# Astroparticle physics

Charles University

Silesian University

Palacky University

Czech Technical University

Academy of Sciences

# Topics/Projects

- **High-energy gamma rays**
  - Past projects: CAT, CELESTE
  - H.E.S.S.
  - Future: Cherenkov Telescope Array

(~ 16 people, 2 phd students)

- **Ultra-high energy cosmic rays**
  - Running project: Pierre Auger Observatory

(~ 30 people, 4 phd students, > 5 master students)

- National cosmic ray detection network
  - CZELTA

(~ 10 people + many high-school students)

- **Nuclear Astrophysics –** talk of J. Mrazek

- **Picasso experiment** – direct dark matter searches

- **LSST**- testing of sensors, dark energy collaboration

(3 people, 1 student)

# CAT, CELESTE

- past projects 1996 – 2004
- **Charles University, Institute of Physics ASCR and Palacky University**
- Activities
  - Physics Analysis
  - Detector operation
  - Mirror design and production

# H.E.S.S

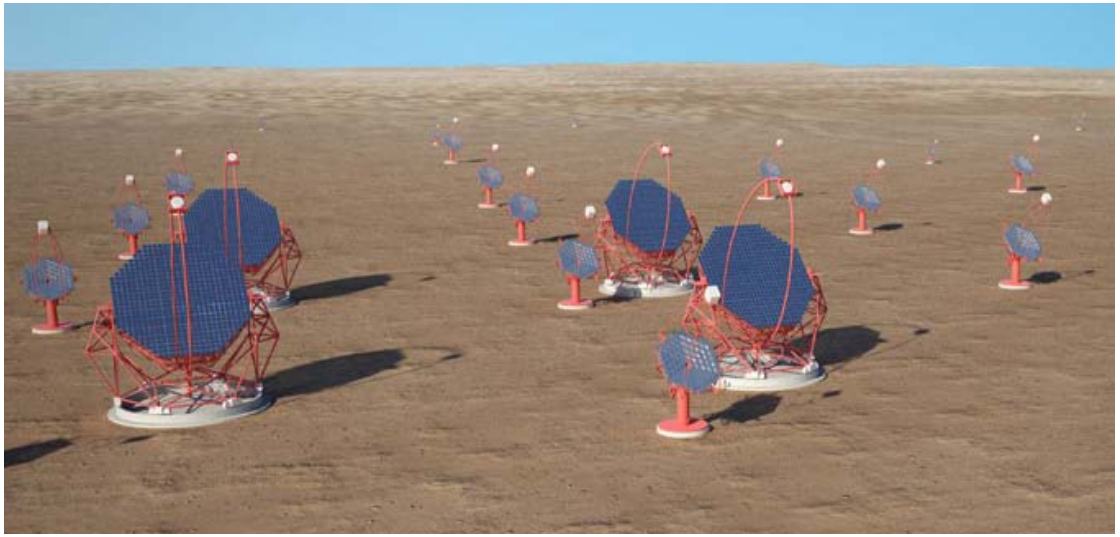
- Charles University – Ladislav Rob and Dalibor Nedbal
- Activities:
  - optical system (mirrors from CR - H.E.S.S. I)
  - data analysis
    - Galactic centre and dark matter
    - Extragalactic sources: starburst galaxies, galaxy clusters

# Cherenkov Telescope Array - CTA

Future gamma ray observatory - *almost* construction ready
ESFRI prioritized project

Natural continuation of our past activities (also w.r.t. Pierre Auger Observatory)

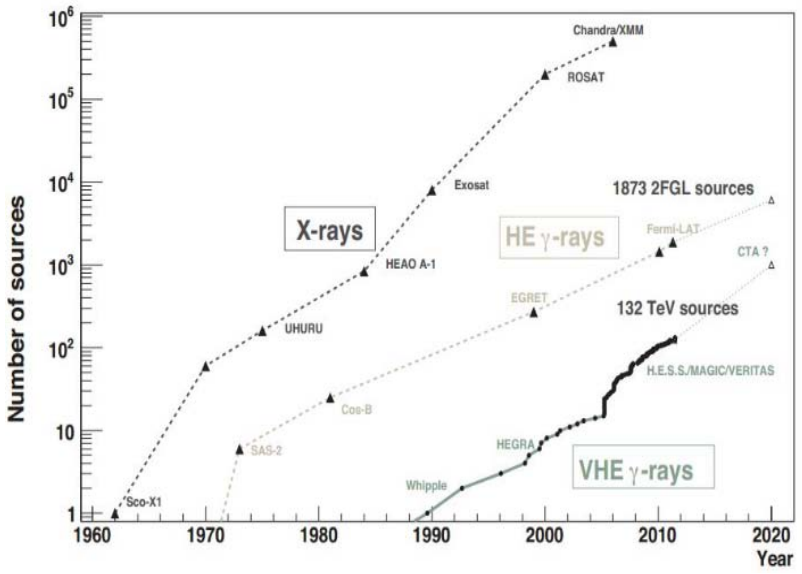
Current national partners:
Charles University, Palacky University and Institute of Physics ASCR

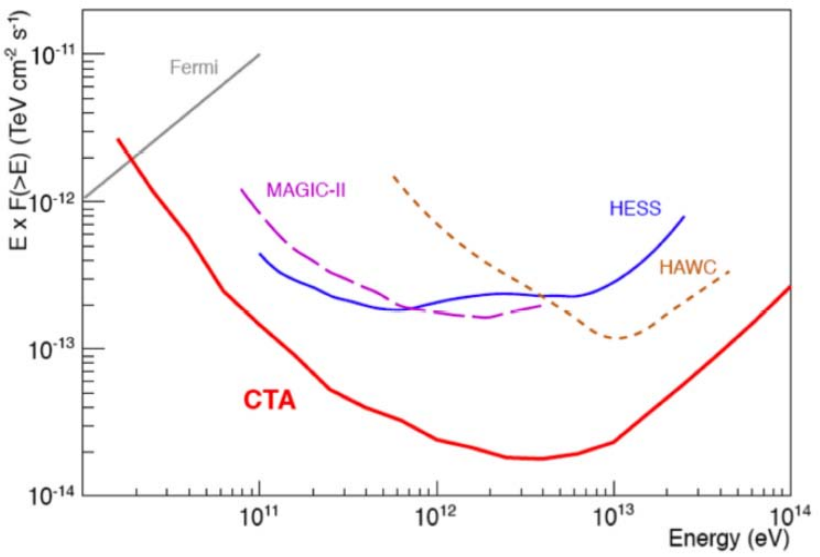


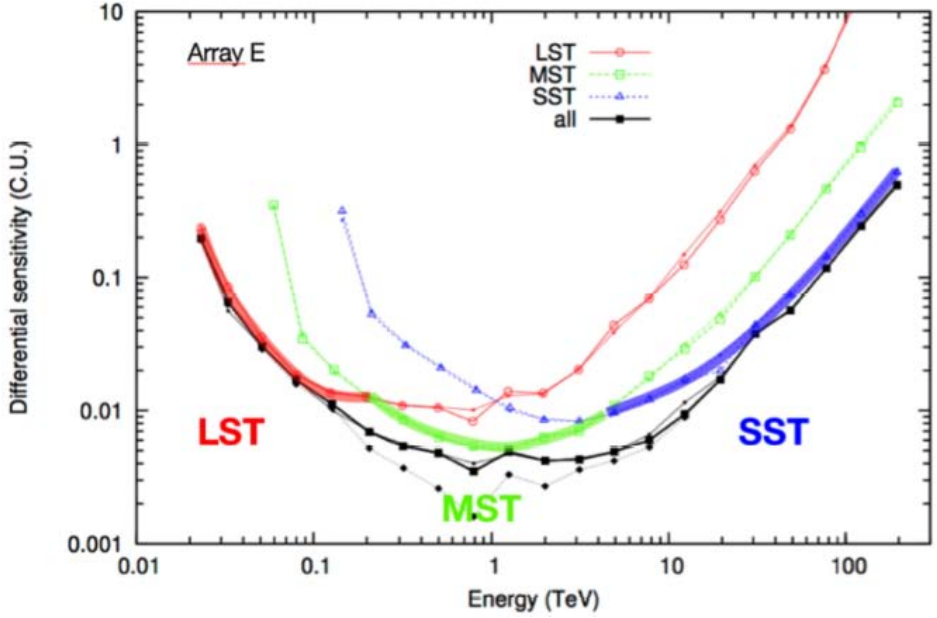
Finance resources:
- Current financing scheme: EUPRO 2013-2016 and INGO 2014-2016 projects of Ministry of Education (MEYS)

- Future scheme: Large Research Infrastructures (MEYS)

# Why Cherenkov Telescope Array?



# Telescopes - CTA

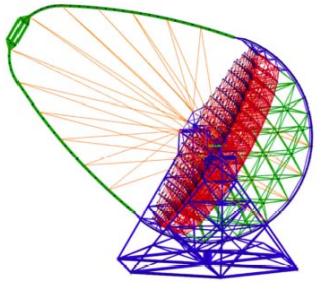


Figure 2: The baseline design for an LST of 23 m diameter, with 4.5° FoV and 2500 pixels of 0.1° diameter.

**Large Size Telescope** - 23 m diameter, with 4.5 deg FoV and 2500 pixels of 0.1 deg diameter

Figure 3: The baseline design for the 12 m diameter MST of Davies-Cotton type, with 8° FoV and 1500

**Medium Size Telescope** - 12 m diameter, with 8 deg FoV and 1500 pixels of 0.18 deg

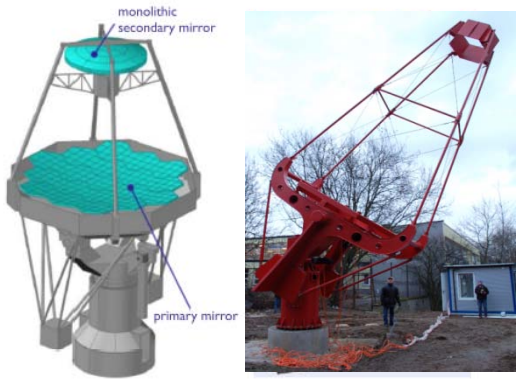
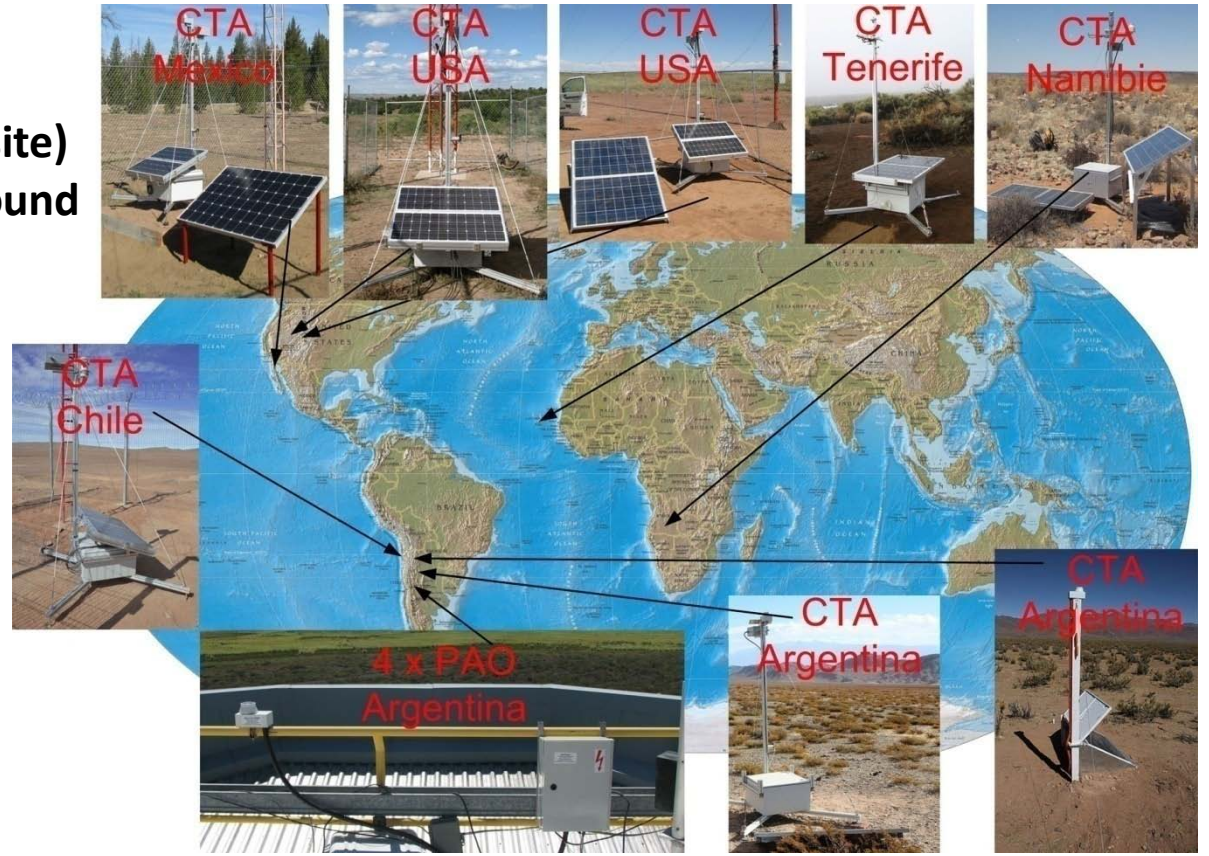


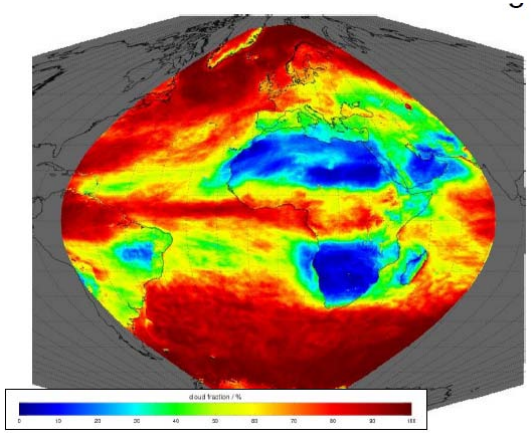

Figure 5: Two possible designs for the SSTs of 4-7 m diameter, with 8-10° FoV and 1500-2000 pixels of 0.2-0.3°. Left: Schwarzschild-Couder dual-mirror optics. Right: Traditional Davies-Cotton design.

**Small Size Telescope** - 4-7 m diameter, with 8-10 deg FoV and 1500-2000 pixels of 0.2-0.3 deg

# CTA – current Czech participation
## *Site selection/characterization*

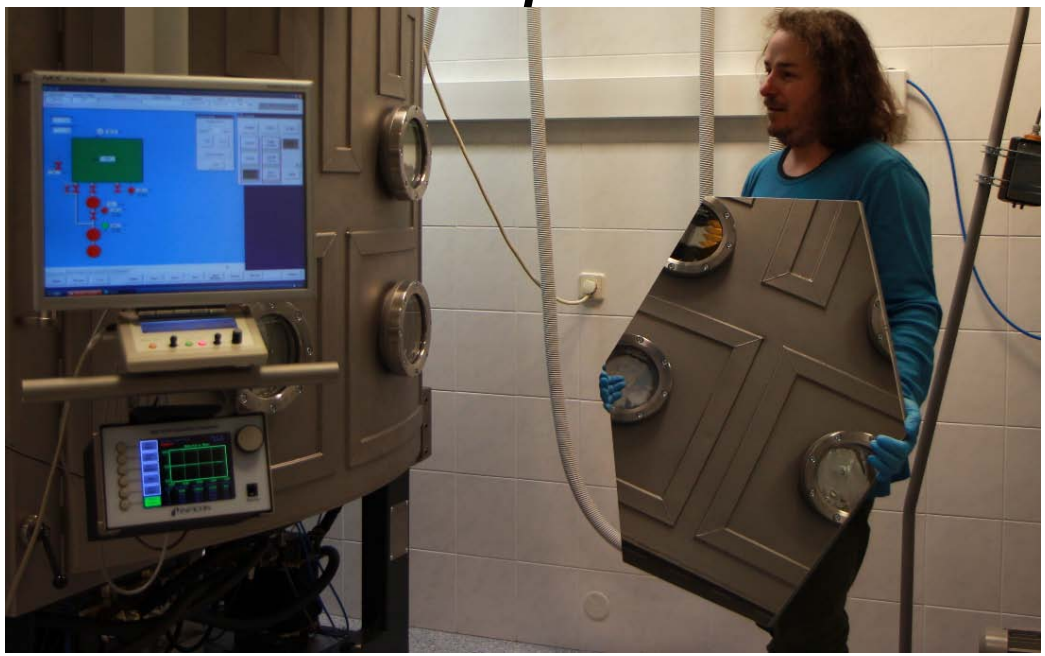
**Cloudiness (>1 year of data per site) from 8 Czech all-sky cameras around the world**



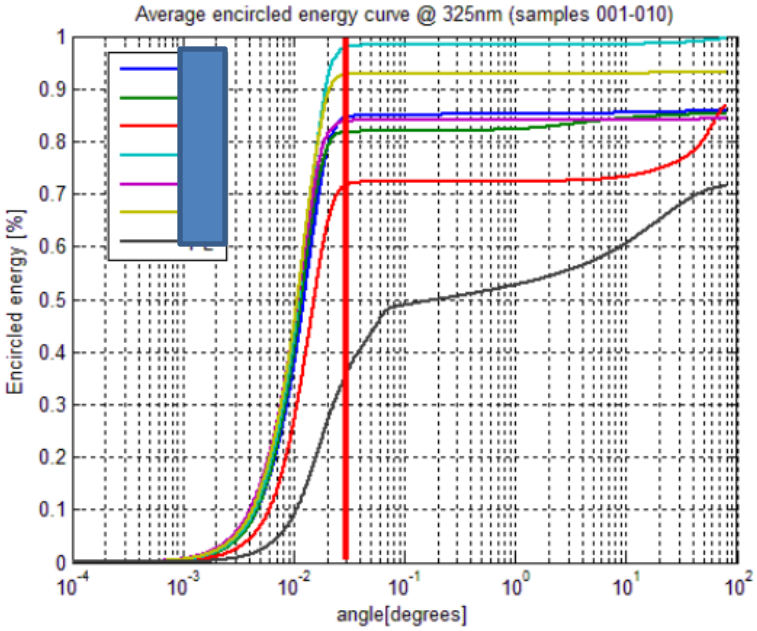



**Long time characterization from satellite images (collaboration with Czech Hydro-meteorological institute and Deutscher Wetterdienst)**

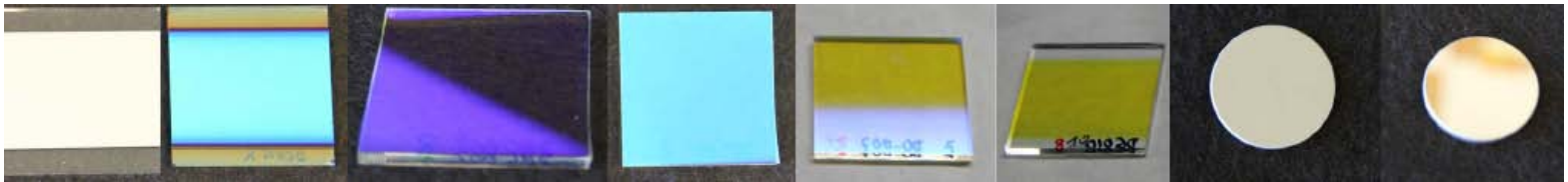
# CTA – current Czech participation
## *Mirror development and testing*



**Technology development for production of SST-DC mirror segments**
**Benefit from experience from CAT, CELESTE and AUGER projects**

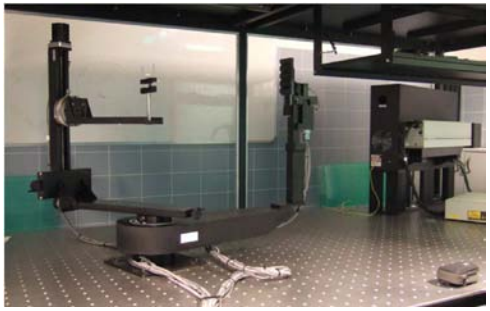



**Extensive testing of mirror samples and segments for many CTA partners (tests on reflectivity, surface roughness, durability tests, scratch tests …)**

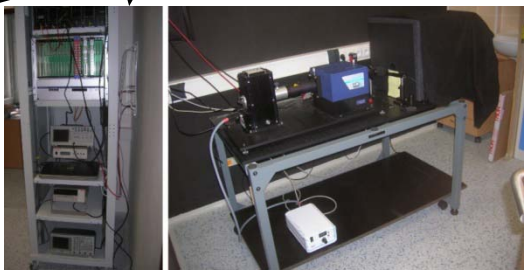


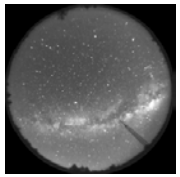
# CTA – current and future Czech participation

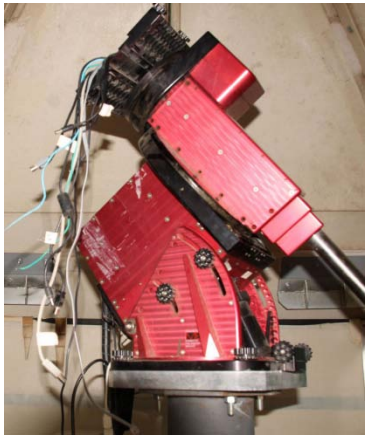
- **SST-DC telescope (mirror segments)**



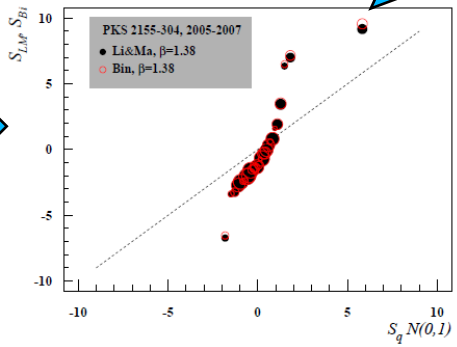
- **Common Test Facilities and Components**
  - Mirror Test Facilities (MTF)
  - Camera Test Facilities (CTF)
  - Central Calibration Facilities (CCF)
  - Common Camera Components (CCC)







- **Physics**



# Pierre Auger Observatory

**HEAT (mirrors from CR)**

**AMARILLA (mirrors from CR)**

**COIHUECO (mirrors from CR)**



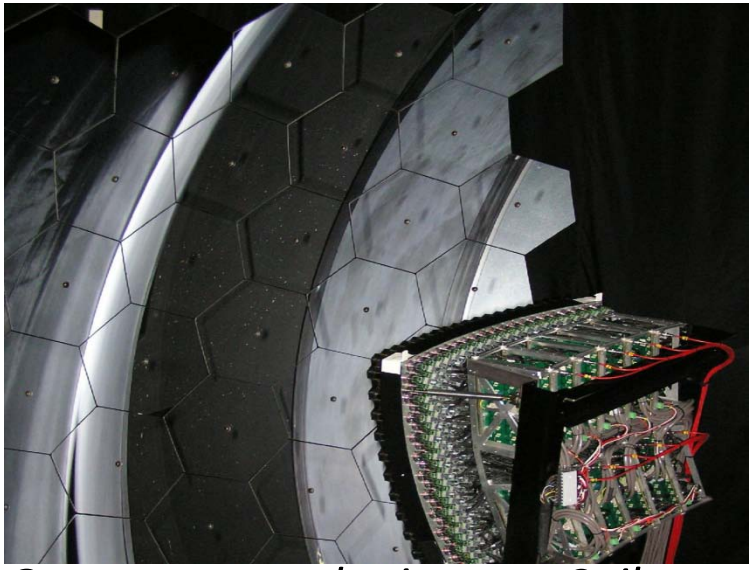

**MORADOS**



**LEONES**

# Pierre Auger Observatory - *activities of Czech teams*

- **HardWare (HW)**
- **Detector Operation, performance studies & data quality (DO),**
- **Physics Analysis (PA)**
- **Investigations of new detection techniques (AMY, MIDAS)**



*One segmented mirror at Coihueco*

Experience already from CAT-CELESTE

**HW**

optical system design for fluorescence telescopes
(spot analysis, corrector rings, ... )
actual design and production of 15 out of 27 telescope mirrors

Segmented mirrors (telescope 3.4 x 3.4 m), reflectivity above 90 % between 300-400 nm, small spot size

# Pierre Auger Observatory

HW

*Glass furnace and glass press in Kavalir Sazava*

- collaboration with glass works Kavalir in Sazava
- production of circular moulded glass segments controlled by our opticians

- preparation of mirror segments in Olomouc lab (cutting, drilling, milling, grinding, polishing, …)

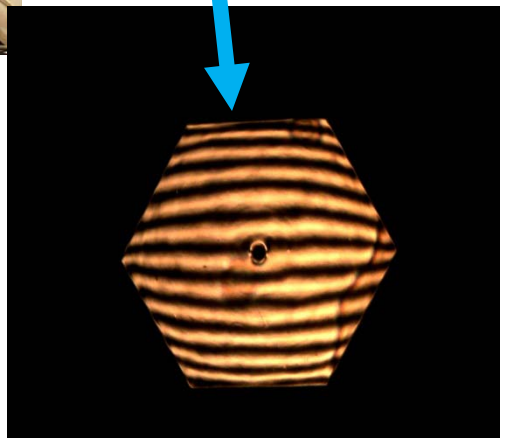
*Polishing machine in Olomouc lab*

# Pierre Auger Observatory

HW

*Aparature to deposite relflective and protective layers (Olomouc lab)*

*Ronchi test to control shape of segment surface*



- preparation of mirror segments in Olomouc lab: deposition of optical thin films, protective silicon oxide layer to cover deposited aluminum reflective layer

# Laboratory equipment (other examples)

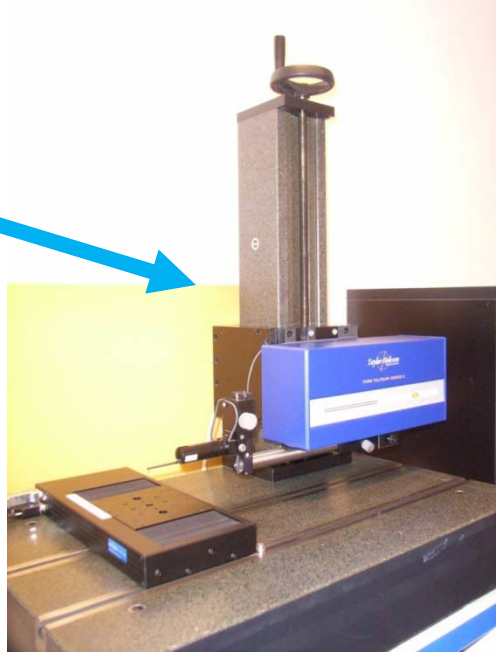
HW

*UV-VIS spektrometer P&E Lambda 850*


*CASI – complete angle scatterometer instrument*

*Confocal Laser Scanning Microscope LEXT*

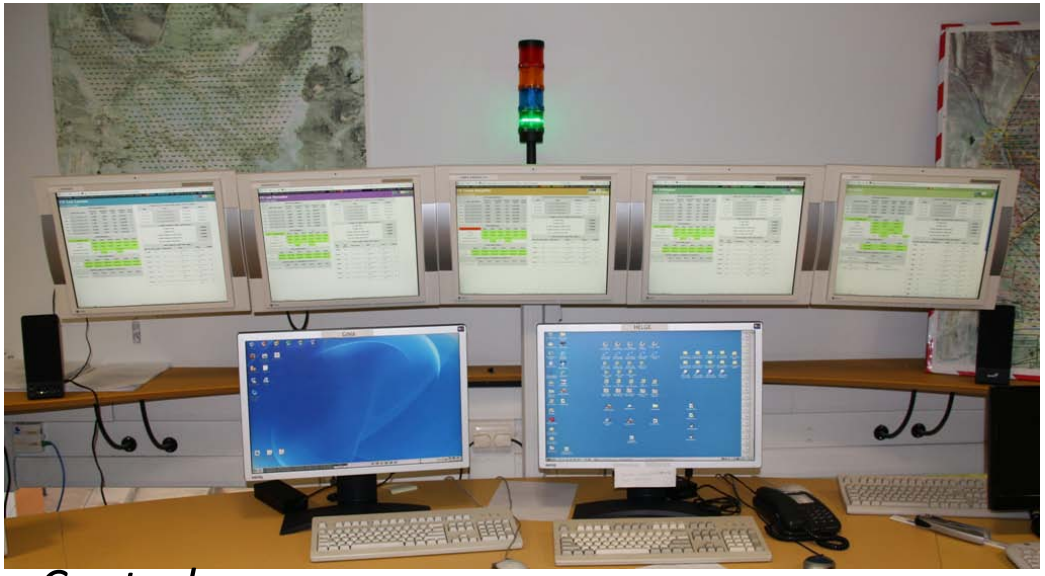
Profilometer T&H



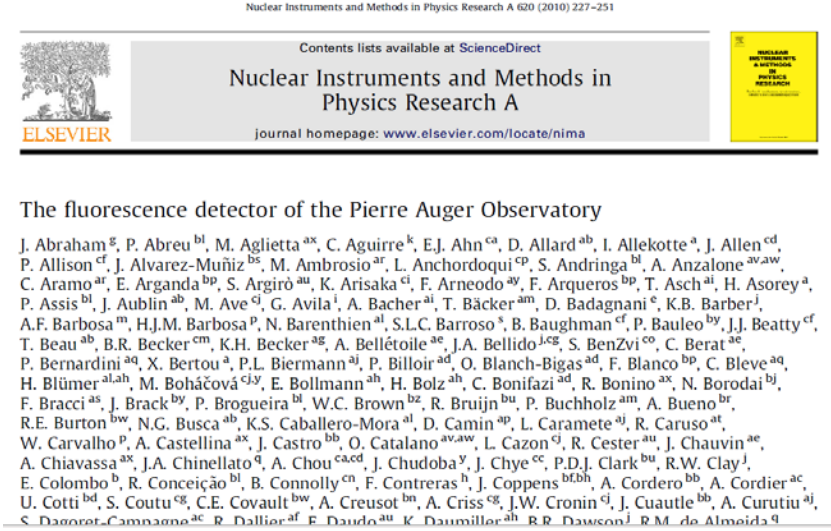
# Pierre Auger Observatory

DO

- J. Ridky served as task leader for Fluorescence Detector (FD) operation for many years, supported by the whole Czech team
- detector performance studies
- FD on-line monitoring, dead time calculation, calibration, accuracy of geometrical reconstruction, PMT ageing ...



*Control room*



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The fluorescence detector of the Pierre Auger Observatory

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*Publication about detector system*

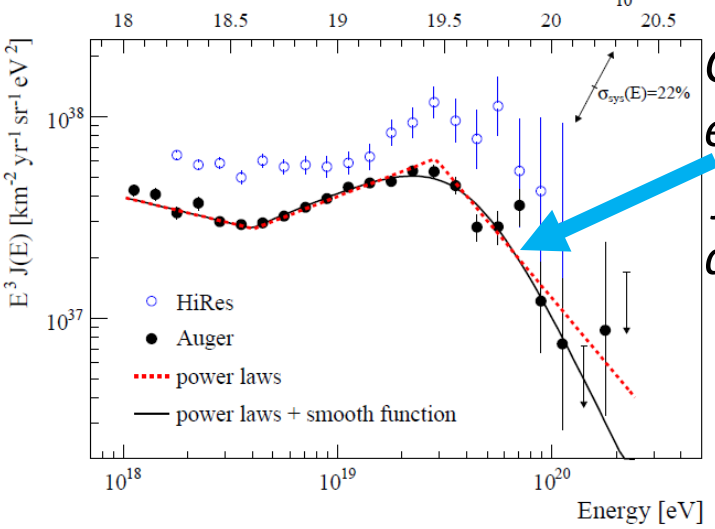
PA

# Pierre Auger Observatory

- MC simulations of shower propagation in the atmosphere using GRID (IoP maitains virtuals organiation AUGER and was the first proponent of grid system within the AUGER collaboration)
- Comparison of models of hadron-hadron interactions with data from Pierre Auger Observatory and chemical composition
- Systematics of energy calibration at AUGER, accuracy of CIC curve determination and energy calibration
- Anisotropy studies (GRB, galactic centre, propagation in magnetic fields, Cen A,…)
- Atmospheric quality and its impact to shower reconstruction (FRAM star monitor, VAOD, non-invasive shoot-the-shower, APF, …)


*Computing farm Golias*

*FRAM telescope to monitor atmospheric extinction*

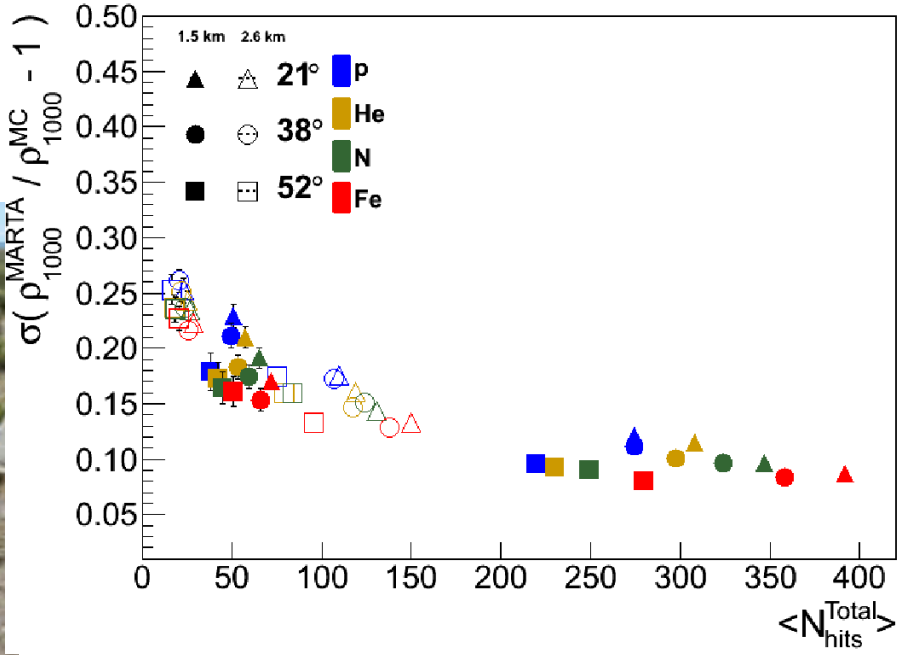



*Combined (SD+FD) energy spectrum - features of ankle and GZK cutoff visible*

# Pierre Auger Observatory

Participation in observatory upgrade:

- MC studies
- FD operation upgrade
- SD upgrade



# Resources

**GAAV A1 010 928/1999** 1999-2002
**MEYS LA138** 2001-2006
**MEYS LA08016** 2008-2012 **(IoP, CU)**
2011-2012 **LG11044 (PU)**
**MEYS LG13007 (IoP, CU, PU)** 2013-2015

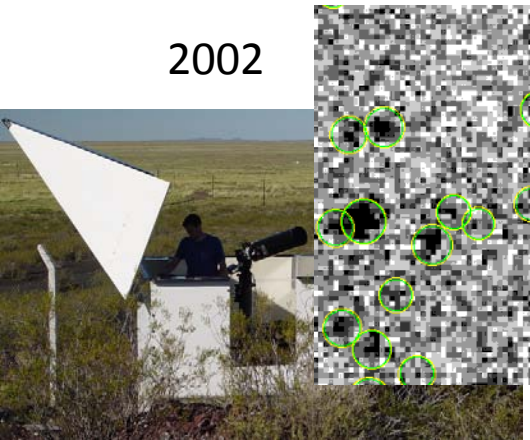
AUGER
COLLABORATION
IN THE CZECH REPUBLIC

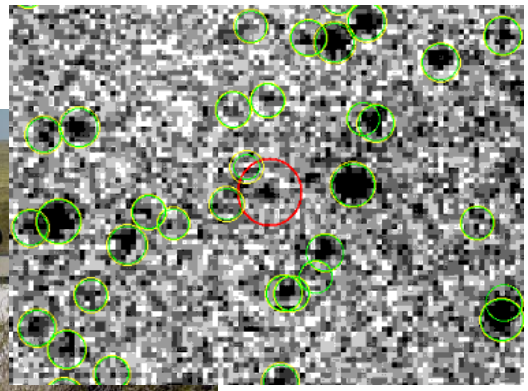

2004

2002

2009-2013-2015

AUGER upgrade
2016-2023





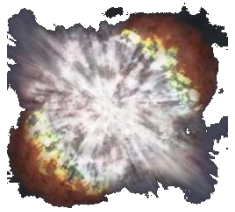
2006

**Promising status of application - MEYS program of large infrastructures (2016-2022)**

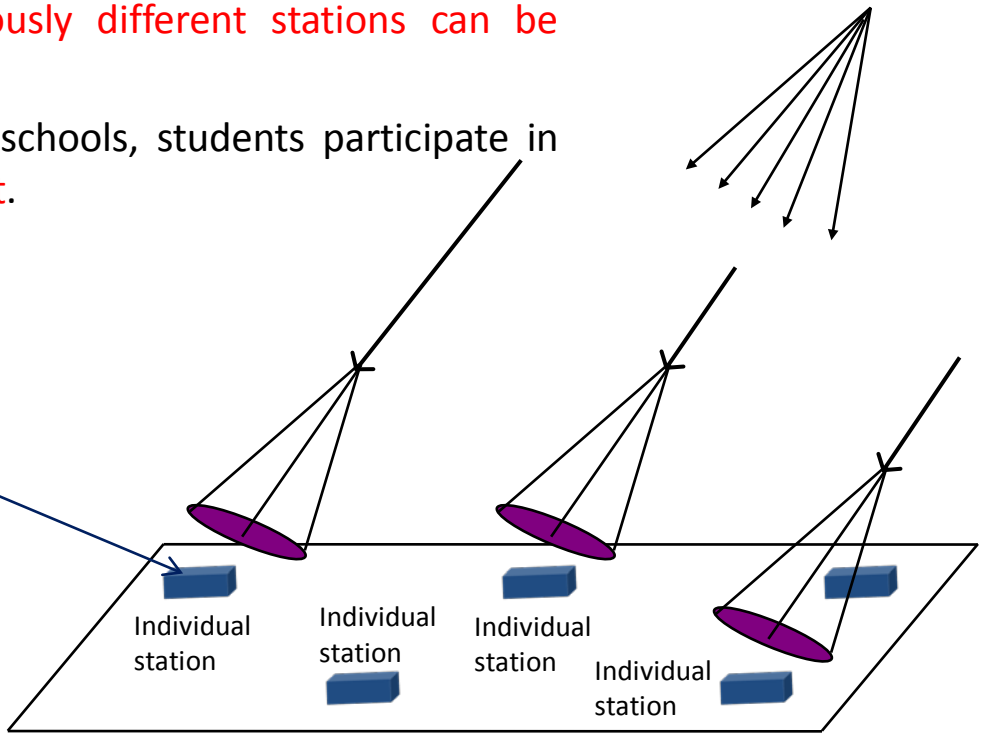
# CZELTA - CZEch Large-area Time coincidence Array

- Project of two Czech institutions:
  - ✓ Czech Technical University in Prague – Institute of Experimental and Applied Physics
  - ✓ Silesian University in Opava – Faculty of Philosophy and Science

- The hardware and the detection station design is the same as is used in the ALTA network (University of Alberta, Canada).
- The sparse network for the detection of high energy cosmic rays (>$10^{14}$ eV) - the global network of detection stations on the Earth = huge „telescope" for the detection of cosmic rays showers.



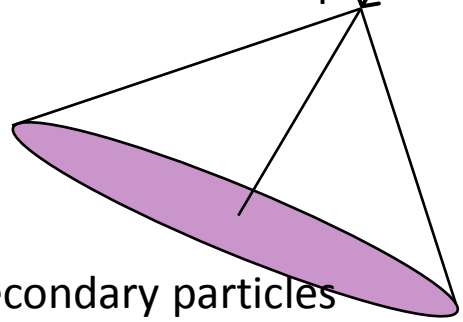
- Individual showers hitting simultaneously different stations can be studied (e.g. Gerasimova-Zatsepin effect).
- Stations are installed at roofs of high schools, students participate in data analysis -> strong educational impact.



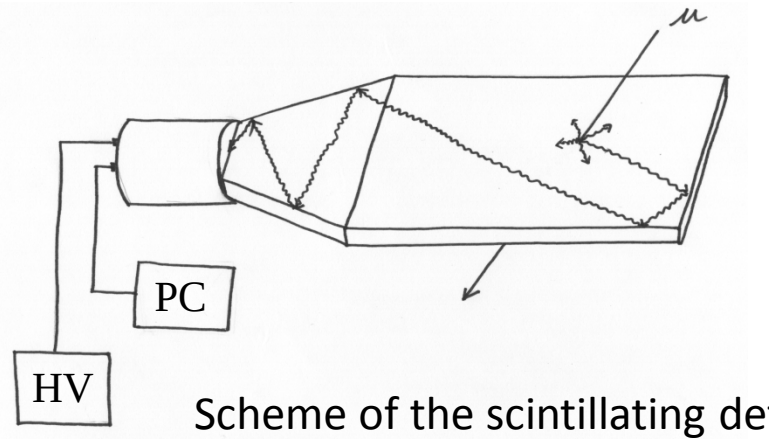
# Detection station

Primary particle

Interaction in the atmosphere

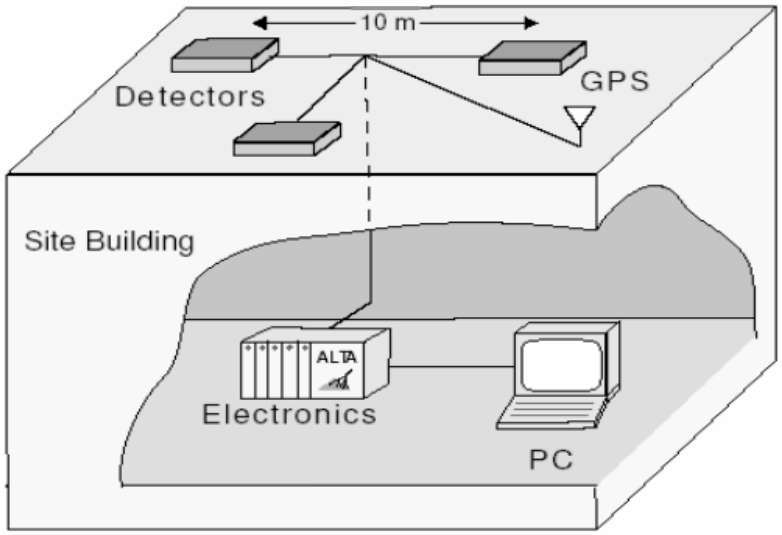


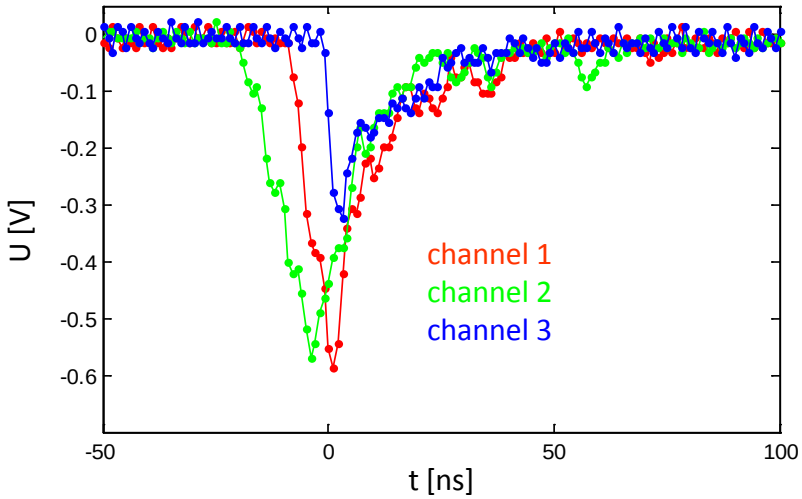
Shower of secondary particles



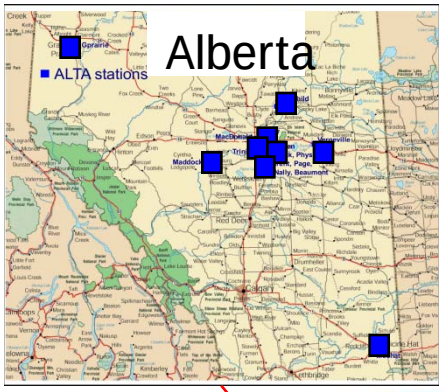

Scheme of the scintillating detector

- 3 scintillators (60 x 60 x 1.5 cm) with photomultipliers in a triangle with a site ~10 m, work in a coincidence => detection of showers with the energy > $10^{14}$ eV.
- GPS for precise time-labeling of detected showers (precision ~16 ns) => it is possible to study space and time coincidence of the detected showers.

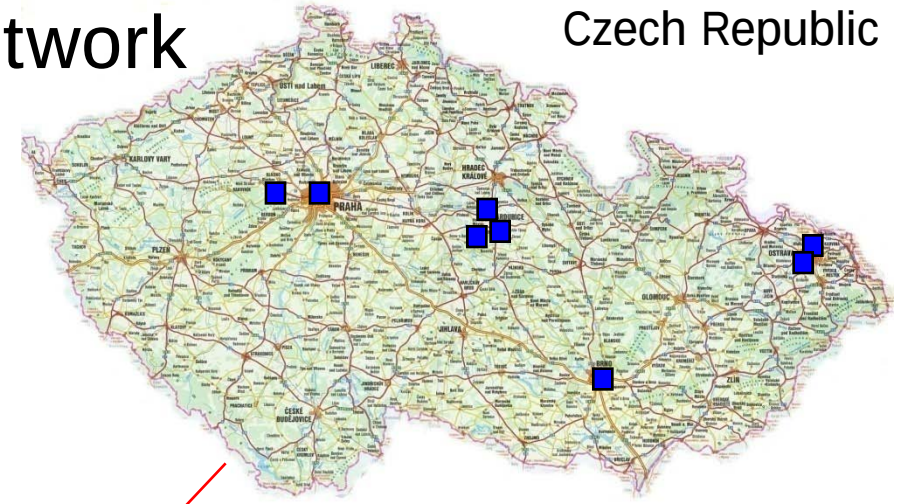


# ALTA/CZELTA detection network




Czech Republic



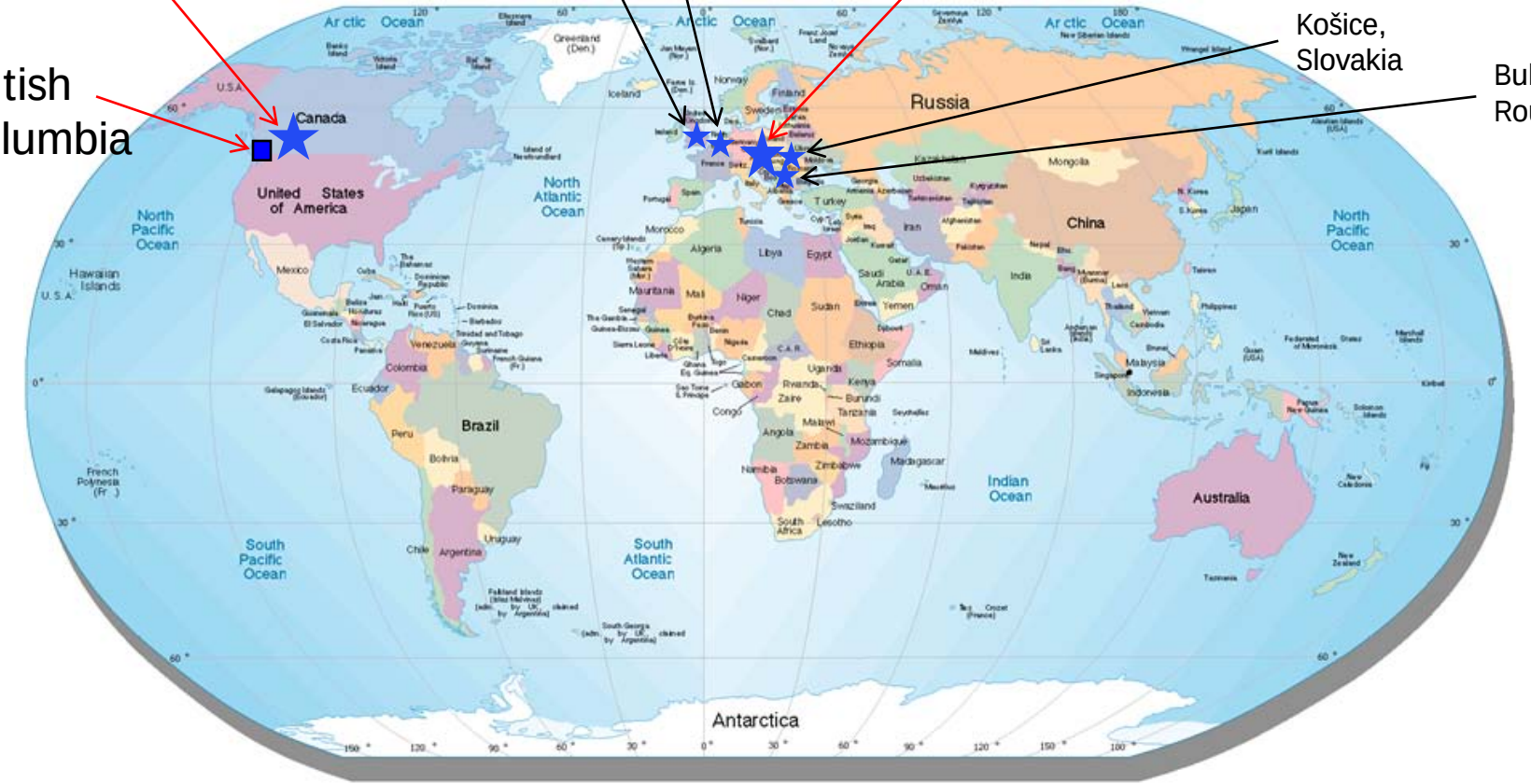
Pons, France

King's College, London

British Columbia

Košice, Slovakia

Bukurest, Roumania



# Summary

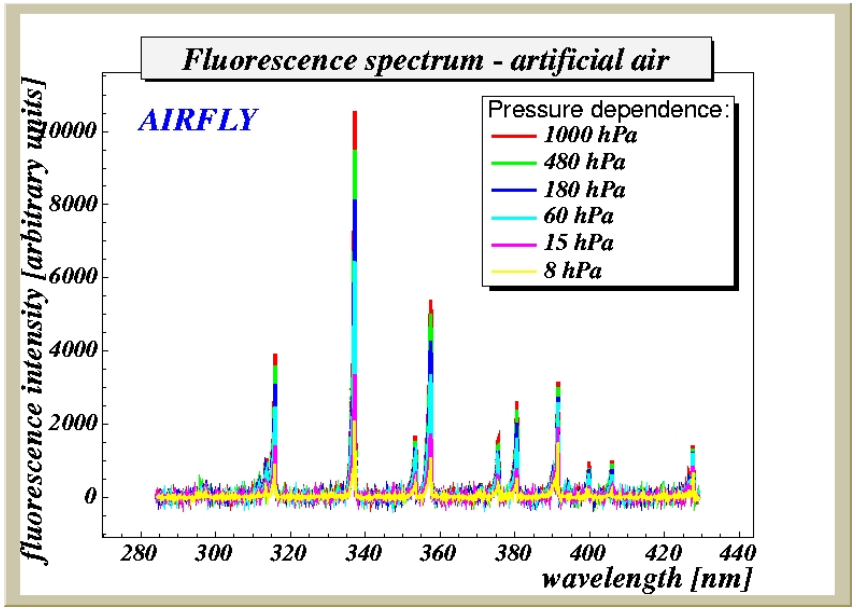
- Long history of astroparticle and cosmic ray physics in the Czech Republic
- Current participation in 2 large international projects: **AUGER** and **CTA** – three institutions involved directly, other three universities active via students
- Project **CZELTA** (Institute of Experimental and Applied Physics, Czech Technical University in Prague) with strong educational impact
- Significant activities in **nuclear astrophysics** **(talk by J. Mrazek)**
- Other interesting projects with Czech participation - **Picasso, LSST**

Backup slides

# AIRFLY (*measurement of fluorescence yield)*

- Pressure dependence
- Spectrum
- Absolute yield
- Temperature dependence for the first time (Czech chamber)
- Measurements in FRASCATI (IT) and ARGONNE (USA)

*Chamber to study temperature dependence of fluorecsence yield*




*Fluorescence spectrum at different air pressures*

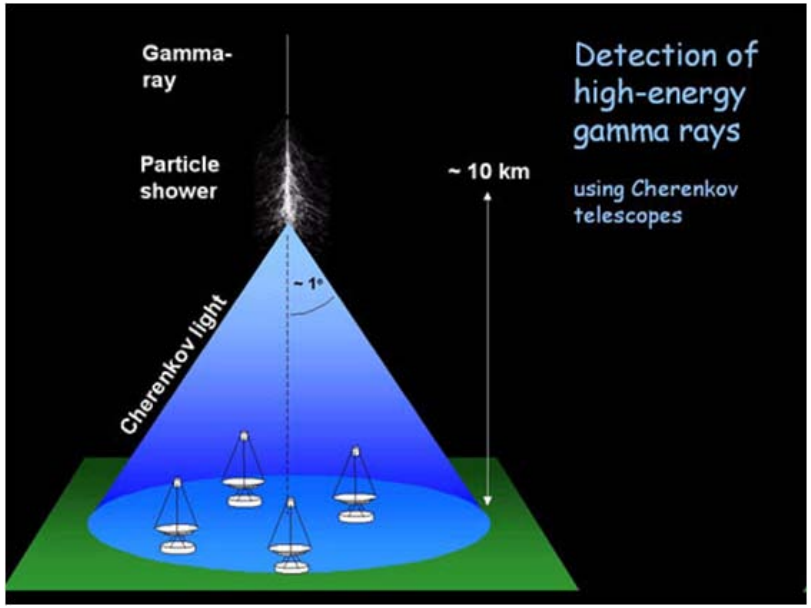
# Cherenkov Telescope Array - CTA

**Galactic Gamma-Ray Sources**
Supernova Remnants
Pulsar Wind Nebulae
Pulsar Physics
Star-Formation Regions
The Galactic Centre
X-Ray Binaries & Microquasars

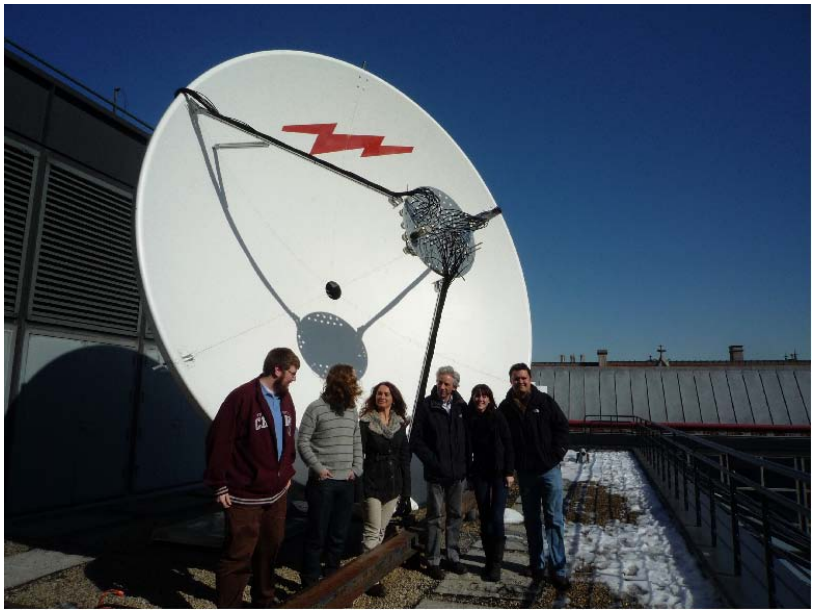
**Extragalactic Gamma-Ray Sources**
Active Galactic Nuclei
Extragalactic Background Light
Gamma-Ray Bursts
Galaxy Clusters

**Fundamental Physics**
Dark Matter
Quantum Gravity
Charged Cosmic Rays

…



# Microwave detection of cosmic rays



MIDAS: Microwave Detection of Air Showers

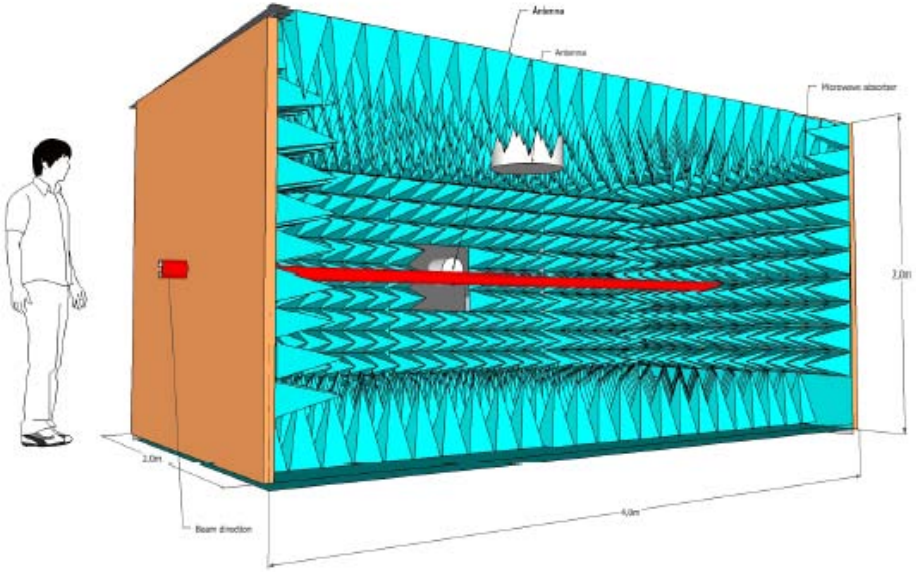
Alternative detection technique to fluorescence telescopes
- larger duty cycle

Prototype was built in Chicago

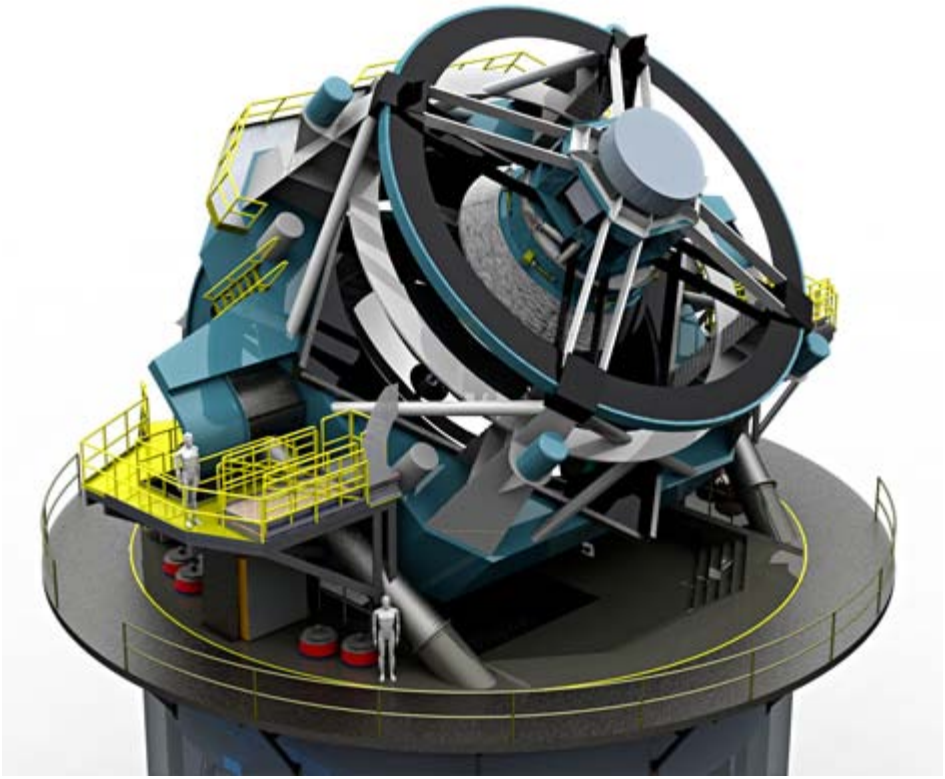
AMY: Air Microwave Yield

Characterize the microwave emission from air shower plasmas
(1-25 GHz)

Beam test facility in Frascati, Italy



# LSST (Large Synoptic Survey Telescope)



- Project of the largest survey telescope; first light in 2017
- Recommended as the best ground project in U.S. Decadal Survey Astro 2010
- FZÚ team involved since 2007 in LSST Camera Team
- FZÚ produced software for CCD characterization and testing
- Starting 2011 our team will operate new lab at FZÚ for special tests of CCDs and other photodetectors