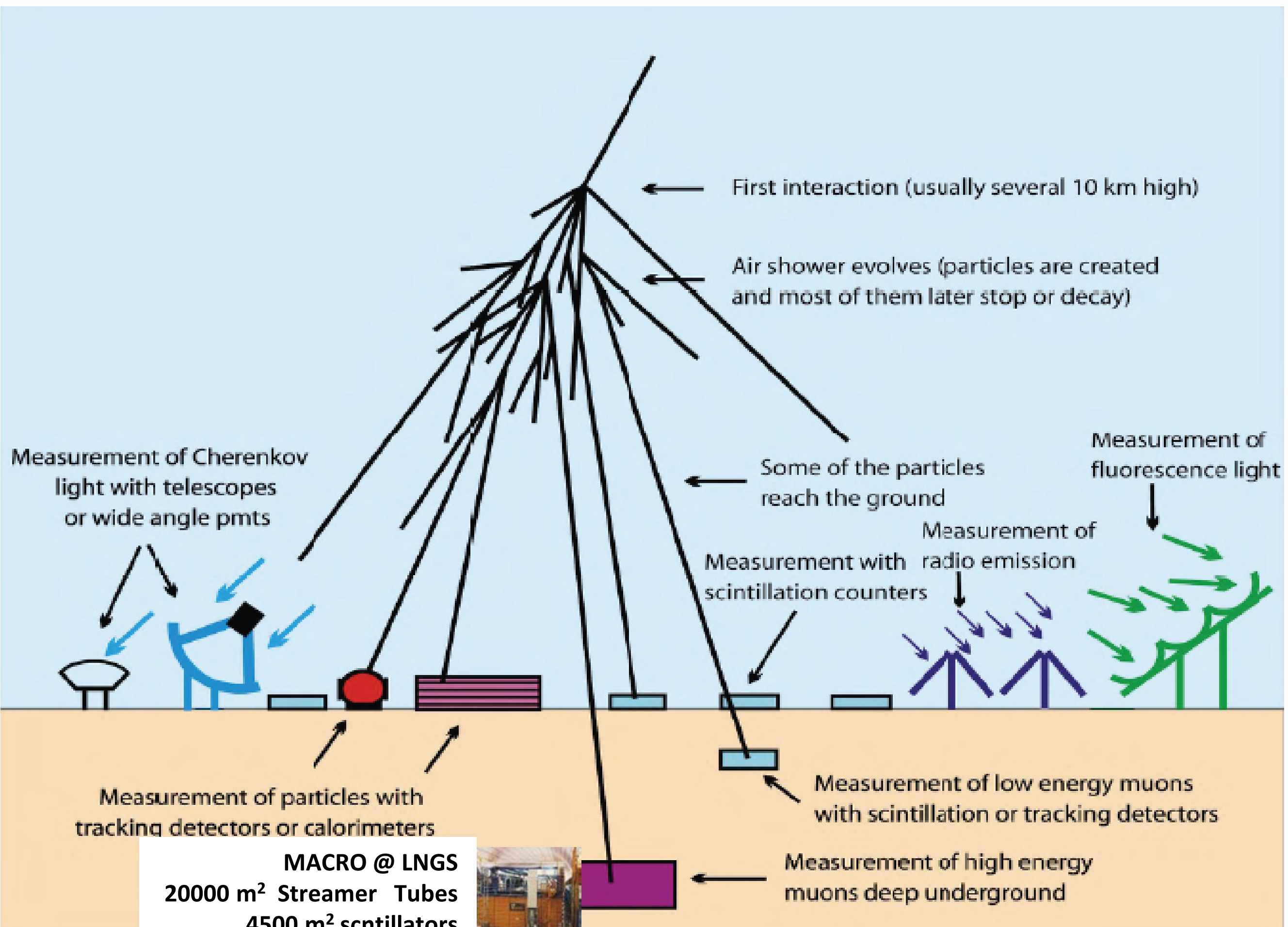
10 TeV primary proton **First interaction at 21km a.s.l.**



Energy range 1 TeV - 10^8 TeV

LADs for Astroparticle Physics

Cosmic Rays : Indirect Measurements



Cerenkov light (> 10^{10-} eV)

Fluorescence (> 10^{17} eV)

Radio (> 10^{15} eV) (R&D)

Infra-Red emission, …

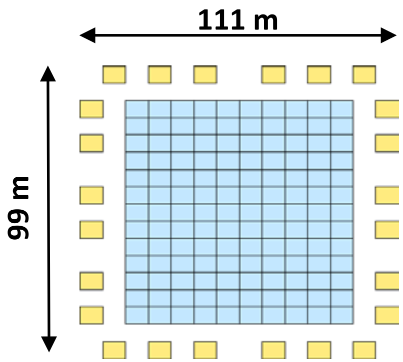
Particle detector arrays
(> 10^{12} eV at high altitude)

Total surfaces
10^{-3} km^2 – $10^{3.5}$ km^2

“cheap” and reliable detectors

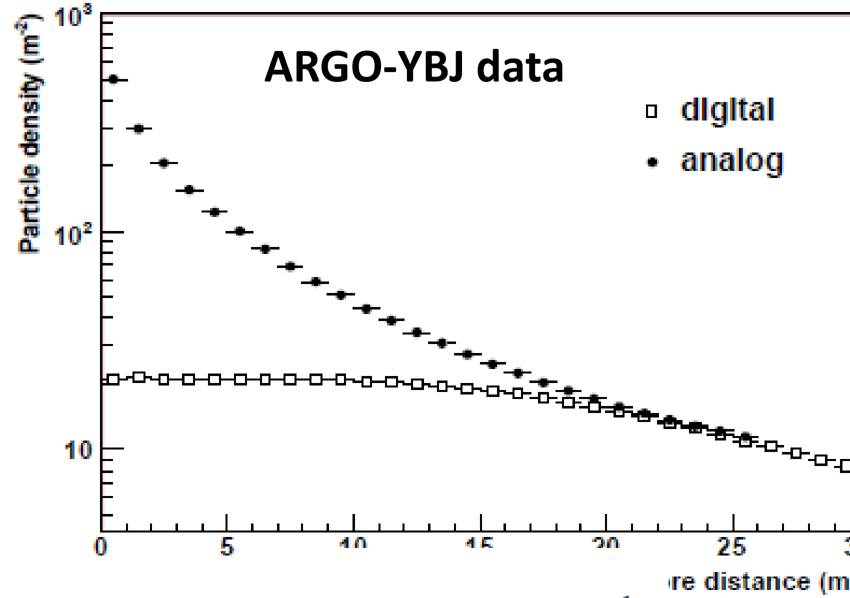
LADs for Astroparticle Physics

Cosmic Rays : Indirect Measurements

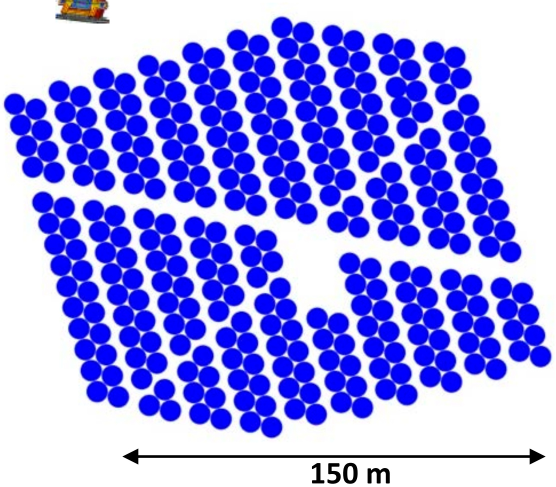


RPC : 6600 m^2

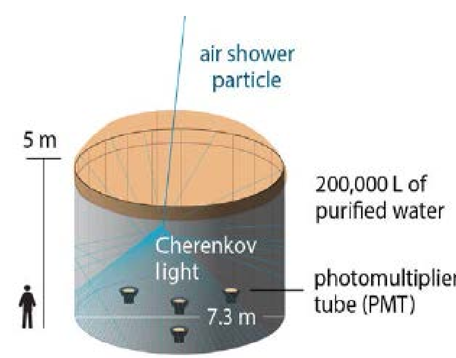
ARGO-YBJ (Tibet)
Streamer mode
digital + analog readout
1.5 ns resolution
Full coverage + guard ring
1 TeV - 10 PeV



ATLAS / CMS



HAWC (Mexico)
Water Cerenkov tanks
Standard PMT readout
Sampling
1 TeV – 100 TeV



dynamic range

LADs for Astroparticle Physics

Cosmic Rays : Indirect Measurements

1 KM2A:
5635 EDs
1221 MDs

LHAASO

1 TeV - 10^6 TeV

WFCTA:
24 telescopes
1024 pixels each

Many different standard techniques used together for the first time

WCDA:
3600 cells
90,000 m^2

Coverage area: 1.3 km^2

ARGO-YBJ

SCDA:
452 detectors

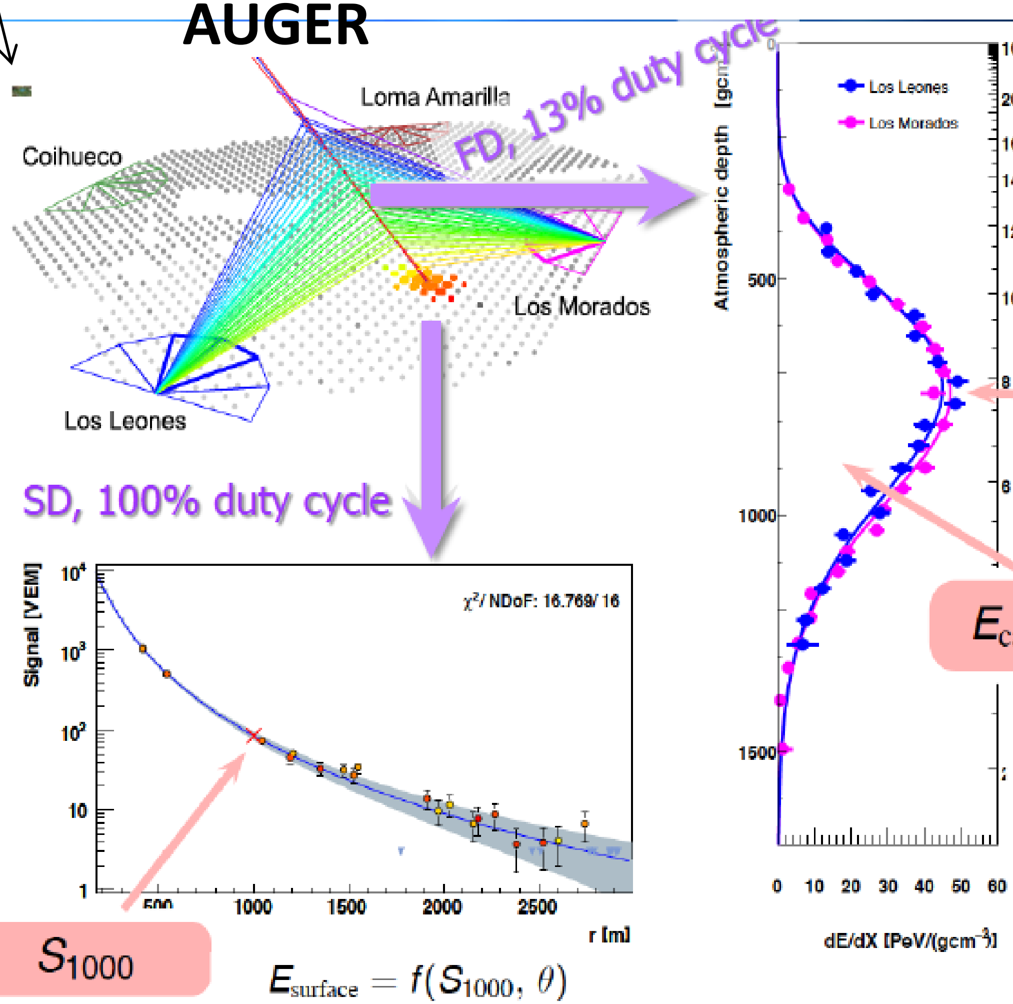
Issues
Detector synchronization and data handlng

LADs for Astroparticle Physics

Cosmic Rays : Indirect Measurements

LHAASO

AUGER



$\sigma X_{\max} < 20\ \mathrm{g/cm^2}$
$\Delta_{\rm sys} \approx 15\ \mathrm{g/cm^2}$

$E_{\rm cal} = \int \frac{\mathrm{d}E}{\mathrm{d}X}\,\mathrm{d}X$

$\sigma_E/E \sim 8\,\%$
$\Delta_{\rm sys} \approx 14\,\%$

$E_{\rm surface} = f(S_{1000},\,\theta)$

AUGER (Argentina)

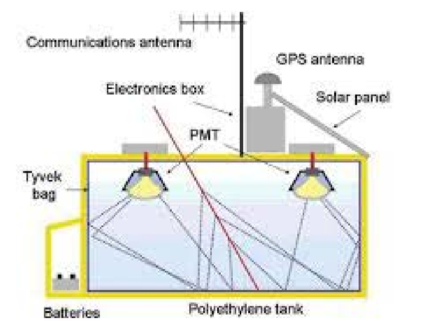
Water Cerenkov tanks

Fluorescence telescopes

Radio antennas

3000 km²

10^5 TeV - 10^8 TeV



TA (Utah)

Scintillator array

Fluorescence telescopes

700 km²

10^5 TeV - 10^8 TeV

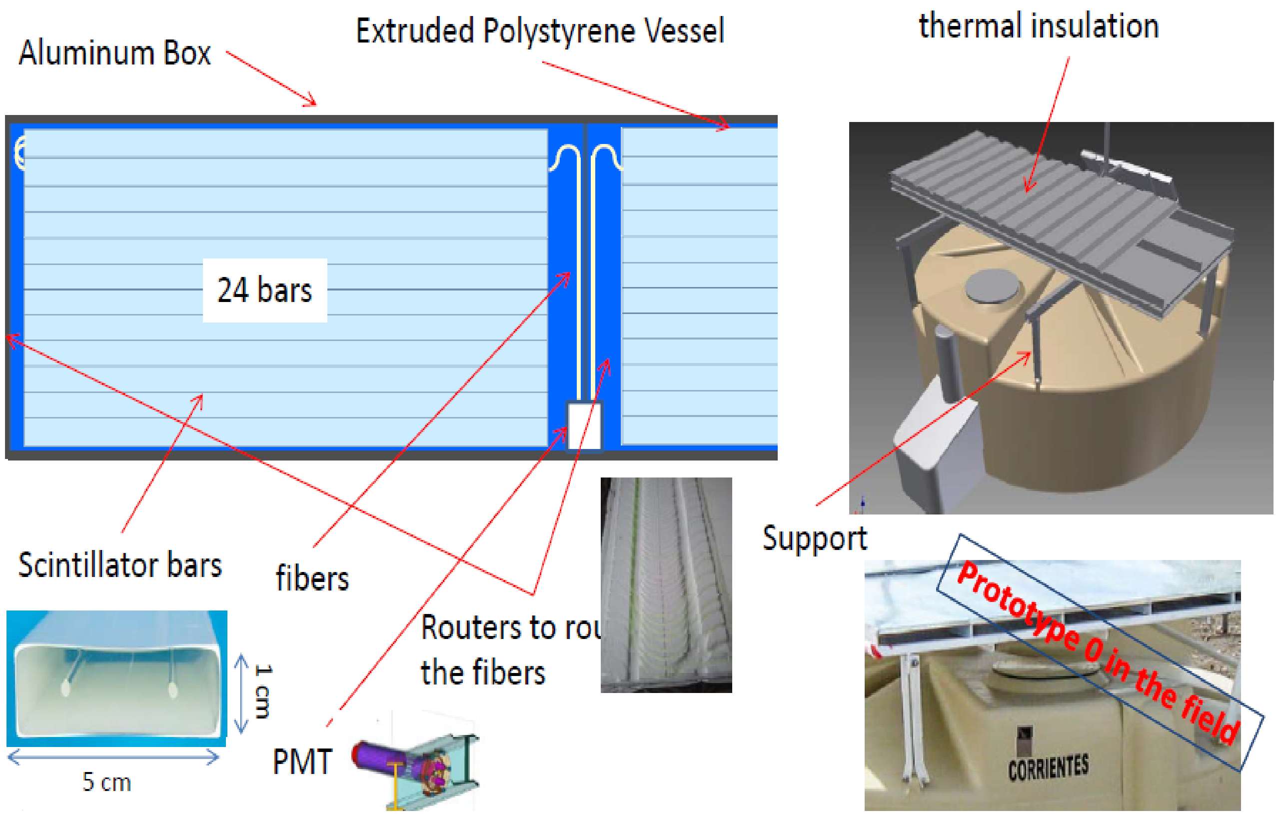
LADs for Astroparticle Physics

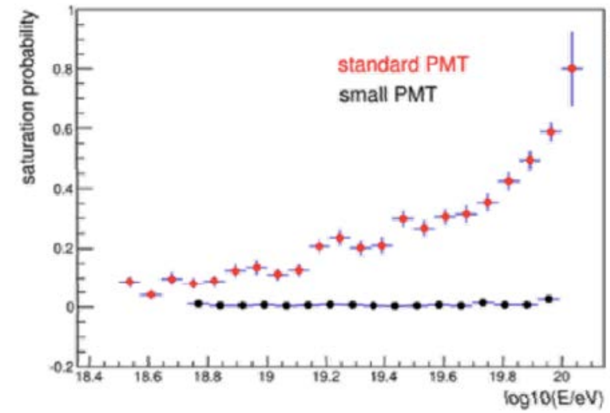
Cosmic Rays : Indirect Measurements

AUGER-PRIME

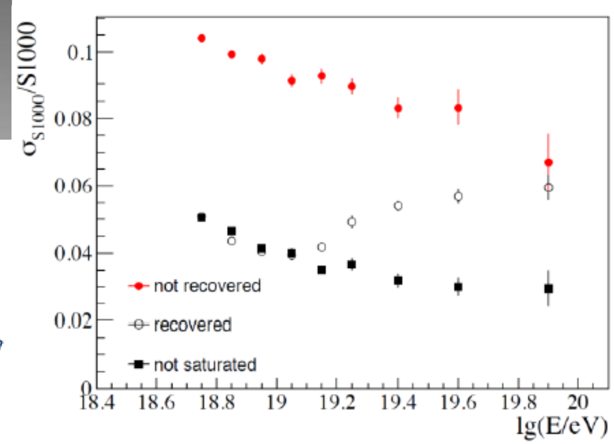
Determine the electromagnetic and muonic components

The Surface Scintillator Detector





dynamic range



Summary

LADs at accelerators:

The progress in the **front end electronics** is mandatory for new colliders

Scintillating detectors:

- Rate and magnetic field compatibility improved thanks to SiPMs readout.
- Time resolution < 1 ns compatible with future colliders requirements.
- Low granularity and high cost for large area detectors still an issue.

Resistive Plate Chambers:

- High granularity.
- Time resolution < 500ps.
- Space resolution < 100 µm.
- Rate capability o(10 kHz/cm^2)
  R&D in progress, target 100 kHz/cm^2.

Silicon Detectors:

- Very High granularity and rate capability.
- Time resolution < 100 ps.
- Space resolution < 30 µm.
- Very high cost. Possible application for high eta region.

LADs for Astroparticle Physics

- Space (SiTracker): technologies at the leading edge
- Space (SiTracker): need for **lower power consumption**
- Ground: Need for a **larger dynamic range**
- Both: **New light sensors** (SiPM, VSiPMT,…)
- …..