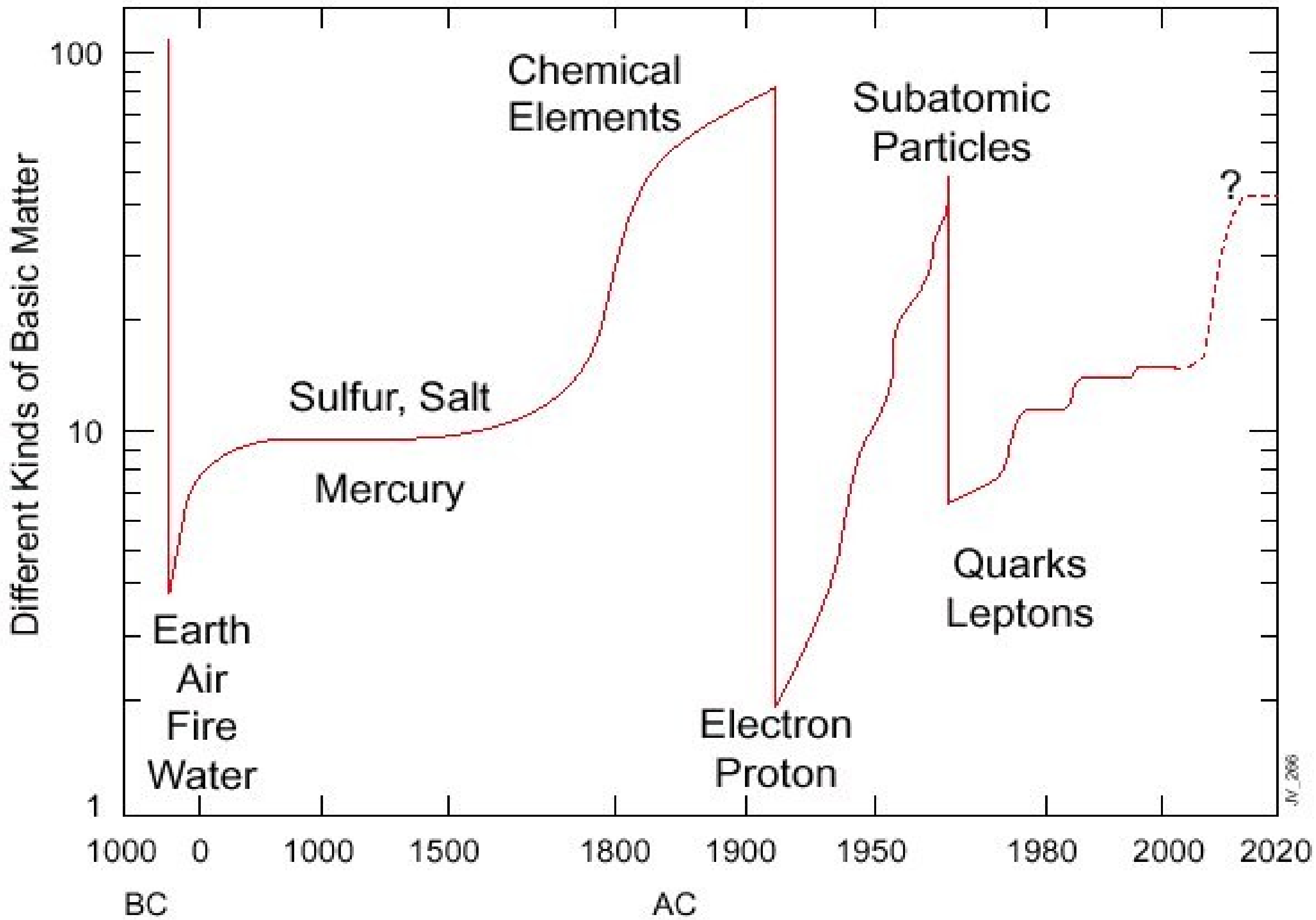
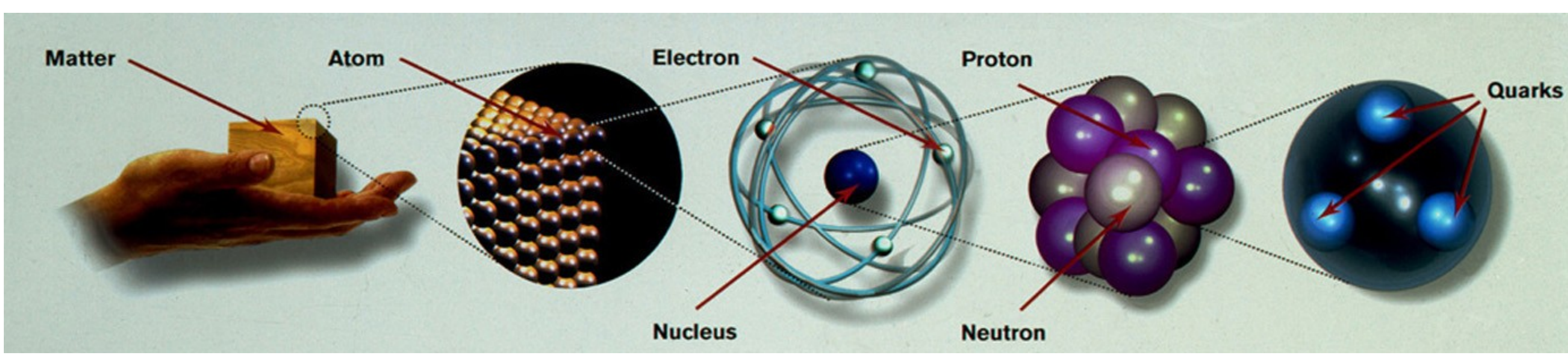
LHC status update, astroparticle and random thoughts...

Michal Marcisovsky, FzU AV CR, v.v.i. & FJFI CVUT

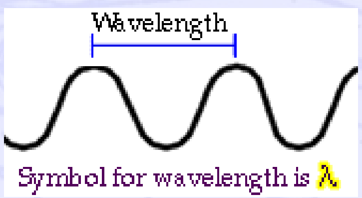
Vývoj zloženia vesmíru

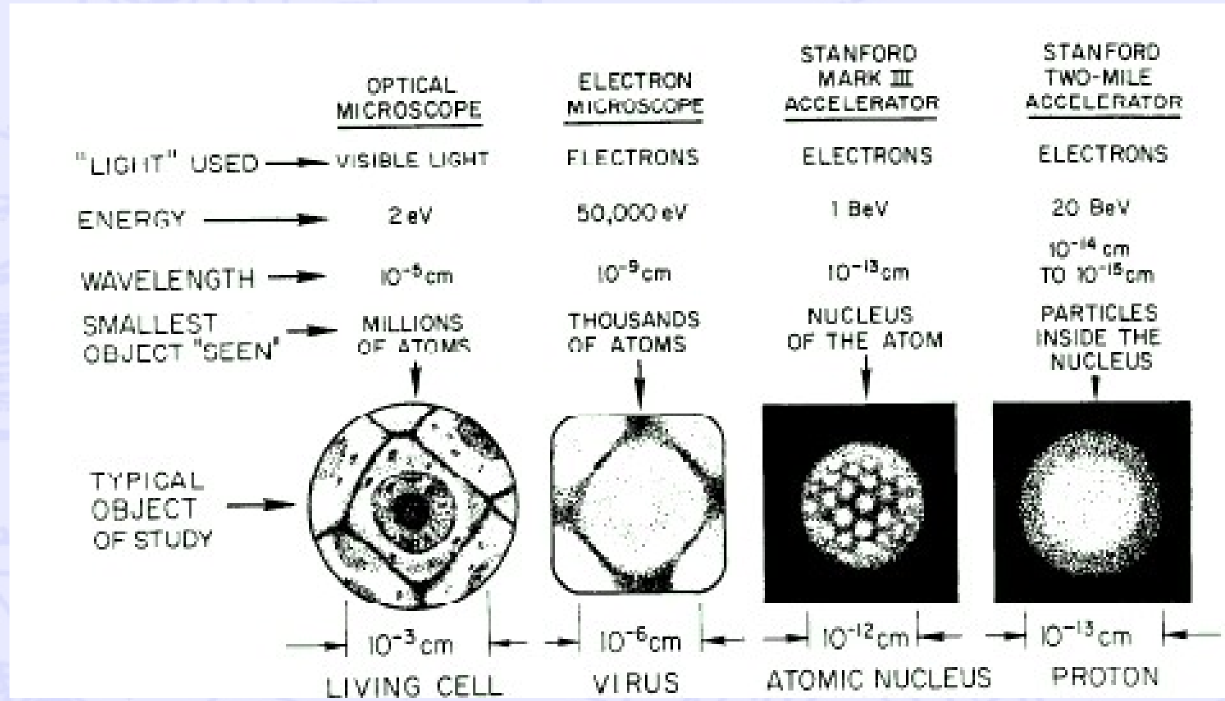




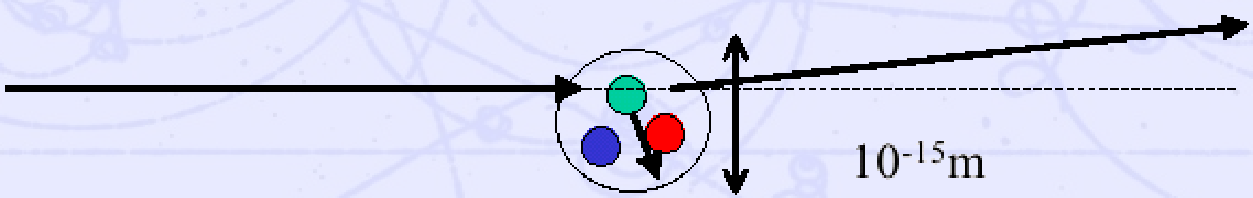
Exploring small scales

$$\lambda = \frac{h}{p}$$

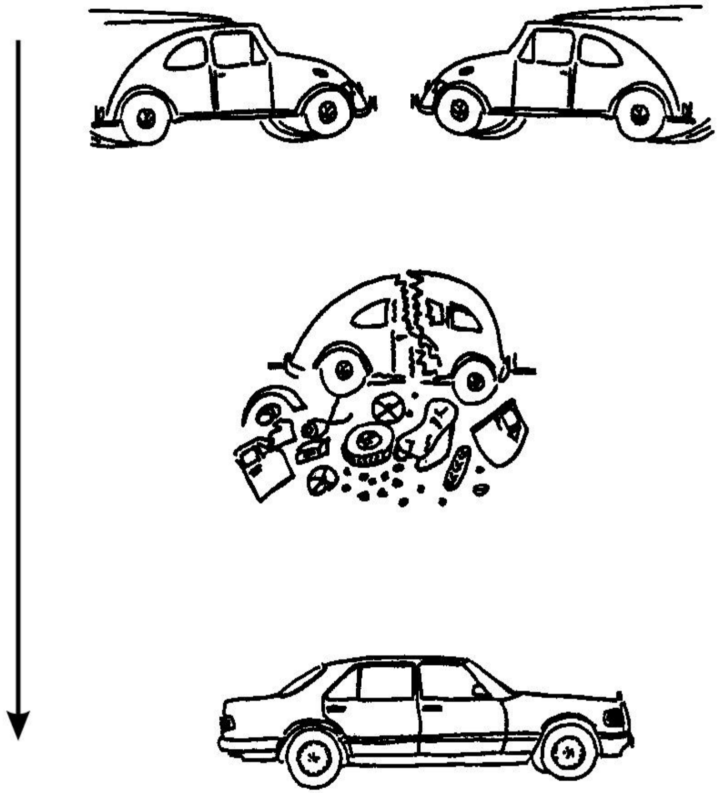




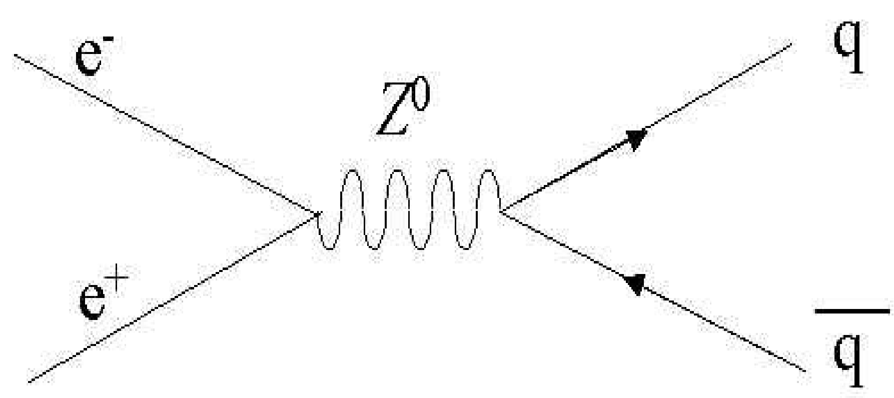
The wavelength of visible light is too large to examine atomic structure.



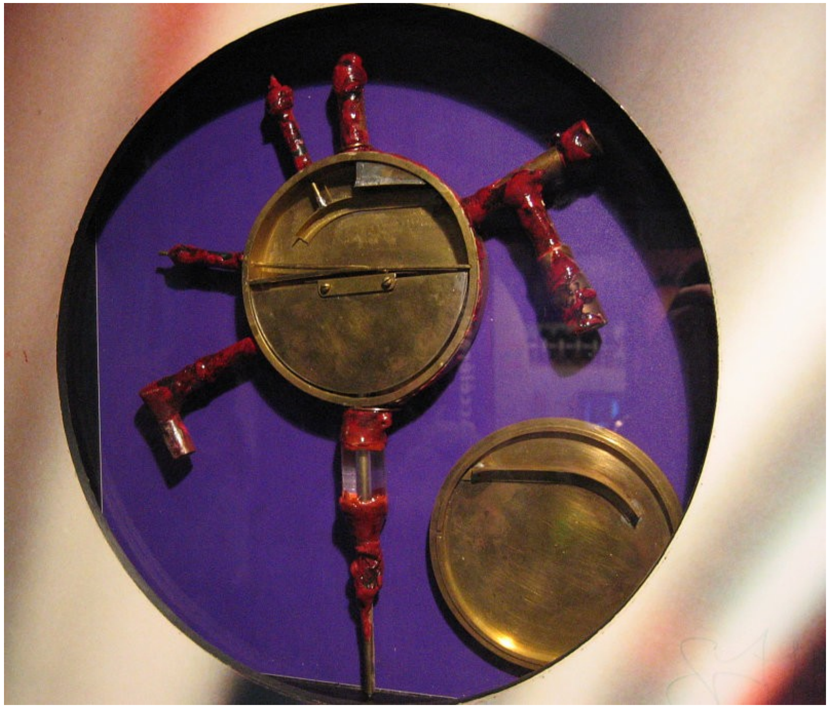
Collider



Higgs production in e^+e^- collisions:
a rare event!



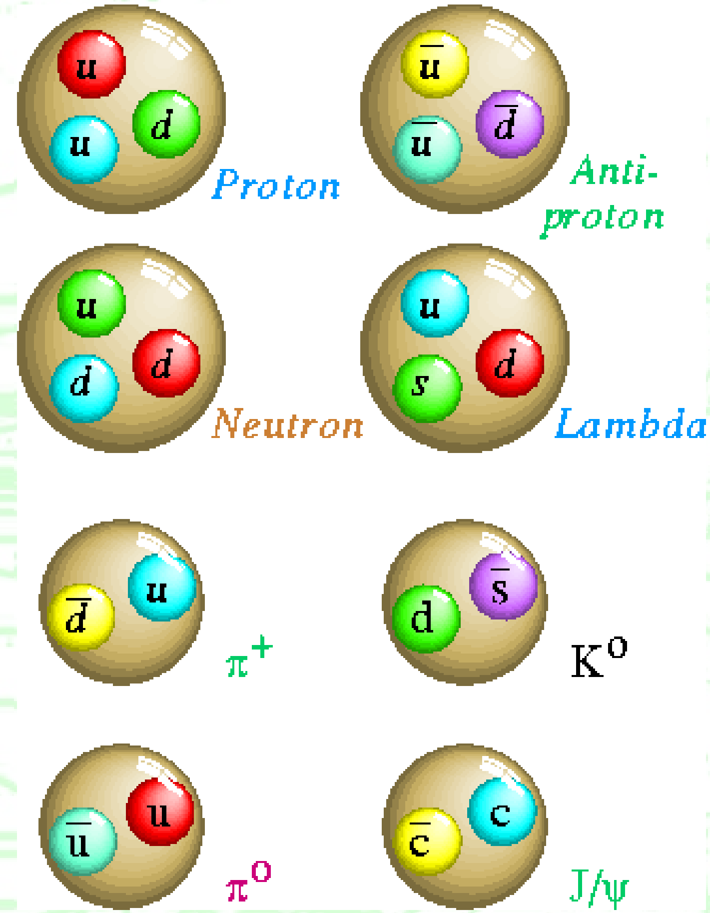
Instrument evolution



Prvý cyklotrởn.

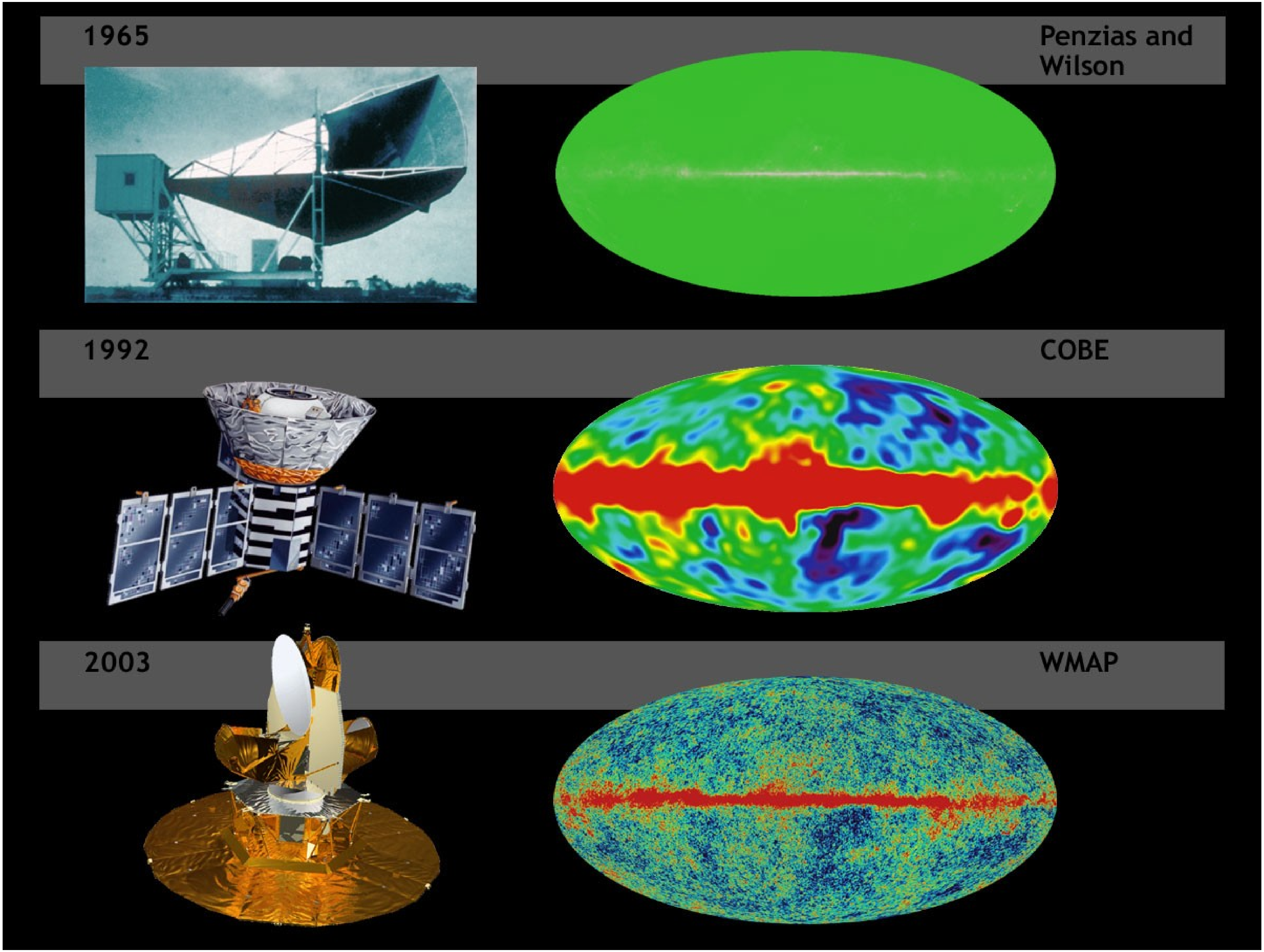
TeVatron @ Fermilab

Standard model

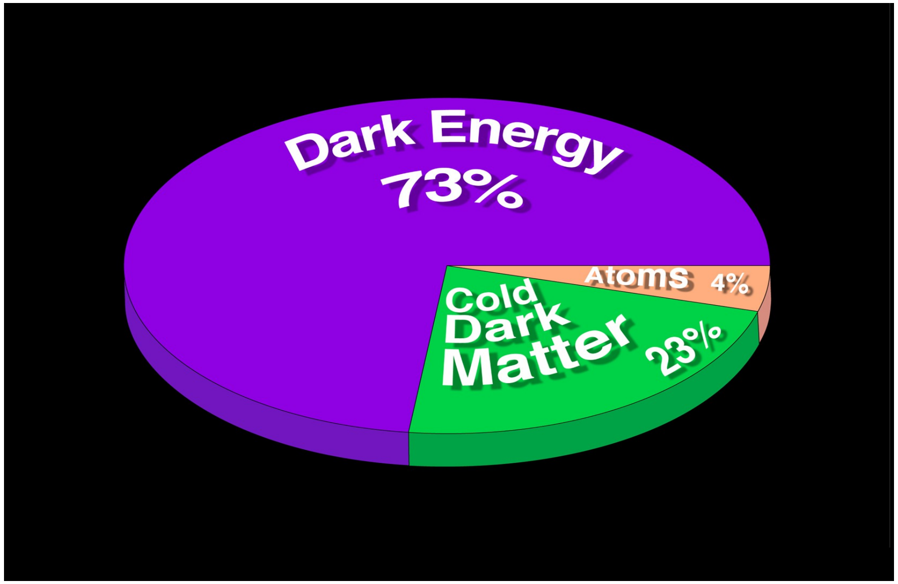


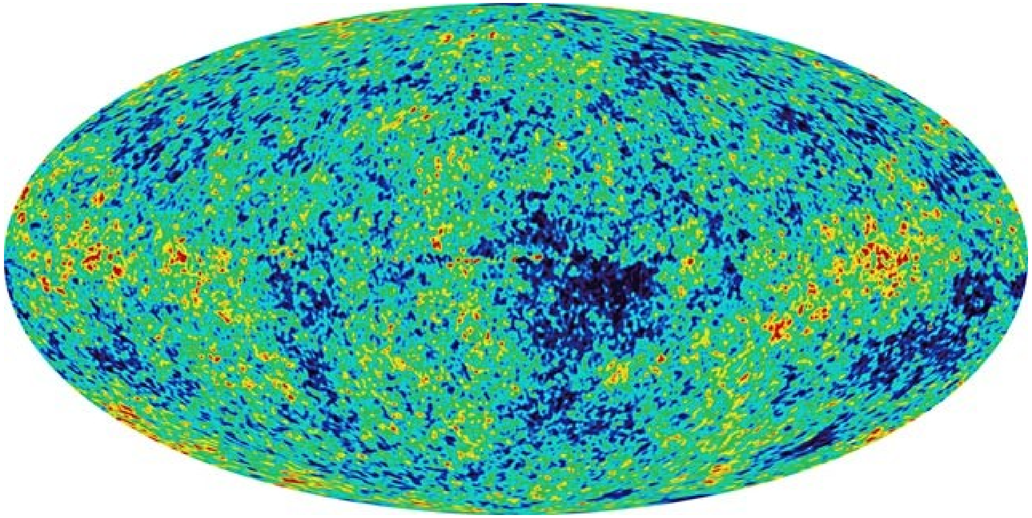
+ antičastice

Is there anything beyond the Standard Model?

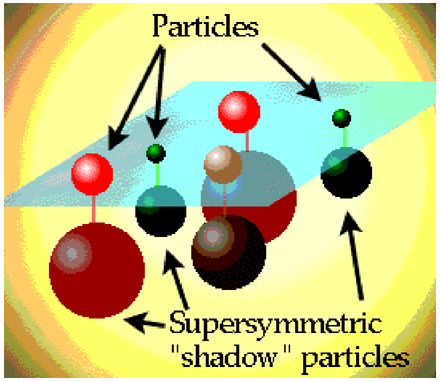

1965
Penzias and Wilson
1992
COBE
2003
WMAP

SUSY?



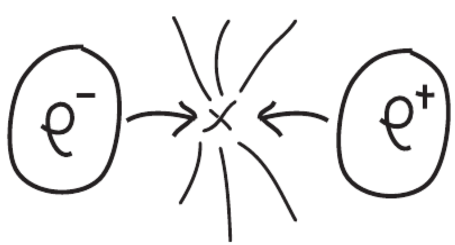


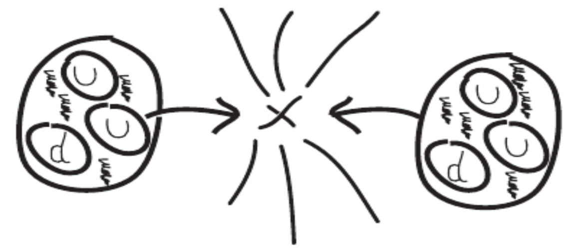
• LSP – nejaké neutralino?



SM Particle type	Particle	Symbol	Spin	R-Parity	Superpartner	Symbol	Spin	R-parity
Fermions	Quark	q	$\frac{1}{2}$	+1	Squark	$\tilde{q}$	0	-1
	Lepton	ℓ	$\frac{1}{2}$	+1	Slepton	$\tilde{\ell}$	0	-1
Bosons	W	W	1	+1	Wino	$\tilde{W}$	$\frac{1}{2}$	-1
	B	B	1	+1	Bino	$\tilde{B}$	$\frac{1}{2}$	-1
	Gluon	g	1	+1	Gluino	$\tilde{g}$	$\frac{1}{2}$	-1
Higgs bosons	Higgs	$h_u h_d$	0	+1	Higgsinos	$\tilde{h}_u, \tilde{h}_d$	$\frac{1}{2}$	-1

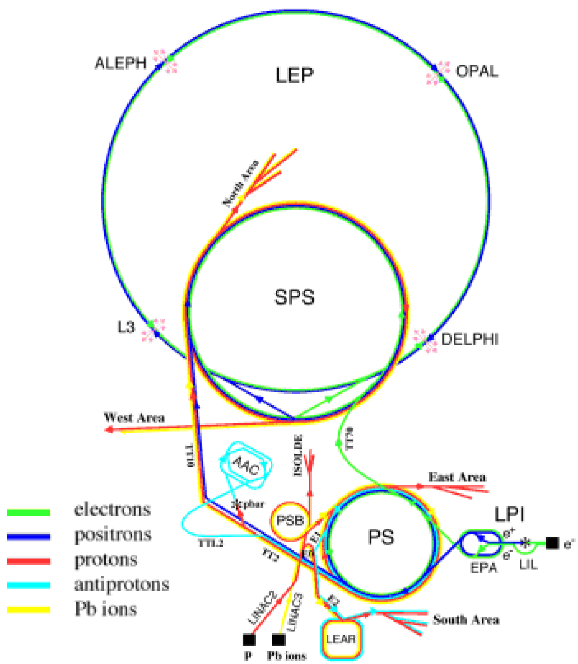
Hadrónové vs leptónové collidery

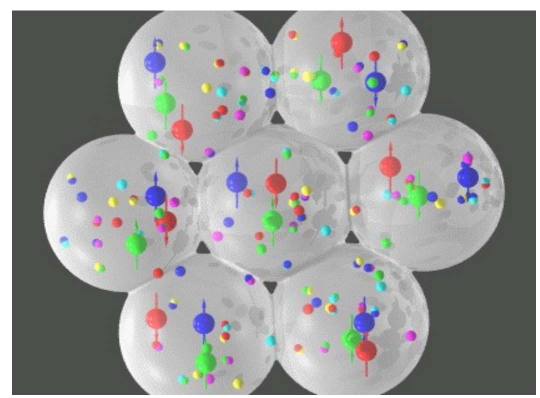


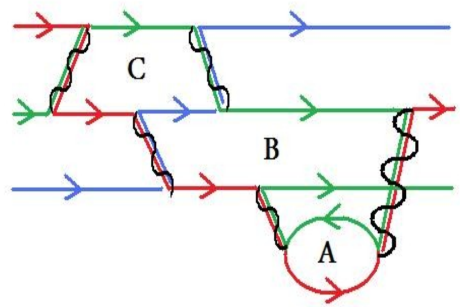


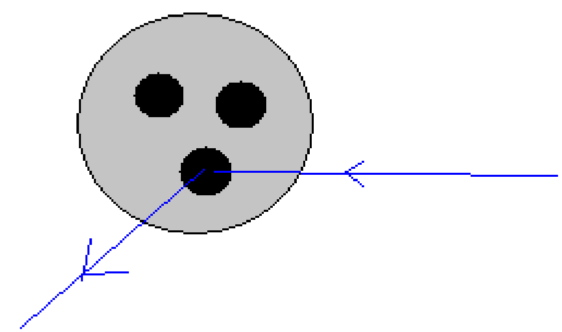
• Precízne energetické scany.
• Pri vyšších energiách strata energie vyžarovaním.

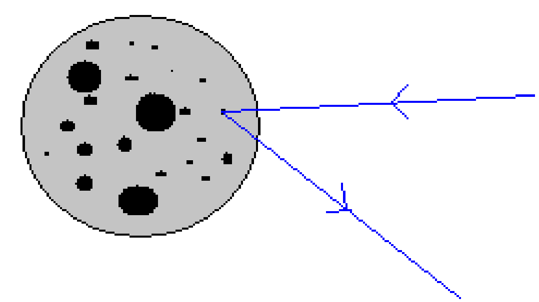
• Distribúcia energie medzi partóny. (PDF)
• S jednou energiou scanovanie širokého spektra energií.



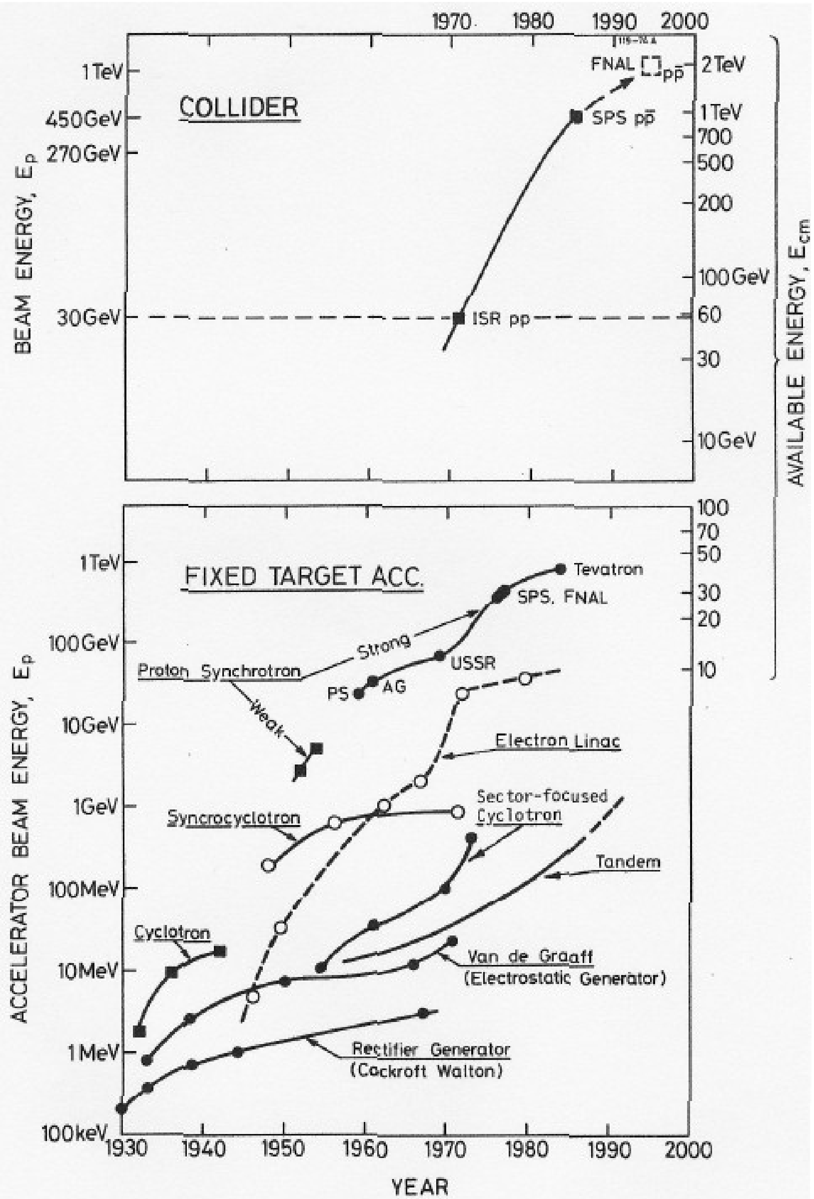


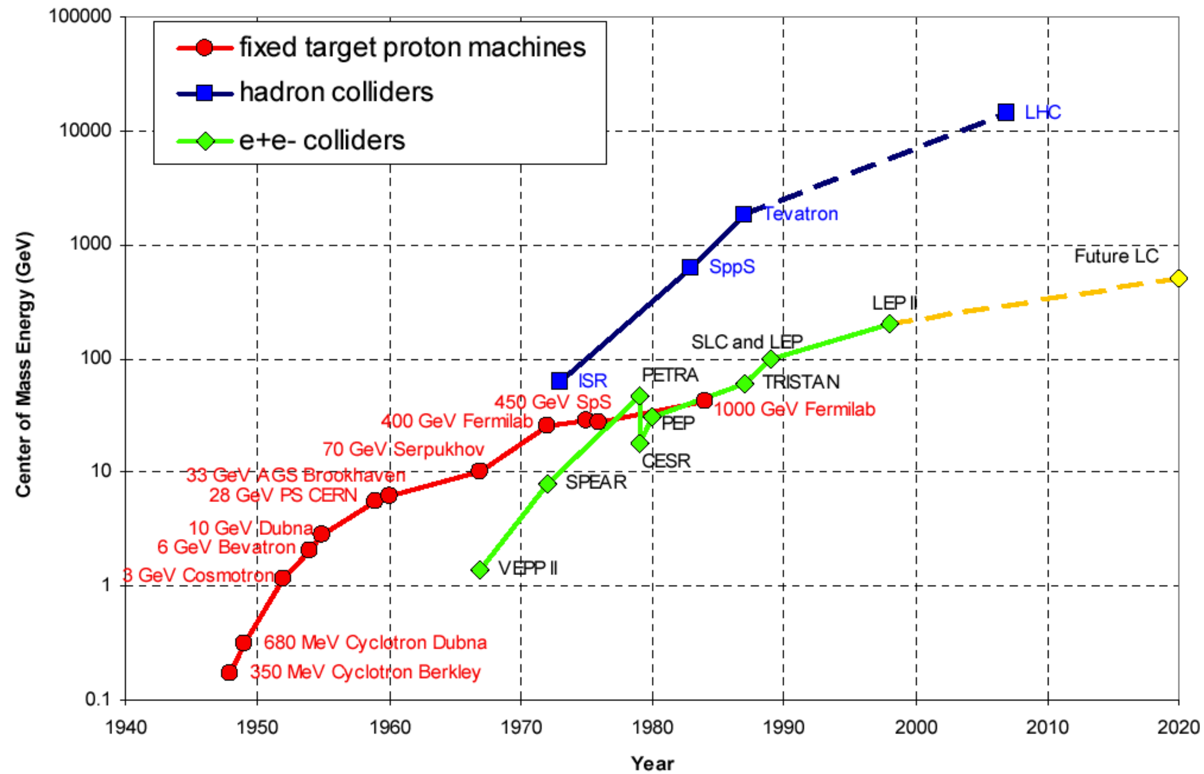






Evolution of accelerators





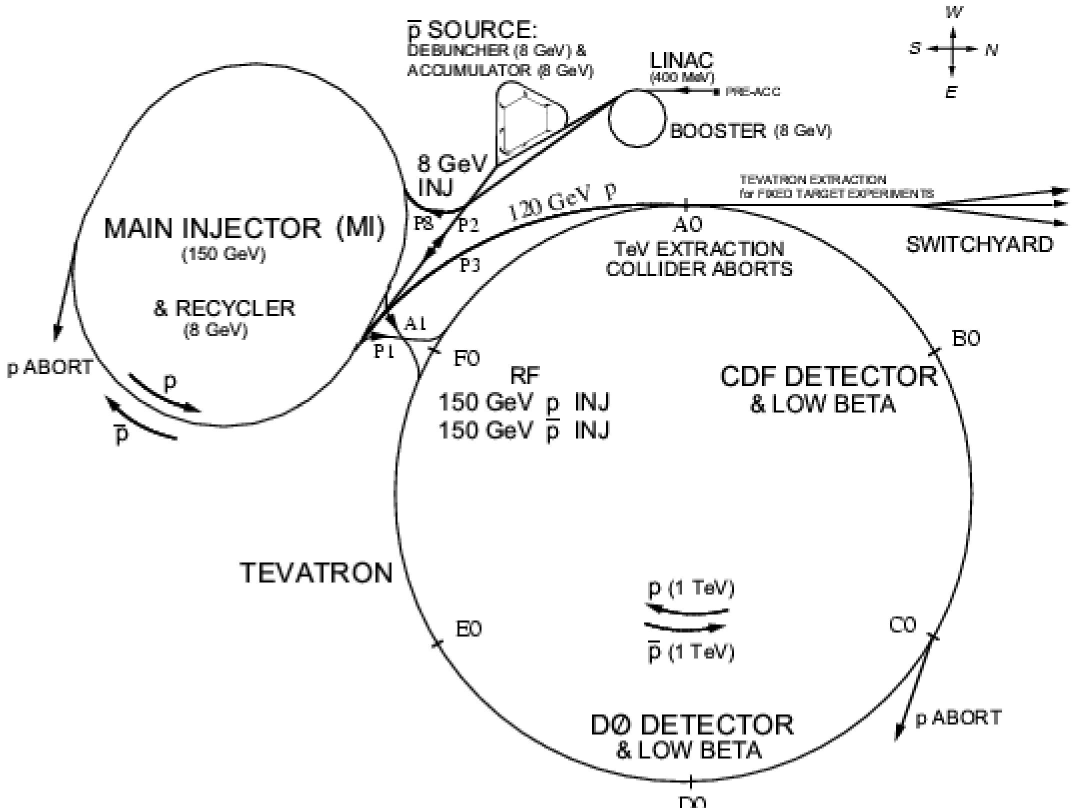
Synchrotrons

Synchrotron	Location & Country	Power (GeV)	Circumference (m)	Commissioned	Decommissioned
Advanced Photon Source (APS)	Argonne National Laboratory, USA	7.0	1104	1995	
ISIS	Rutherford Appleton Laboratory, UK	0.8	163	1985	
Australian Synchrotron	Melbourne, Australia	3	216	2006	
LNLS	Campinas, Brazil	1.37	93.2	1997	
Bevatron	Lawrence Berkeley Laboratory, USA	6	114	1954	1993
Advanced Light Source	Lawrence Berkeley Laboratory, USA	1.9	196.8	1993	
Cosmotron	Brookhaven National Laboratory, USA	3	72	1953	1968
Nimrod	Rutherford Appleton Laboratory, UK	7		1957	1978
Alternating Gradient Synchrotron (AGS)	Brookhaven National Laboratory, USA	33	800	1960	
Stanford Synchrotron Radiation Laboratory	Stanford Linear Accelerator Center, USA	3	234	1973	
Cornell High Energy Synchrotron Source (CHESS)	Cornell University, USA	5.5	768	1979	
Soleil	Paris, France	3	354	2006	
Proton Synchrotron	CERN, Switzerland	28	628.3	1959	
Tevatron	Fermi National Accelerator Laboratory, USA	1000	6300	1983	
Swiss Light Source	Paul Scherrer Institute, Switzerland	2.8	288	2001	
Large Hadron Collider (LHC)	CERN, Switzerland	7000	26659	2008	
BESSY II	WISTA in Berlin, Germany	1.7	240	1998	
European Synchrotron Radiation Facility (ESRF)	Grenoble, France	6	844	1988	
MAX-I	MAX-lab, Sweden	0.55	30	1986	
MAX-II	MAX-lab, Sweden	1.5	90	1997	
MAX-III	MAX-lab, Sweden	0.7	36	2008	
ELETTRA	Trieste, Italy	2-2.4	260	1993	
Diamond Light Source	Oxfordshire, England	3	561.6	2002	
DORIS III	DESY, Germany	4.5	289	1980	
PETRA II	DESY, Germany	12	2 304	1995	2007
Canadian Light Source	University of Saskatchewan, Canada	2.9	171	2002	
SPring-8	RIKEN, Japan	8	1436	1997	
Taiwan Photon Source	Hsinchu Science Park, Taiwan	3.3	518.4	2008	
Siam Photon Source	Suranaree University of Technology, Thailand	1.2	43.19	2008	
Indus 1	Raja Ramanna Centre for Advanced Technology, Indore, India	0.45		1999	
Indus 2	Raja Ramanna Centre for Advanced Technology, Indore, India	2.5	36	2005	

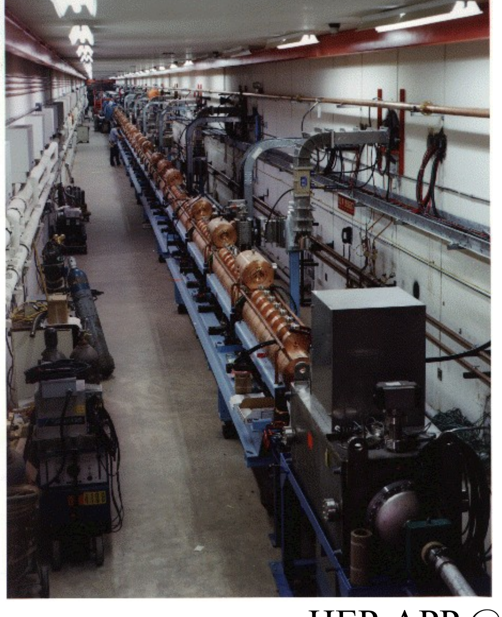
TeVatron

$\sqrt{s}$=1.96 TeV

TeVatron



- Cockroft-Walton 750 keV
- 400 MeV linac
- 8 GeV booster
- 150 GeV Main Injector
- 0.98 TeV TeVATRON



Conseil Européen pour la Recherche Nucléaire

1973: The discovery of neutral currents in the Gargamelle bubble chamber.

1983: The discovery of W and Z bosons in the UA1 and UA2 experiments.

1989: The determination of the number of neutrino families at the Large Electron Positron Collider (LEP) operating on the Z boson peak.

1995: The first creation of antihydrogen atoms in the PS210 experiment.

2001: The discovery of direct CP-violation in the NA48 experiments.

+ ISOLDE
+ CNGS
+ R&D
+ ....

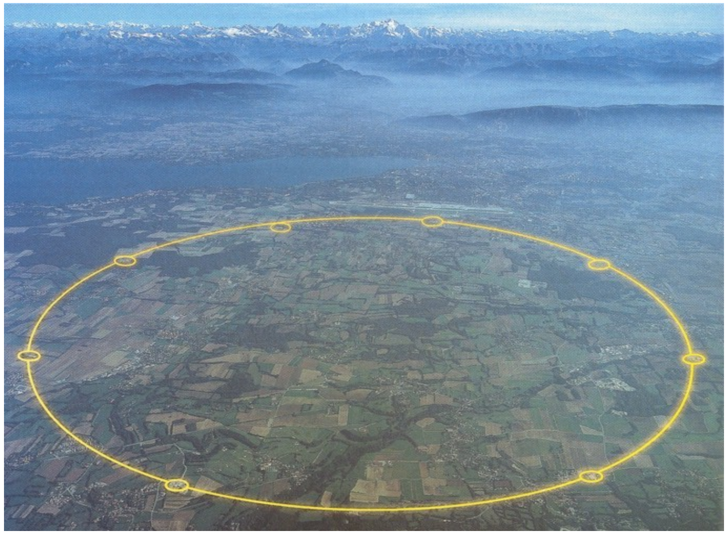
LHC

The Large Hadron Collider (LHC) is being built in a circular tunnel 27 km in circumference. The tunnel is buried around 50 to 175 m. underground. It straddles the Swiss and French borders on the outskirts of Geneva.

It is designed to collide two counter circulating beams of bunches of protons or heavy ions. Proton-proton collisions are foreseen at an energy of 7 TeV per beam with a planned start-up in ~~middle 2008~~.

LHC has a total stored beam energy:
10^{14} protons of $14 \cdot 10^{12}$ eV $\sim 10^{8}$ J
...or, if you like one 100 T truck
at 100 km/h

High energy physics today



Large Hadron Collider

- Length of 27 km.
- Has 4 large detectors.
- Unprecedented energy scales.
- It is most complex human-built machine.

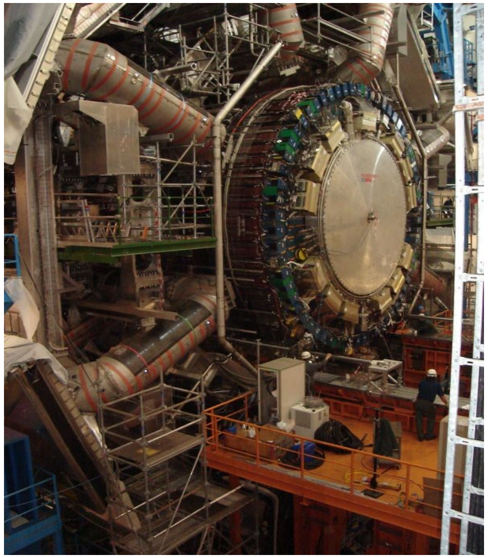
Fundamental questions:

What is the origin of mass?

Why there was less antimatter than matter?

What is dark matter and dark energy?

Are there extra dimensions?



Also, new technologies emerge:

- The WWW
- The GRID
- Medical applications
- Storage challenge
- Data processing
- Superconductors, electronics, etc.

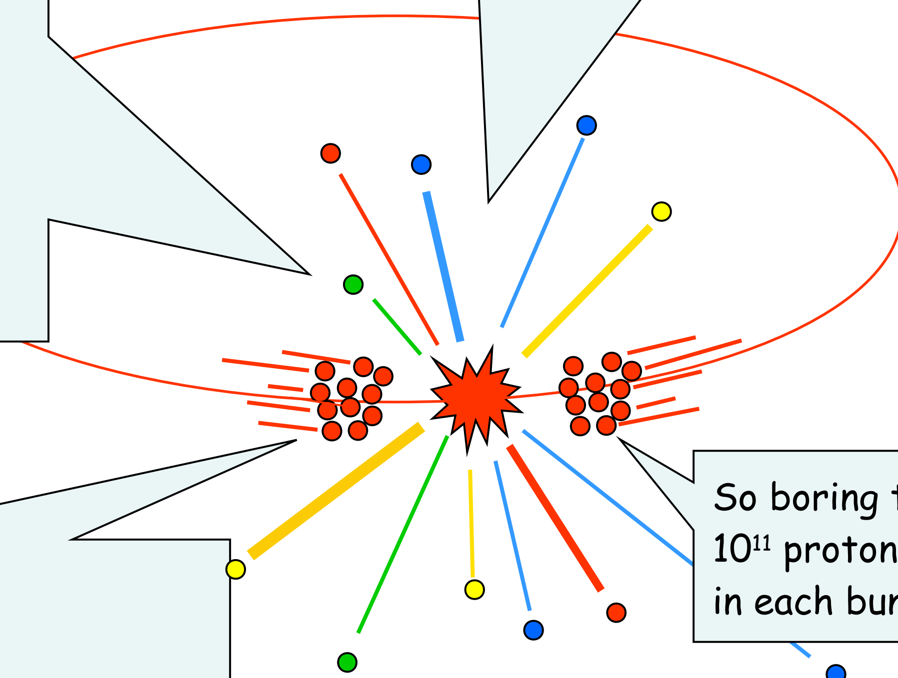
The collision point is “watched” by surrounding detector.

Some particles just escaped from the collision zone, the next collision threatens.

The detector should:

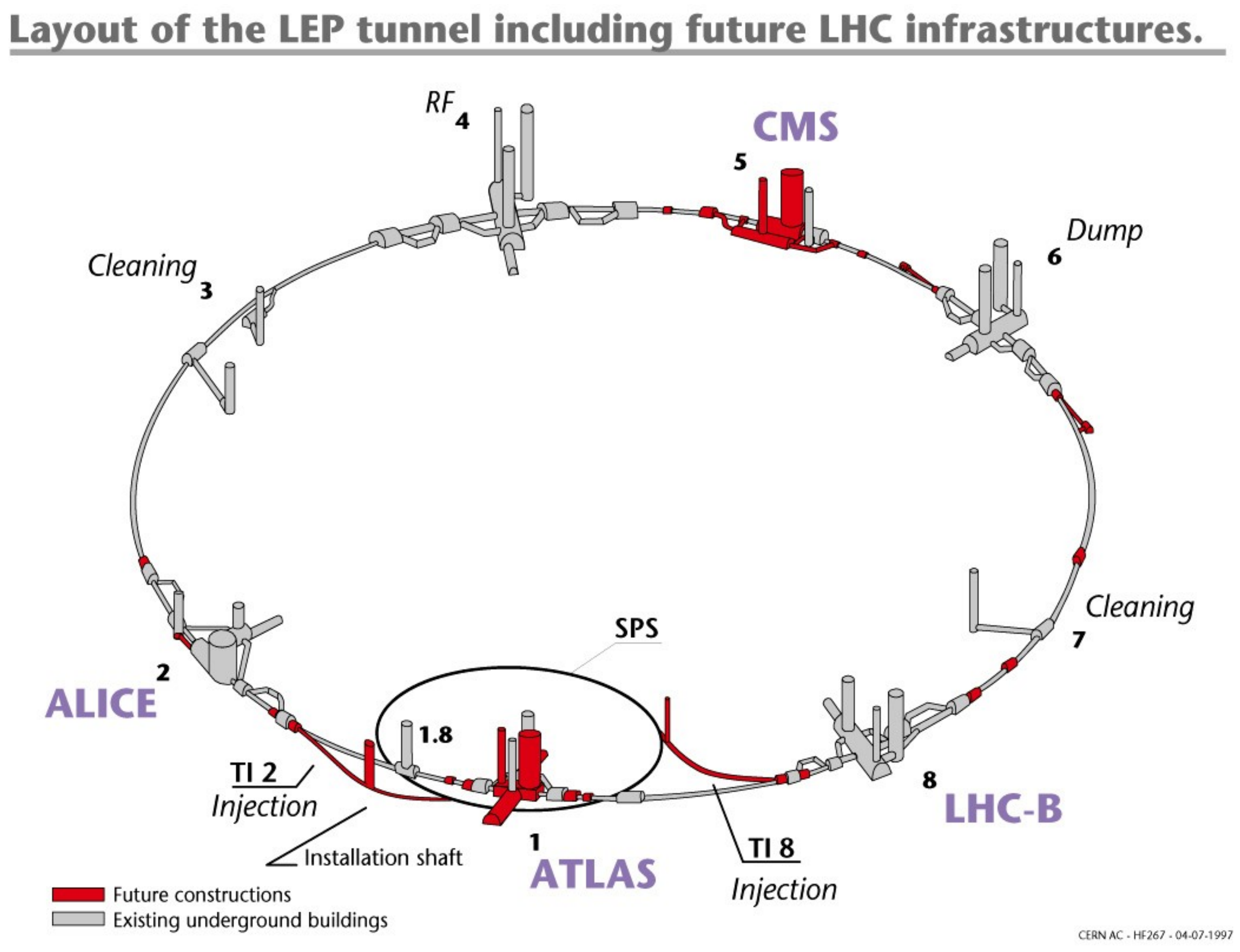
- have large coverage (catch most particles)
- be precise
- be fast (and cheap and ...)

Each meeting of two bunches results in about 23 proton-proton collisions. The mean number of particles born in all these collisions is about 1500. The detector should record as many of them as possible.

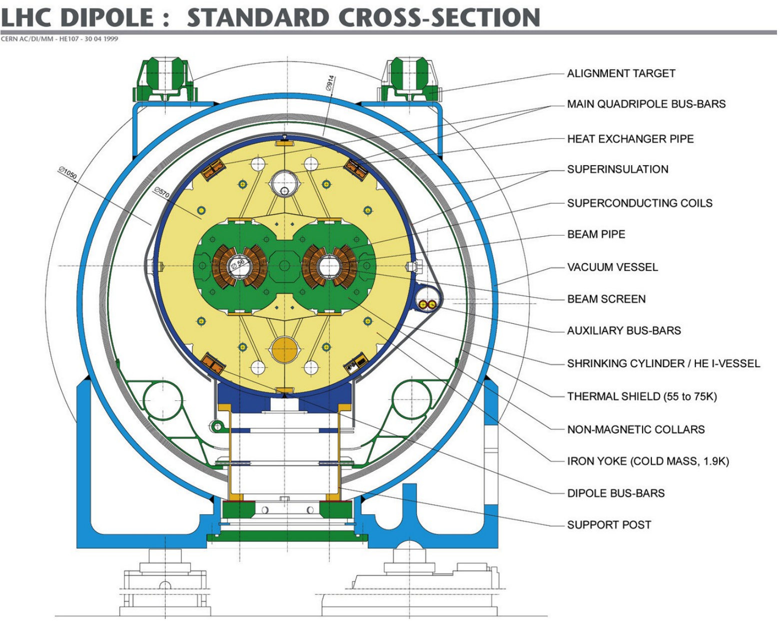


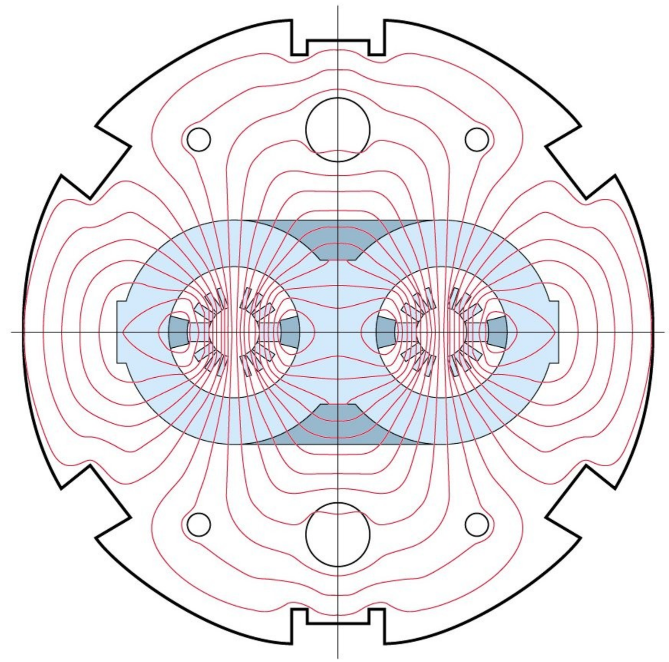
So boring to paint 10^{11} protons in each bunch ...

Each proton carries energy 7 TeV.
So each bunch with 10^{11} protons carries energy $10^{11} \times 7 \times 10^{12}$ eV = 7×10^{23} eV = 44 kJ.
This is a macroscopic energy!!!
In order to reach such kinetic energy on a bike, you go with a speed of more than 30 km/h!

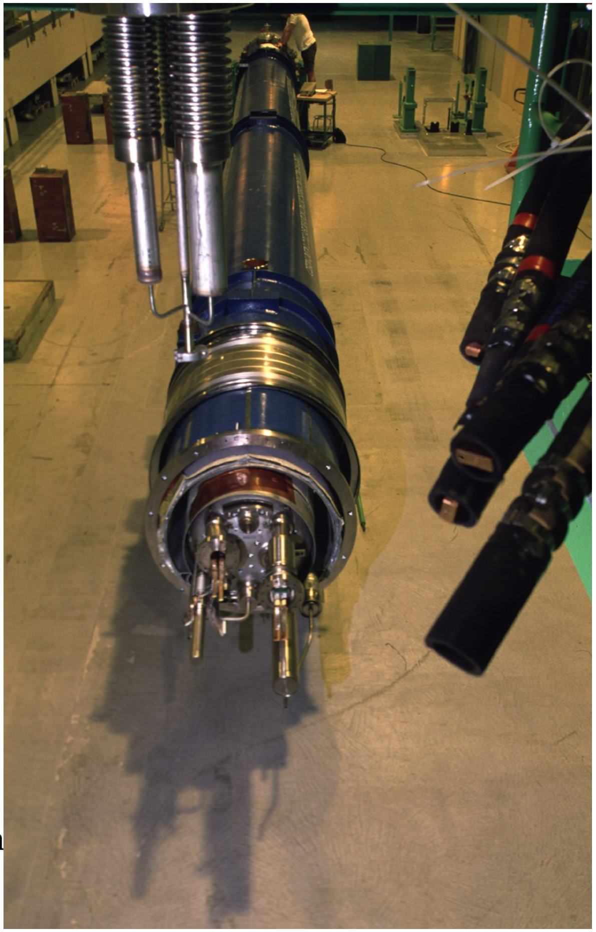

Layout of the LEP tunnel including future LHC infrastructures.
RF
4
CMS
5
Dump
6
Cleaning
3
Cleaning
7
SPS
2
ALICE
1.8
TI 2
Injection
Installation shaft
1
ATLAS
TI 8
Injection
8
LHC-B
Future constructions
Existing underground buildings
CERN AC - HF267 - 04-07-1997

Magnety

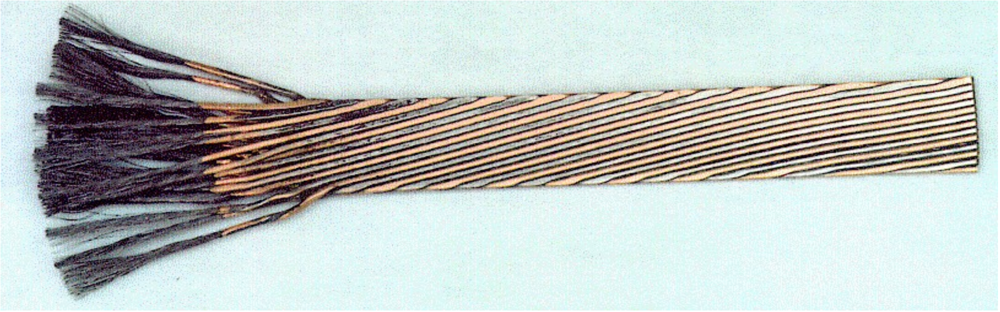


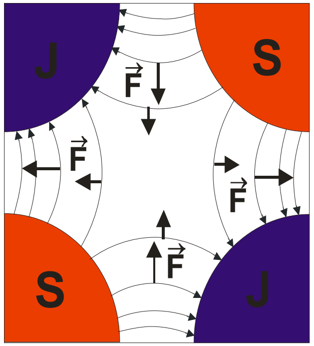


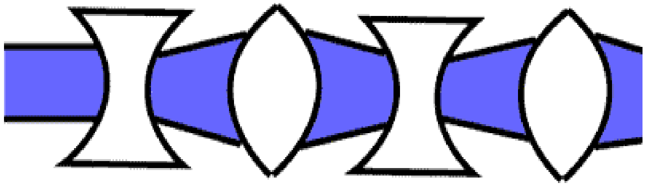
Computed magnetic flux map at B_0=10 Tesla



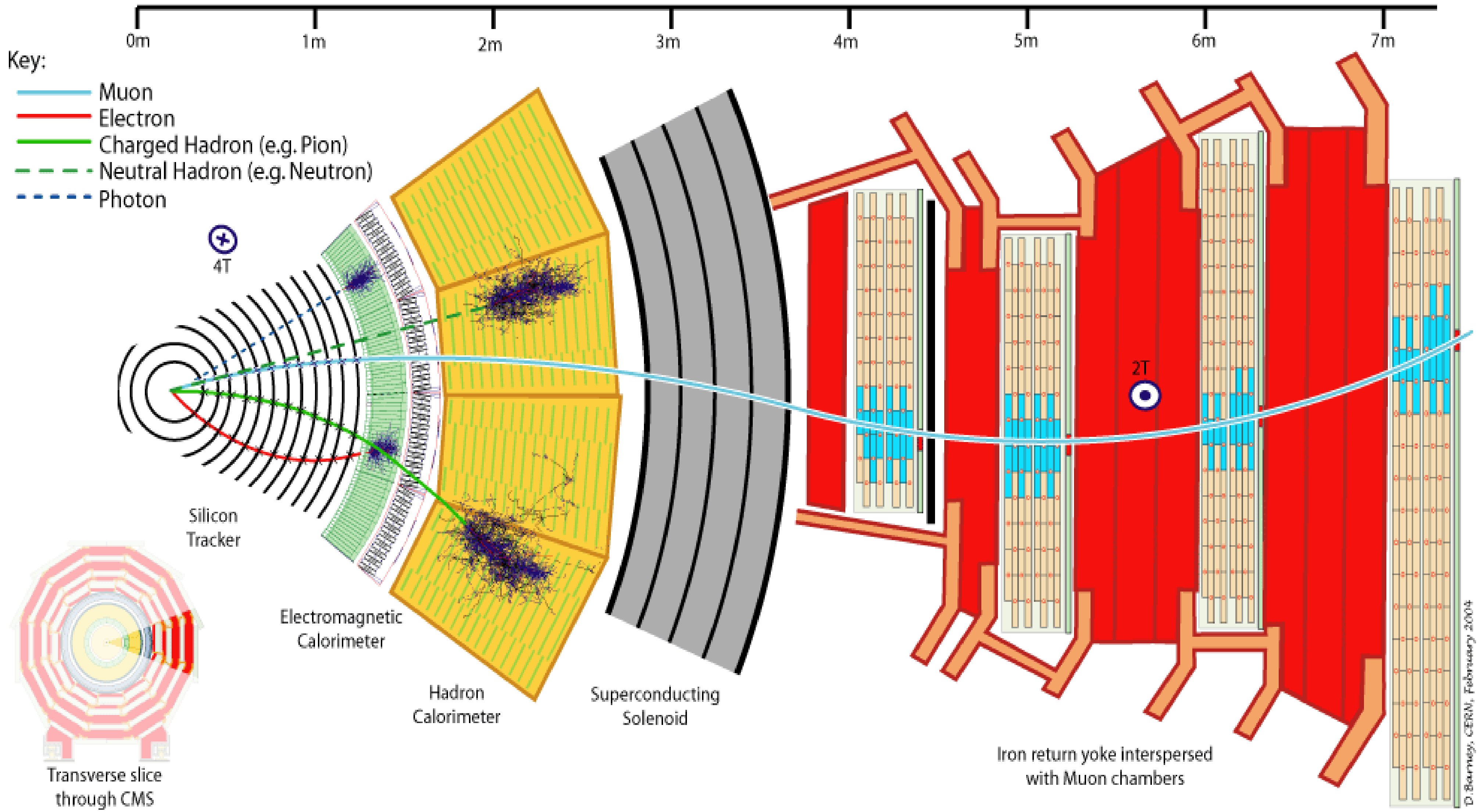
1232 Dipole magnets
Length about 15 m
Magnetic Field 8.3 T
Two beam-tubes with an opening of 56 mm





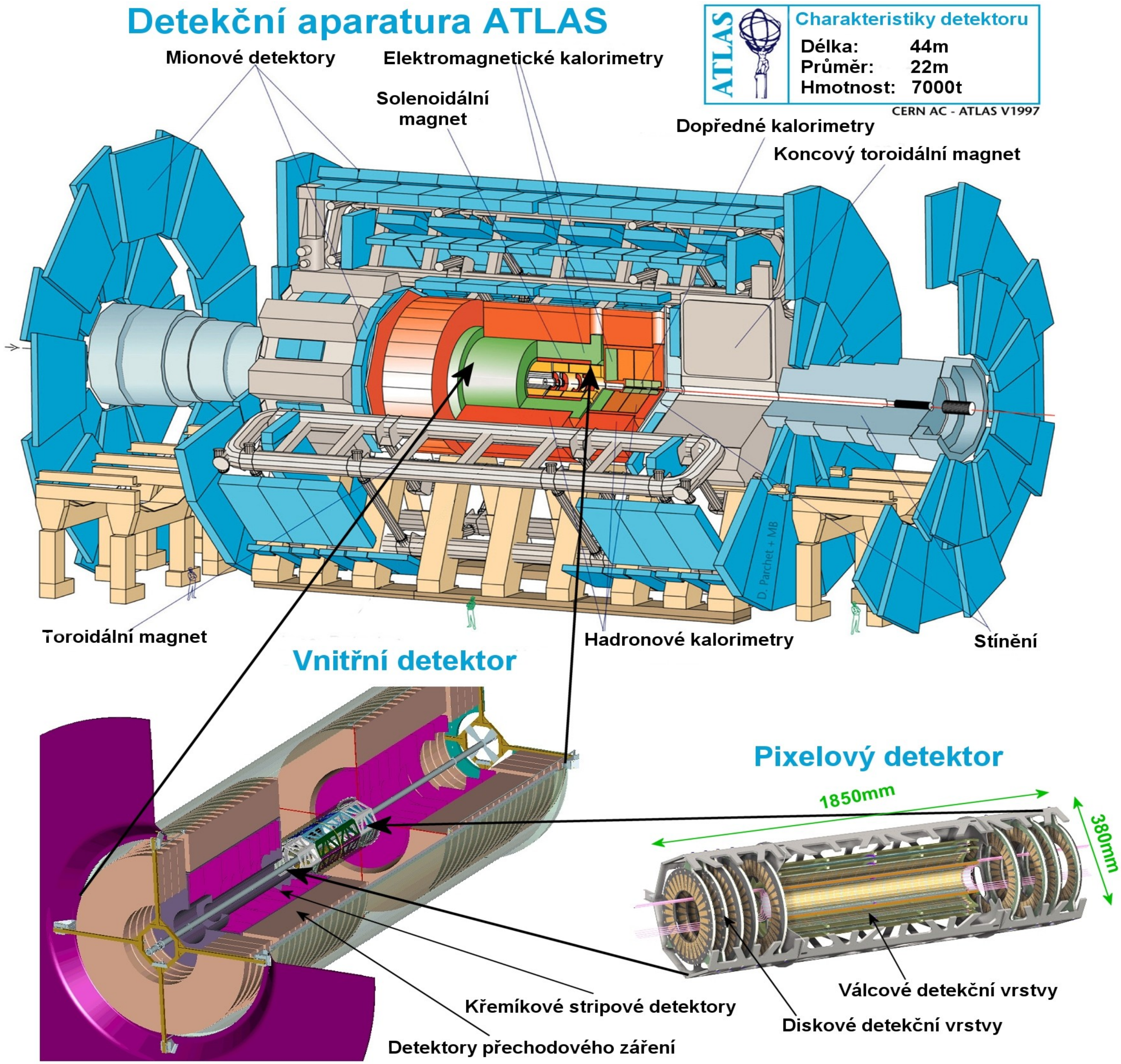


Detektory

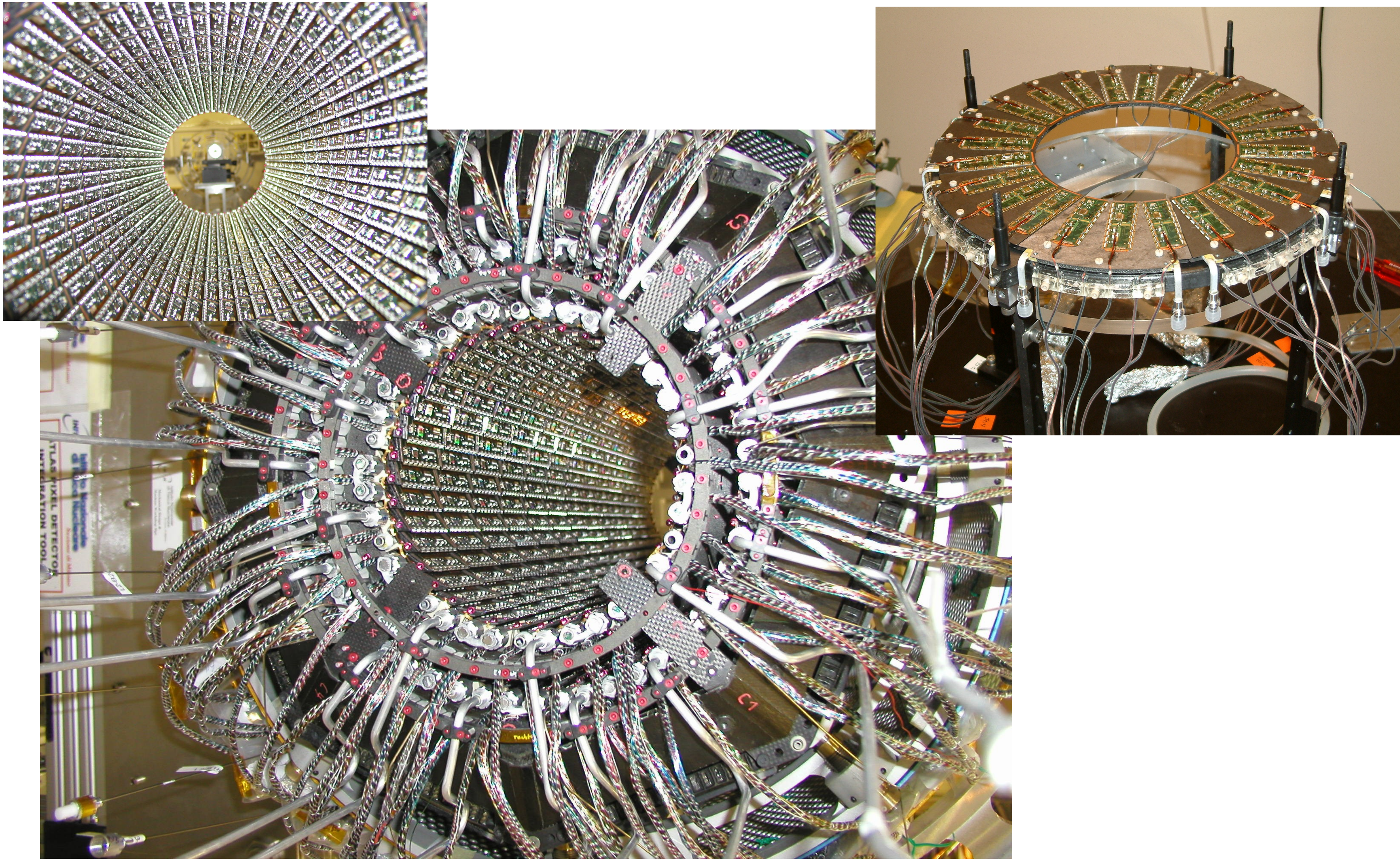


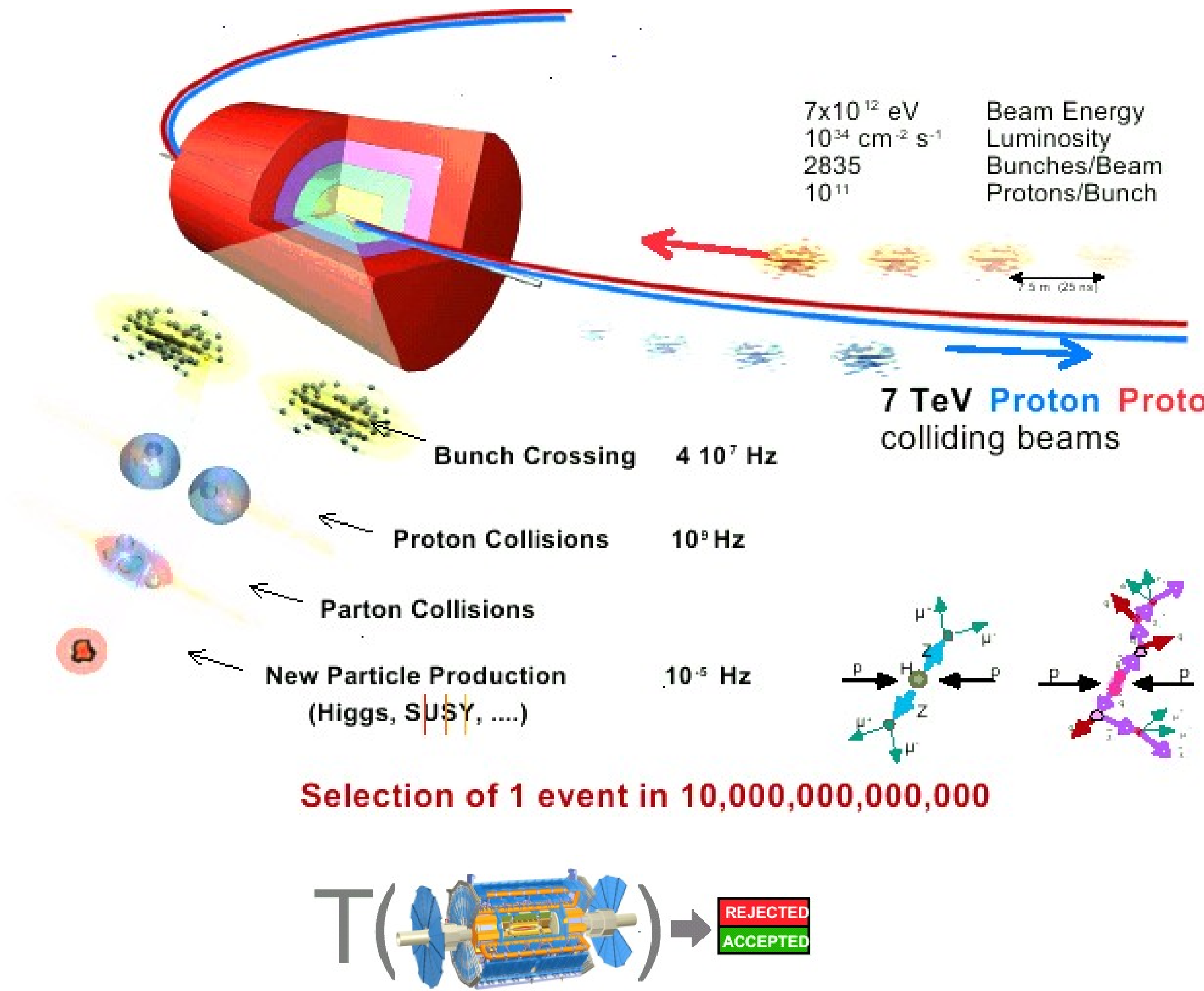
0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
D.Barney, CERN, February 2004

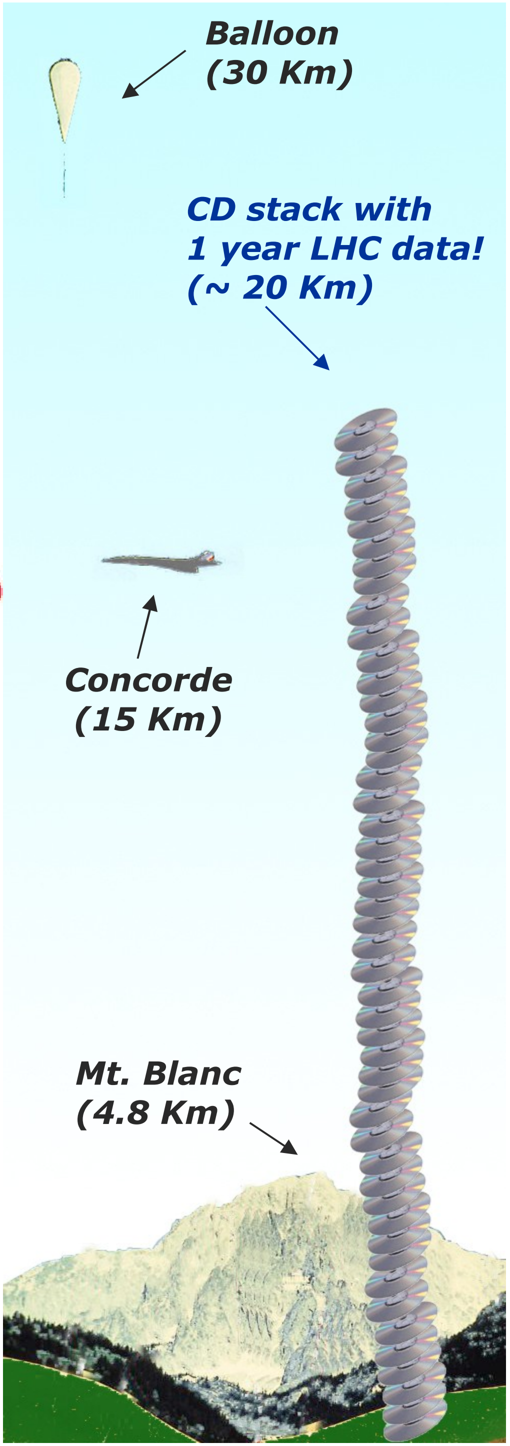
Detekční aparatura ATLAS



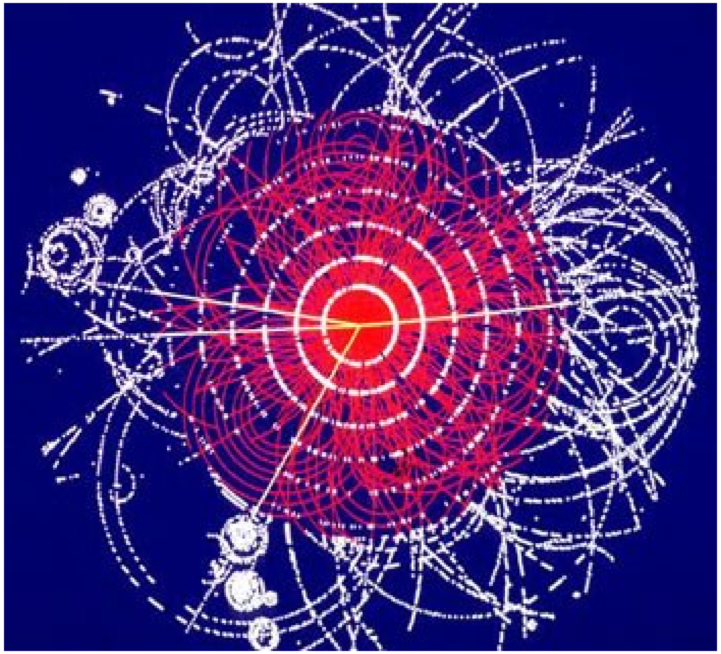
Skládání vrstev pixelového detektoru @ CERN

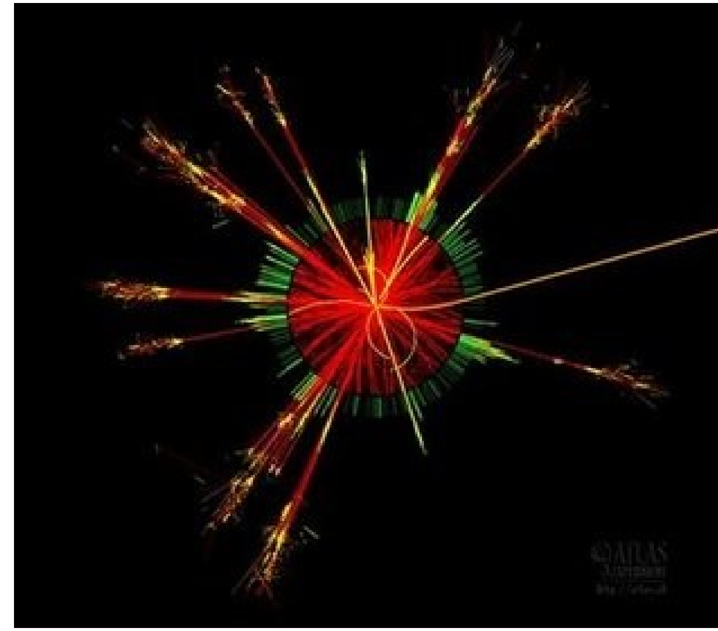


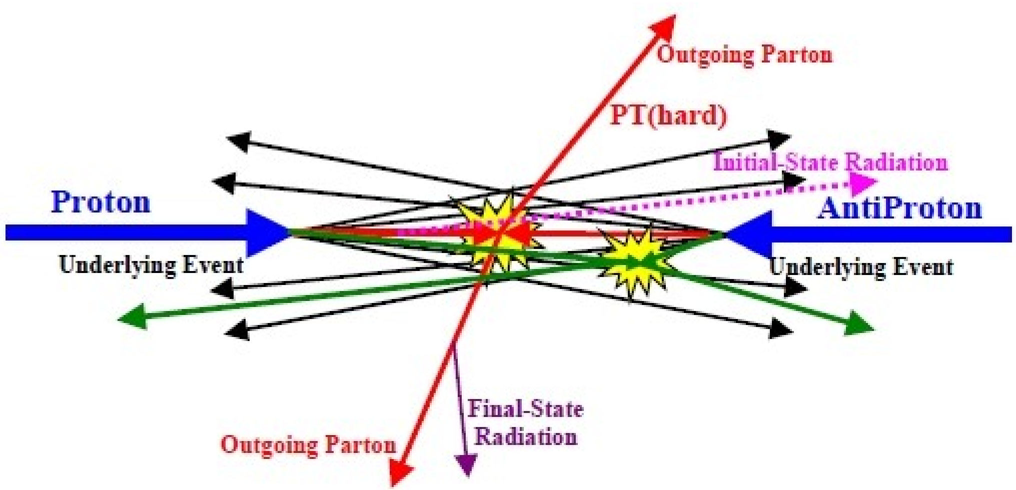

$7x10^{12}$ eV Beam Energy
10^{34} cm^{-2} s^{-1} Luminosity
2835 Bunches/Beam
10^{11} Protons/Bunch
7 TeV Proton Proto
colliding beams
Bunch Crossing $4\ 10^{7}$ Hz
Proton Collisions 10^{9} Hz
Parton Collisions
New Particle Production 10^{-5} Hz
(Higgs, SUSY, ...)
Selection of 1 event in 10,000,000,000,000
T(
)
REJECTED
ACCEPTED


Balloon
(30 Km)
CD stack with
1 year LHC data!
(~ 20 Km)
Concorde
(15 Km)
Mt. Blanc
(4.8 Km)

Bordel...

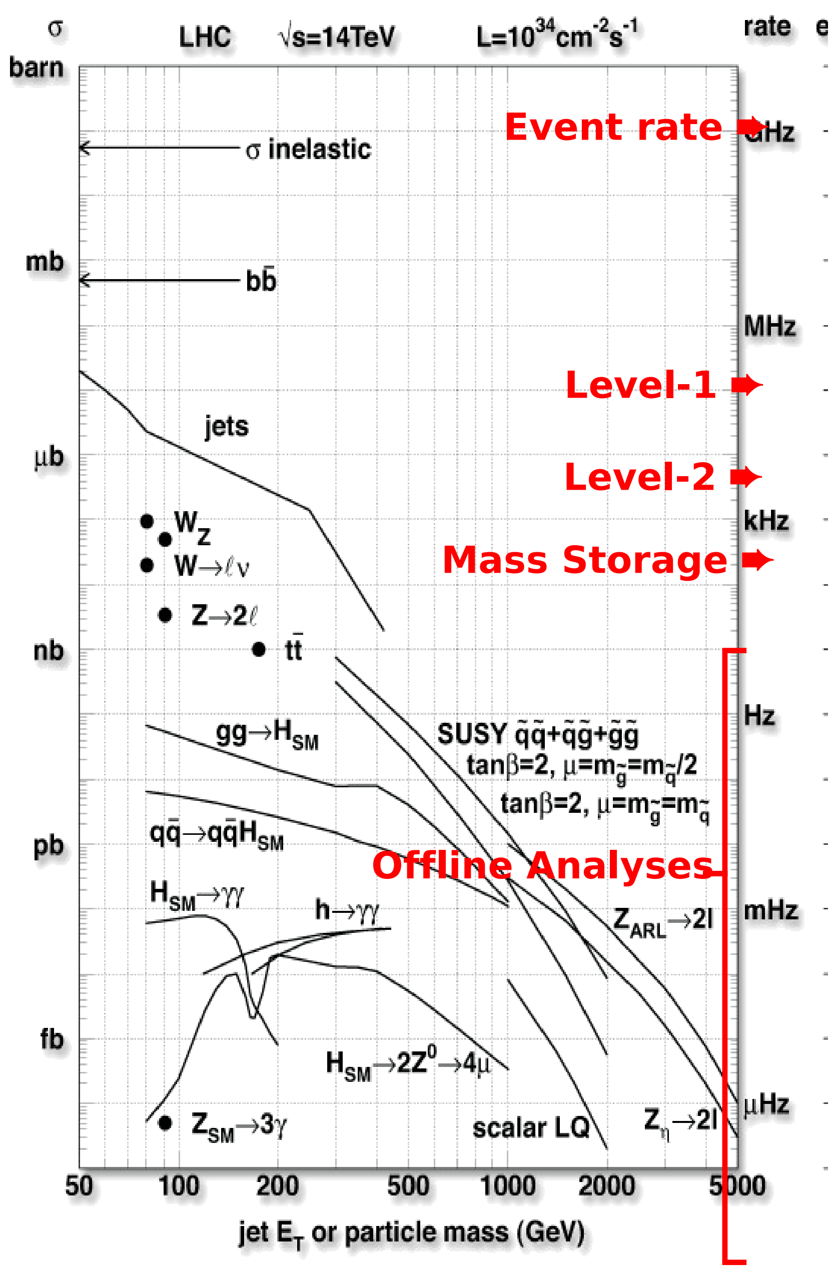




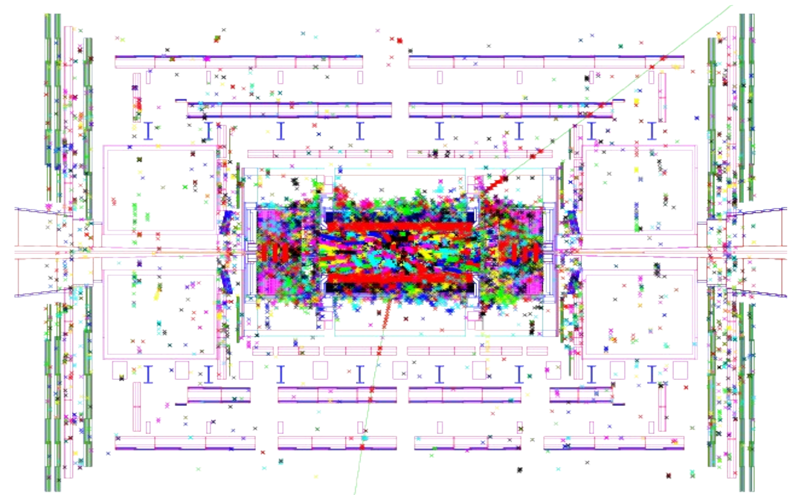


Outgoing Parton
PT(hard)
Initial-State Radiation
Proton
AntiProton
Underlying Event
Underlying Event
Final-State
Radiation
Outgoing Parton

The Challenge of Trigger at LHC



- **Bunch crossing** **40 MHz**
- **σ total** **70 mb**
- **Event rate** **~1 GHz**
- **Number of event/BC** **~25**
- **Number of part./event** **~1500**
- **Event size** **~1.5MB**
- **Mass storage rate** **~200Hz**



- Need to have Trigger of high performance
  - ~6 order of rate reduction
  - Complex event and 140 M channels

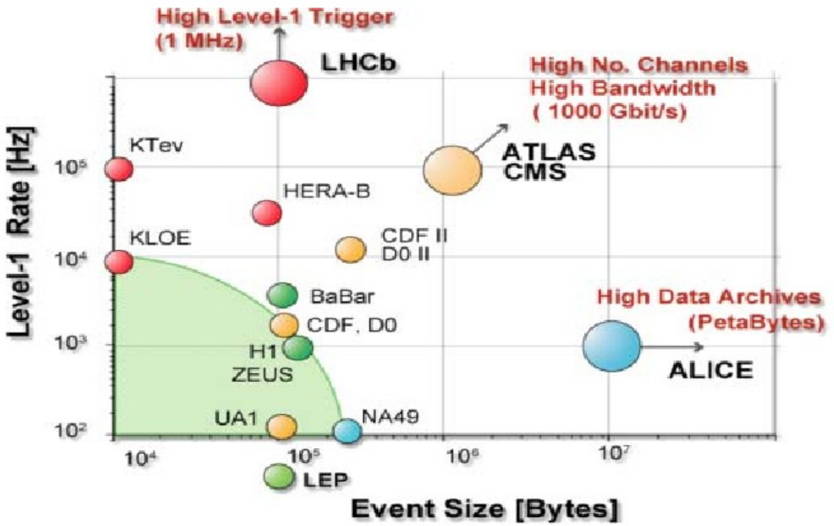
The Atlas Trigger

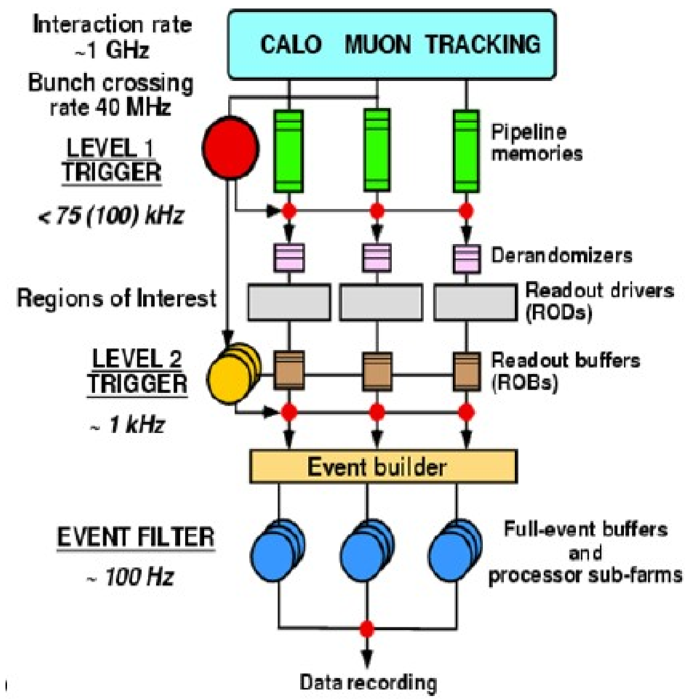
- 40 MHz
- 1 GHz interaction rate
- must reduce to 100 Hz

Inputs: CALO + MUONS

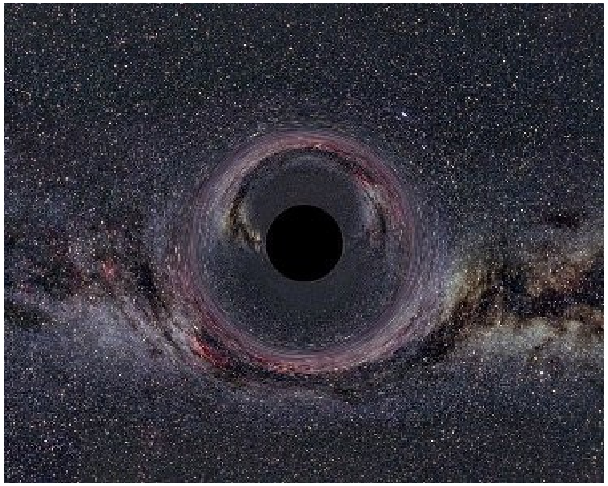
Hladaju sa high-p_t elektrony, fotony, jety a tau rozpadajuce sa na hadrony ako aj missing E_t. (towers, scalar sum)

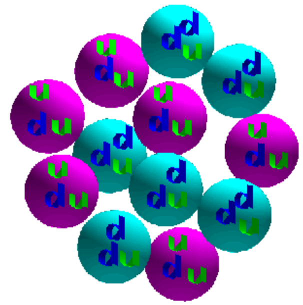
- hardware-based (FPGAs and ASICs)
- coarse granularity 1 from calo / muon
- 2.5μs max. latency (pipelines)

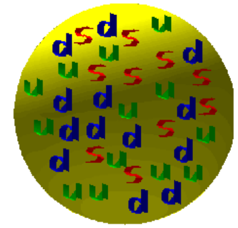


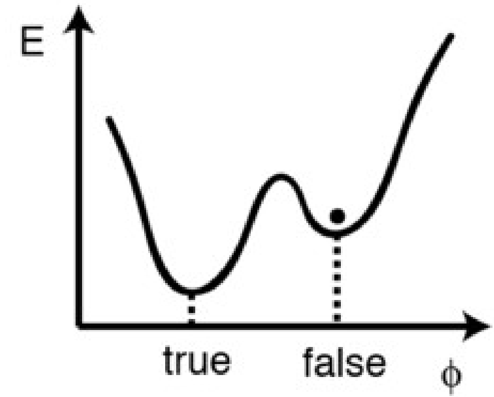


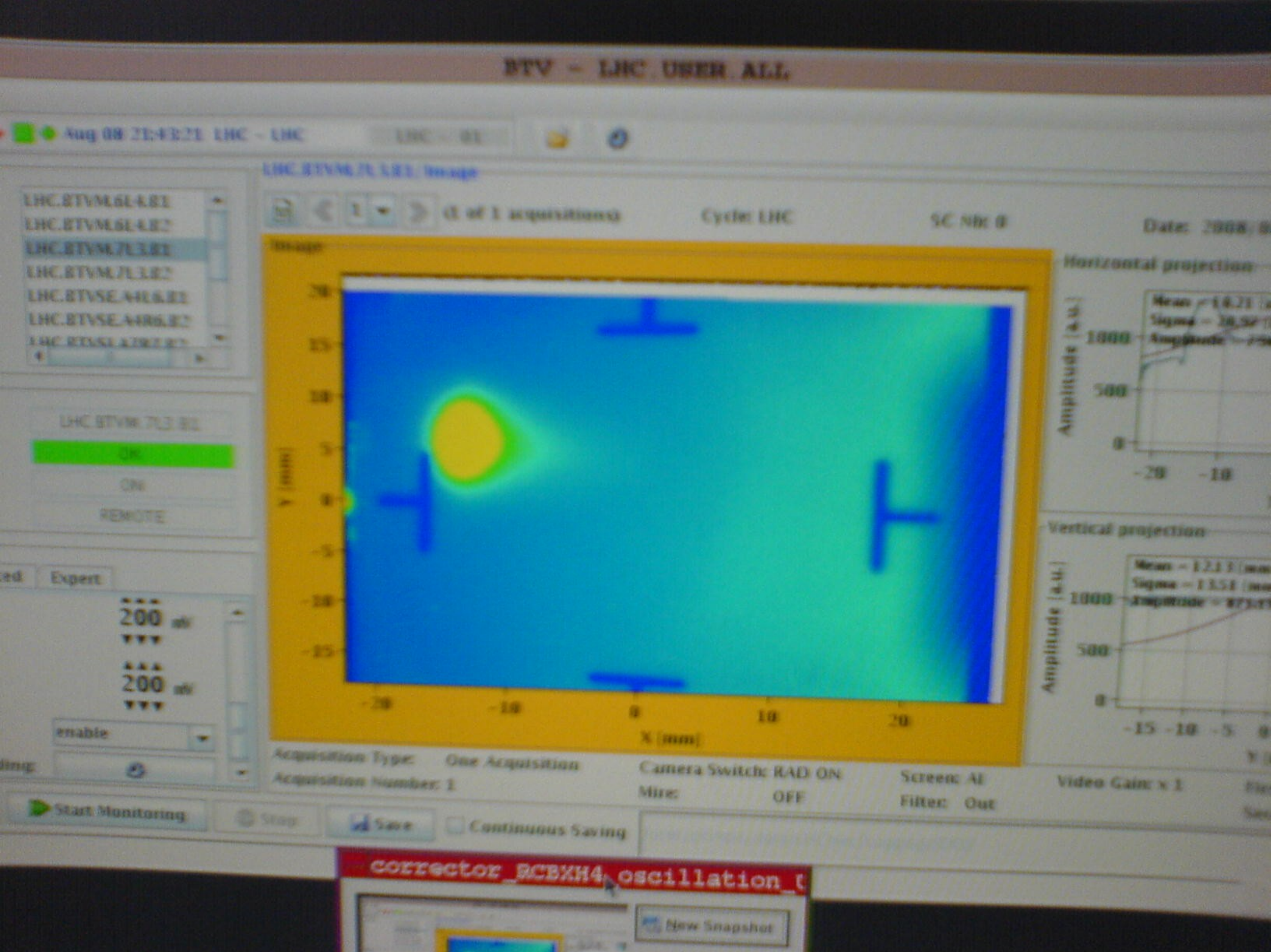
Obavy z LHC



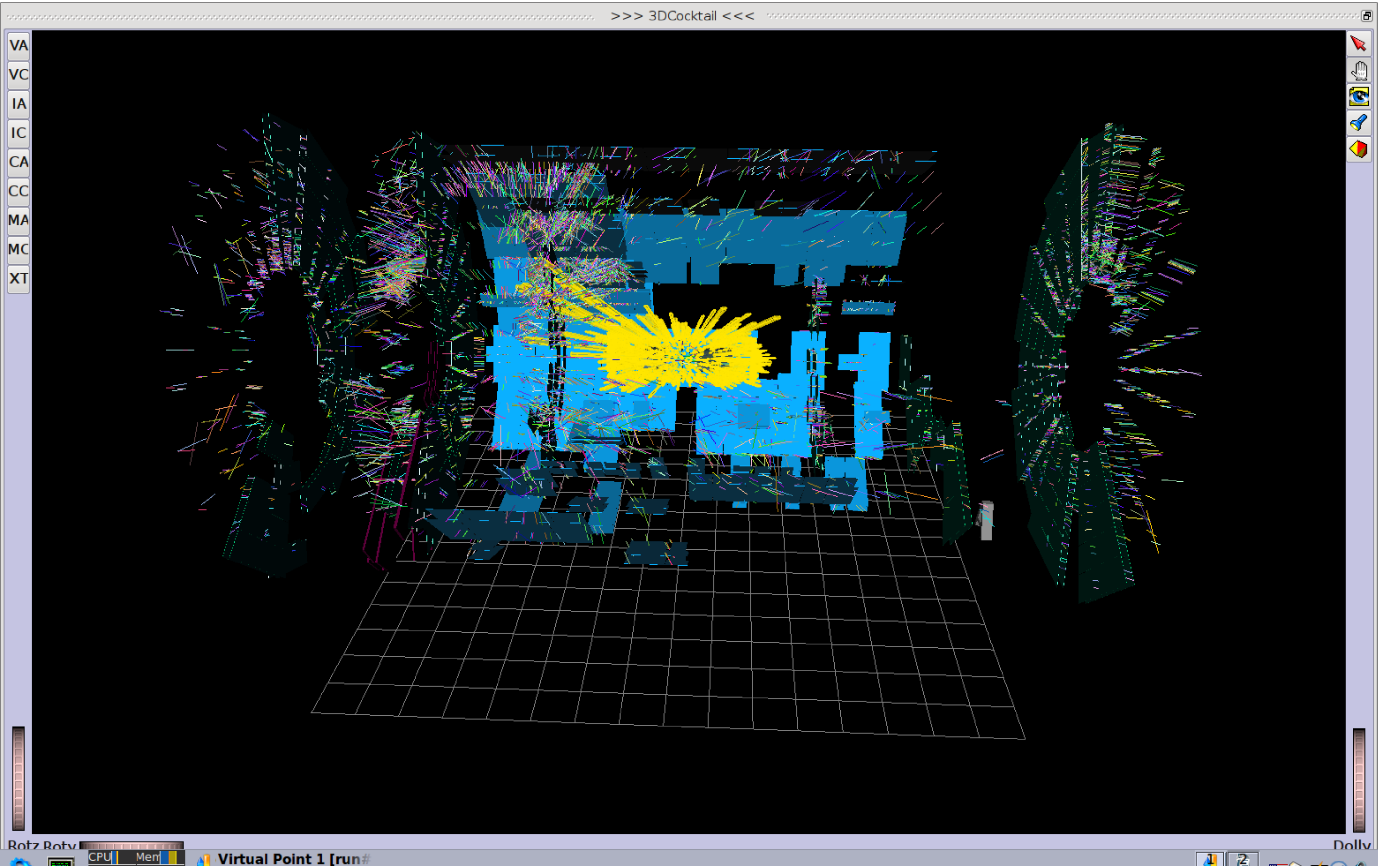


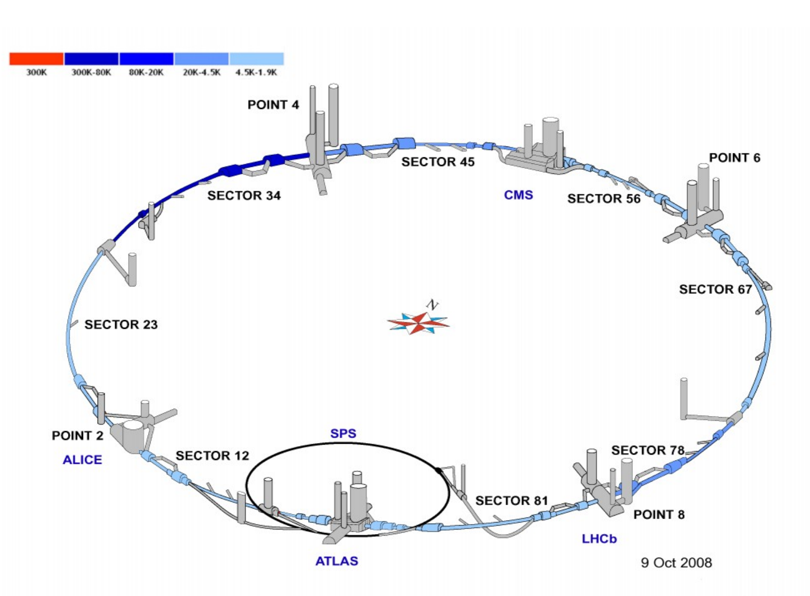


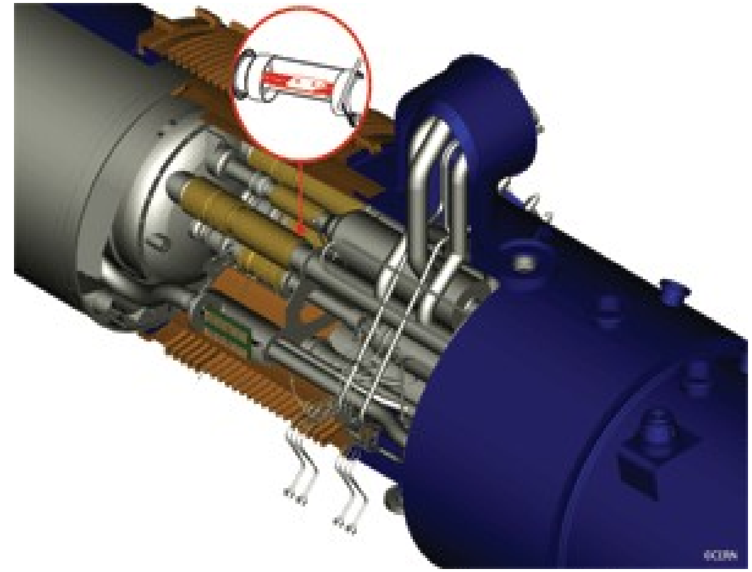



BTV - LHC USER ALL
Aug 08 21:43:21 LHC - LHC
(1 of 1 acquisitions)
Cycle: LHC
Image
Horizontal projection
Vertical projection
Amplitude [a.u.]
X [mm]
Y [mm]
OK
ON
REMOTE
Expert
200
200
enable
Acquisition Type: One Acquisition
Acquisition Number: 1
Camera Switch: RAD ON
Mire: OFF
Screen: Al
Filter: Out
Video Gain: x 1
Start Monitoring
Stop
Save
Continuous Saving
corrector_RCBXH4_oscillation_
New Snapshot

ATLAS beam splash







On 19 September 2008, during powering tests of the main dipole circuit in sector 3-4 of the LHC, an electrical fault occurred resulting in mechanical damage and release of helium from the magnet cold mass. Proper safety procedures were in force, safety systems performed as expected, and no one was put at risk. An ad hoc task force was set up on 22 September 2008 to investigate the incident, establish the sequence
of events, analyse and explain their development in relation with design assumptions and manufacturing and test data, and recommend preventive and corrective actions for further powering of the machine. Today a number of findings have been established, but inspections are not completed and investigations are continuing. Consequently this is an interim summary report of this task force as of
15 October 2008.

The CERN Management today confirmed the restart schedule for the Large Hadron Collider resulting from the recommendations from the Chamonix workshop. The new schedule foresees **first beams in the LHC at the end of September this year, with collisions following in late October.**

A short technical stop has also been foreseen over the Christmas period. **The LHC will then run through to autumn next year**, ensuring that the experiments have adequate data to carry out their first new physics analyses and have results to announce in 2010. The new schedule also permits the possible collisions of lead ions in 2010.

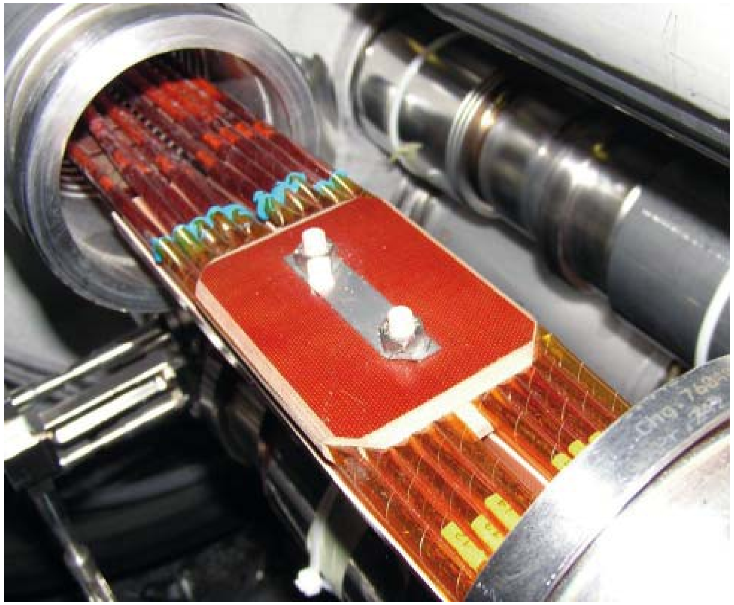
This new schedule represents a delay of 6 weeks with respect to the previous schedule which foresaw LHC "cold at the beginning of July". The cause of this delay is due to several factors such as **implementation of a new enhanced protection system for the busbar and magnet splices**, installation of new pressure relief valves to reduce the collateral damage in case of a repeat incident, application of more stringent safety constraints, and scheduling constraints associated with helium transfer and storage.

In Chamonix there was consensus among all the technical specialists that the new schedule is tight but realistic.

The enhanced protection system measures the electrical resistance in the cable joints (splices) and is much more sensitive than the system existing on 19 September.

The new pressure relief system has been designed in two phases. The first phase involves installation of relief valves on existing vacuum ports in the whole ring. Calculations have shown that in an incident similar to that of 19 September, the collateral damage (to the interconnects and super-insulation) would be minor with this first phase.

The second phase involves adding additional relief valves on all the dipole magnets and would guarantee minor collateral damage (to the interconnects and super-insulation) in all worst cases over the life of the LHC. One of the questions discussed in Chamonix was whether to warm up the whole LHC machine in 2009 so as to complete the installation of these new pressure relief valves or to perform these modifications on sectors that were warmed up for other reasons. The Management has decided for 2009 to install relief valves on the four sectors that were already foreseen to be warmed up. The dipoles in the remaining four sectors will be equipped in 2010.



Electricity cost constraint

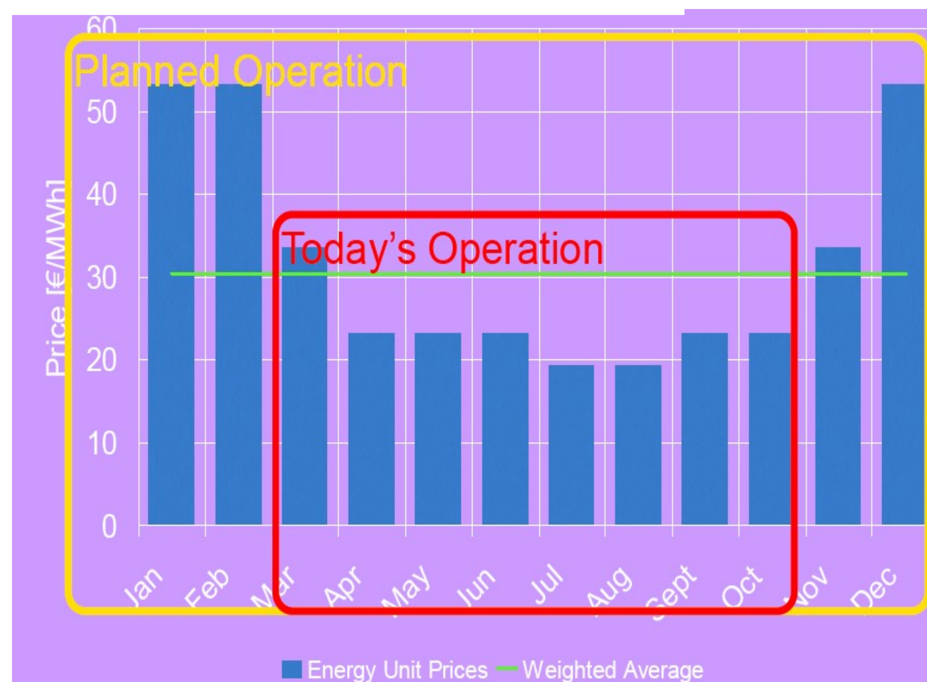
Year	2009											2010														
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Baseline	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH		SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	SH	SH	SH	SH
Base*	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	SH	SH	SH	SH	SH	SH
Delay (4W)	SH	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	SH	SH	SH	SH	SH
Delay (8W)	SH	SH	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	SH	SH	SH	SH

24 weeks physics possible

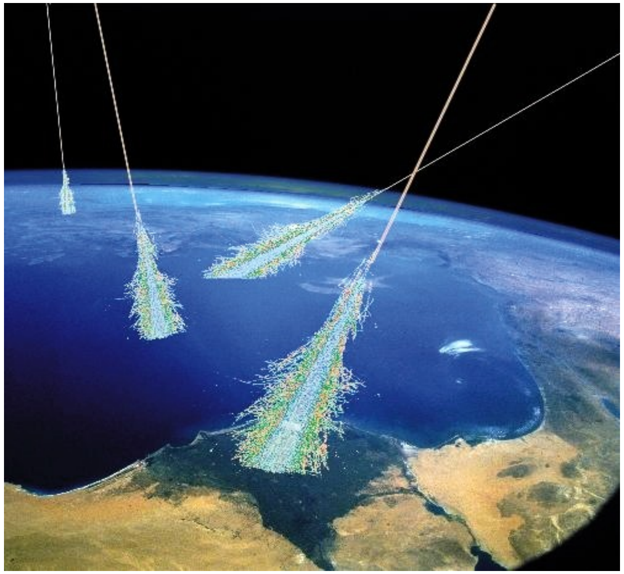
44 weeks physics possible

Gain 20 weeks of physics in 2010 by running during winter months

HIGH price Electricity



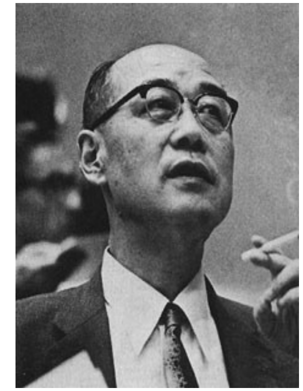
Cosmic Rays



Cosmic ray showers

V. Hess

C. Anderson



H. Yukawa

P. Auger

10 1 *High energy astrophysics – two approaches*

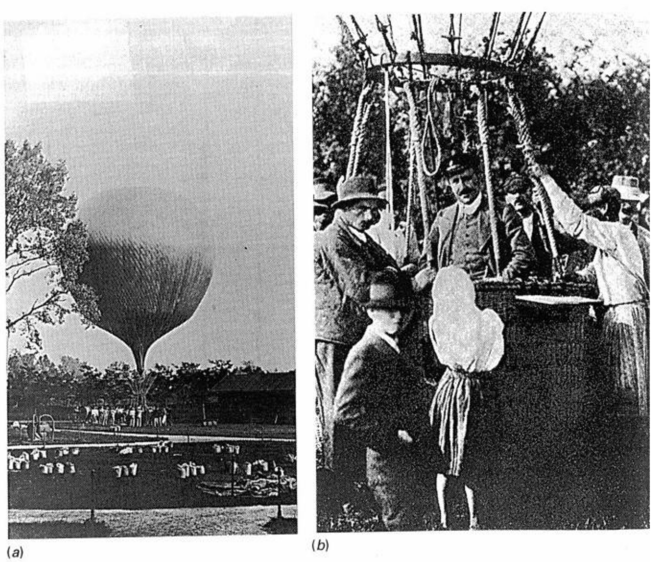
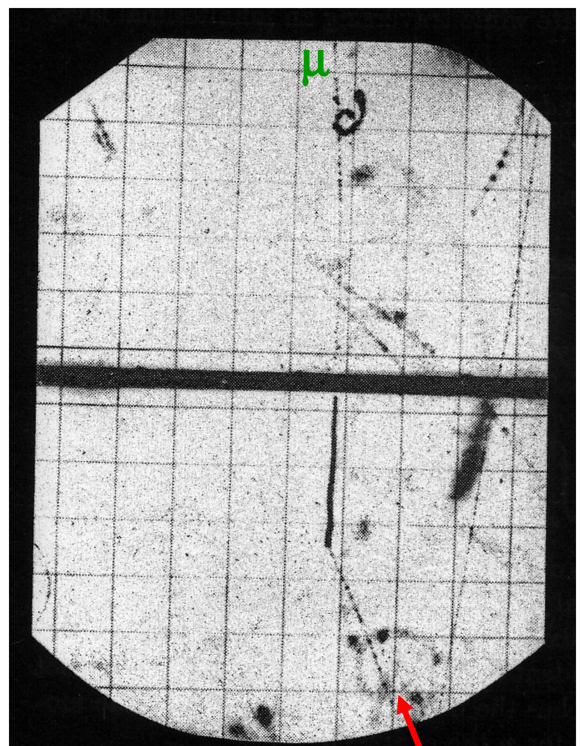
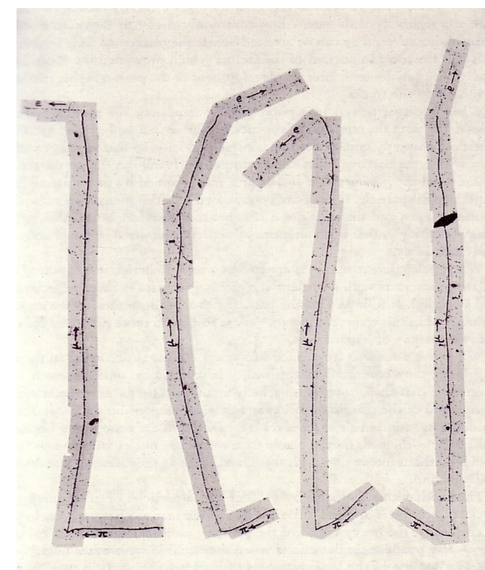


Figure 1.3. The balloon flights of Victor F. Hess. (*a*) Preparation for one of his flights in the period 1911–12. (*b*) Hess after one of the successful balloon flights in which the increase in ionisation with altitude through the atmosphere was discovered. (From Y. Sekido and H. Elliot (eds) (1985). *Early history of cosmic ray studies*, Dordrecht: D. Reidel Publishing Company.)

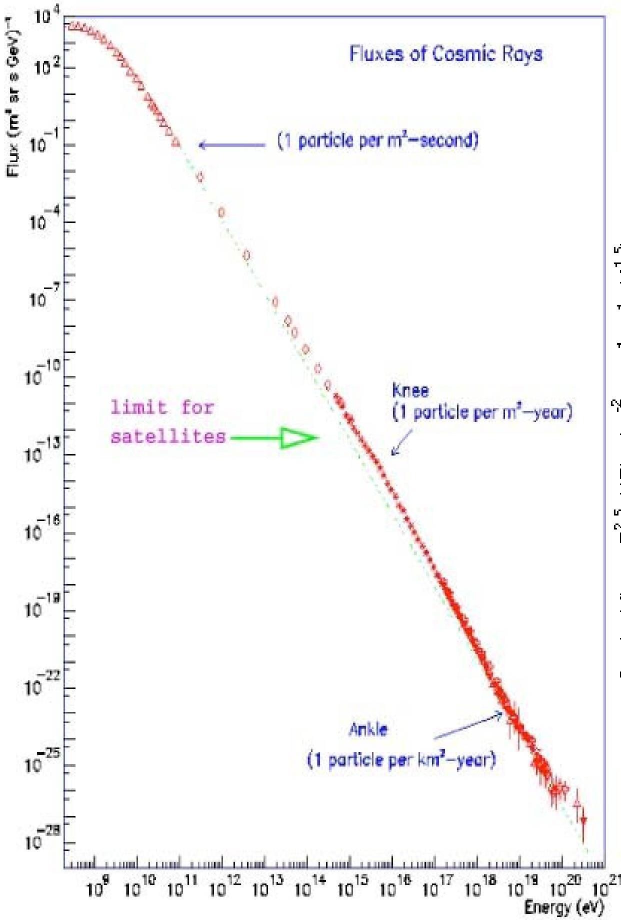


decay electron track

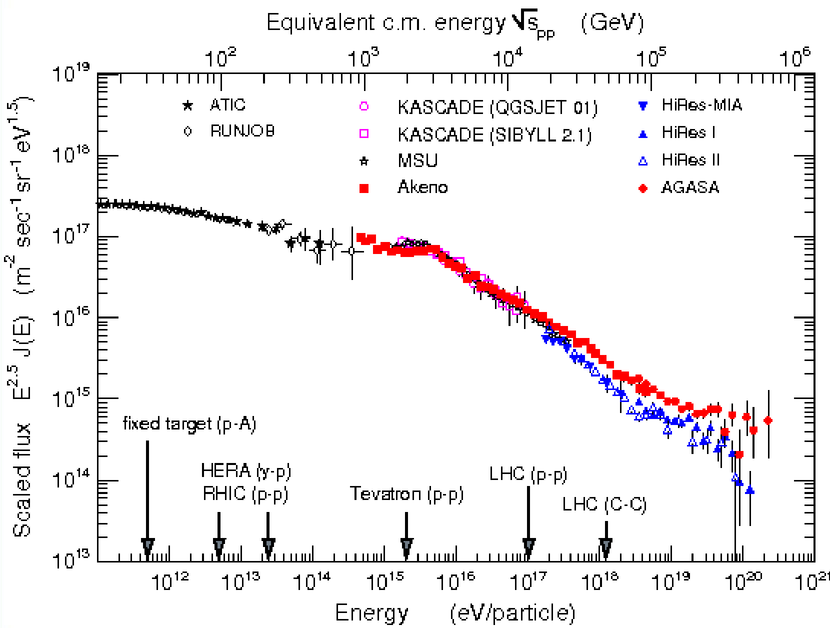


Four events showing the decay of a π^+ coming to rest in nuclear emulsion

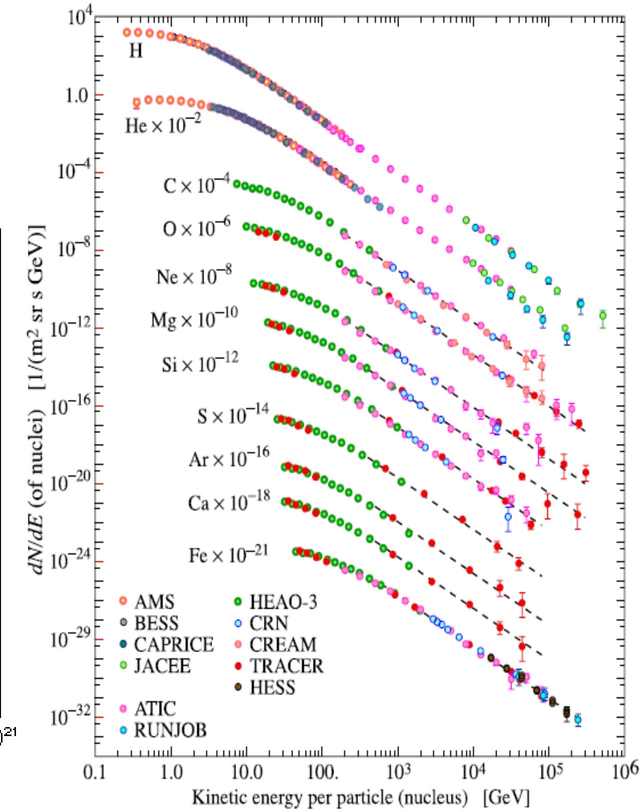
Primary CR



Energy spectrum

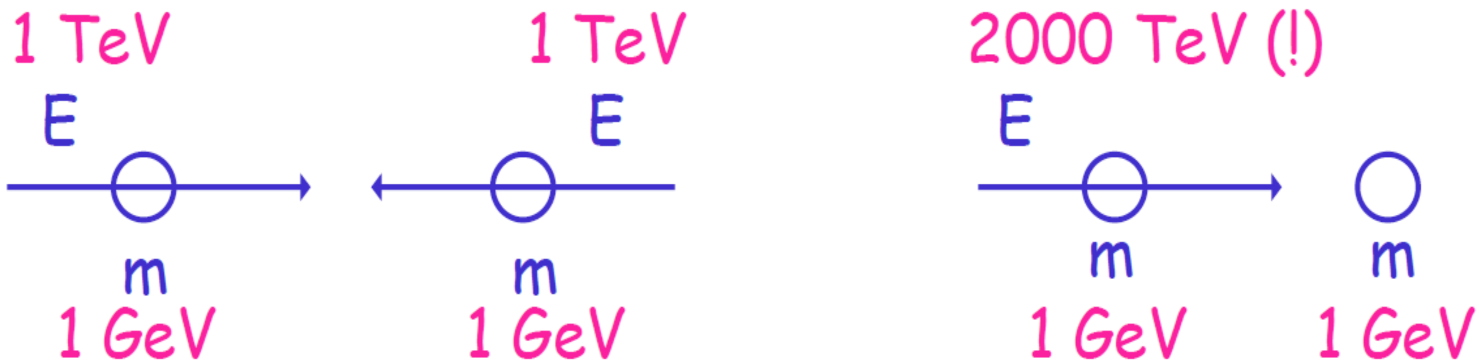


Energy spectrum



Composition >2 GeV

Fixed Target Vs Collider



$$s = [(E_1, \vec{p_1}) + (E_2, \vec{p_2})]^2$$
$$= [(2E, \vec{0})]^2$$
$$= 4E^2$$

$$\sqrt{s} = 2\,TeV$$

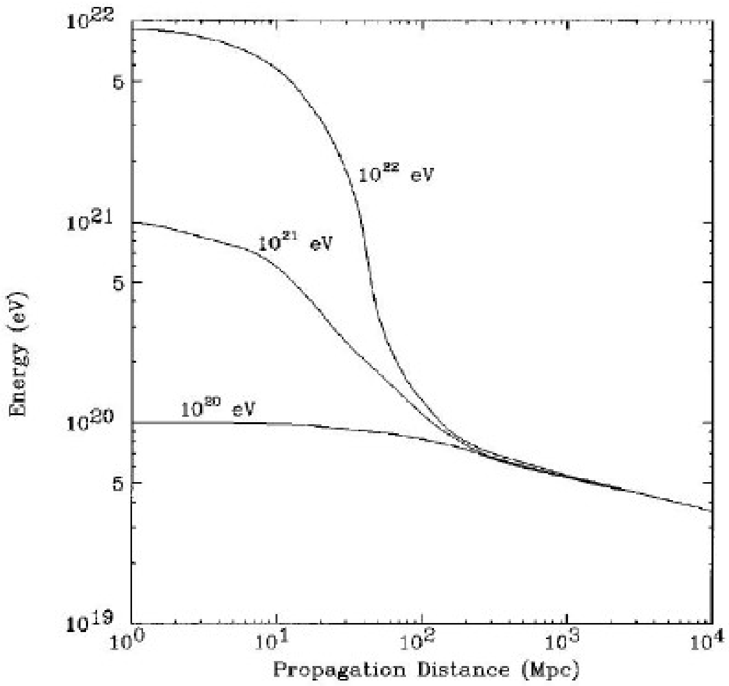
$$s = [(E_1, \vec{p_1}) + (E_2, \vec{p_2})]^2$$
$$= [(E, \vec{p}) + (m, \vec{0})]^2$$
$$= (E+m)^2 - \vec{p}^{\,2}$$
$$= E^2 + 2mE + m^2 - (E^2 - m^2)$$
$$= 2mE + 2m^2$$
$$\approx 2mE$$

$$\sqrt{s} = 2\,TeV$$

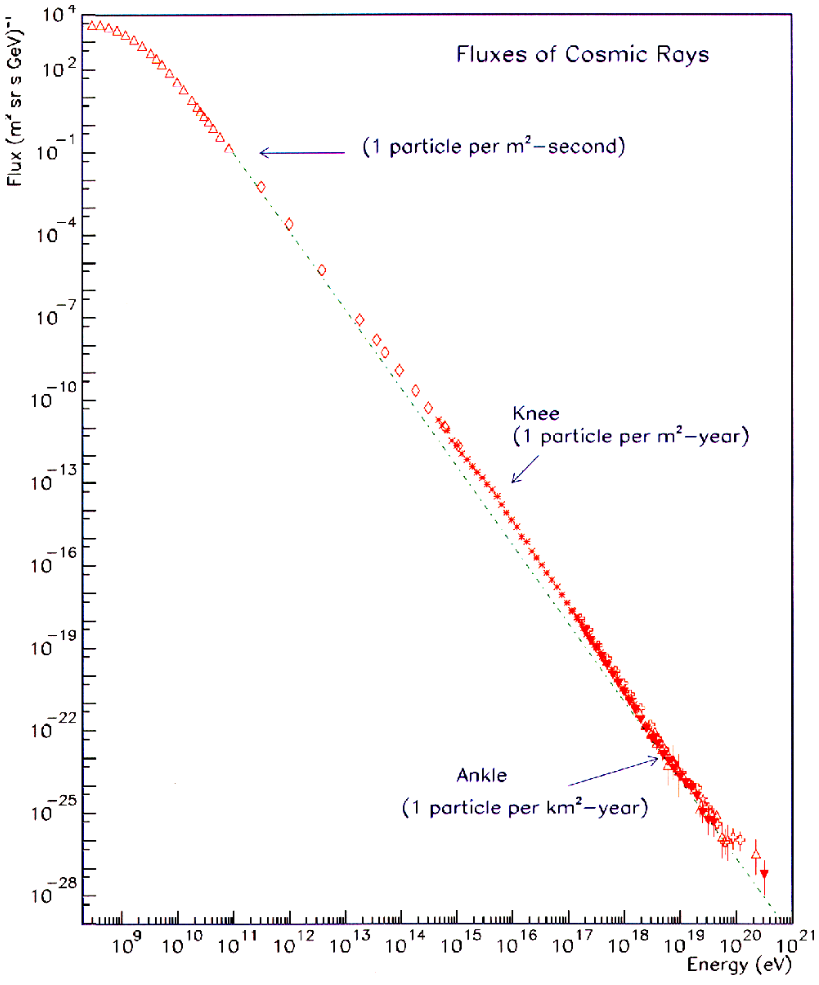
GZK-Cutoff (Greisen-Zatsepin-Kuzmin, 1966)

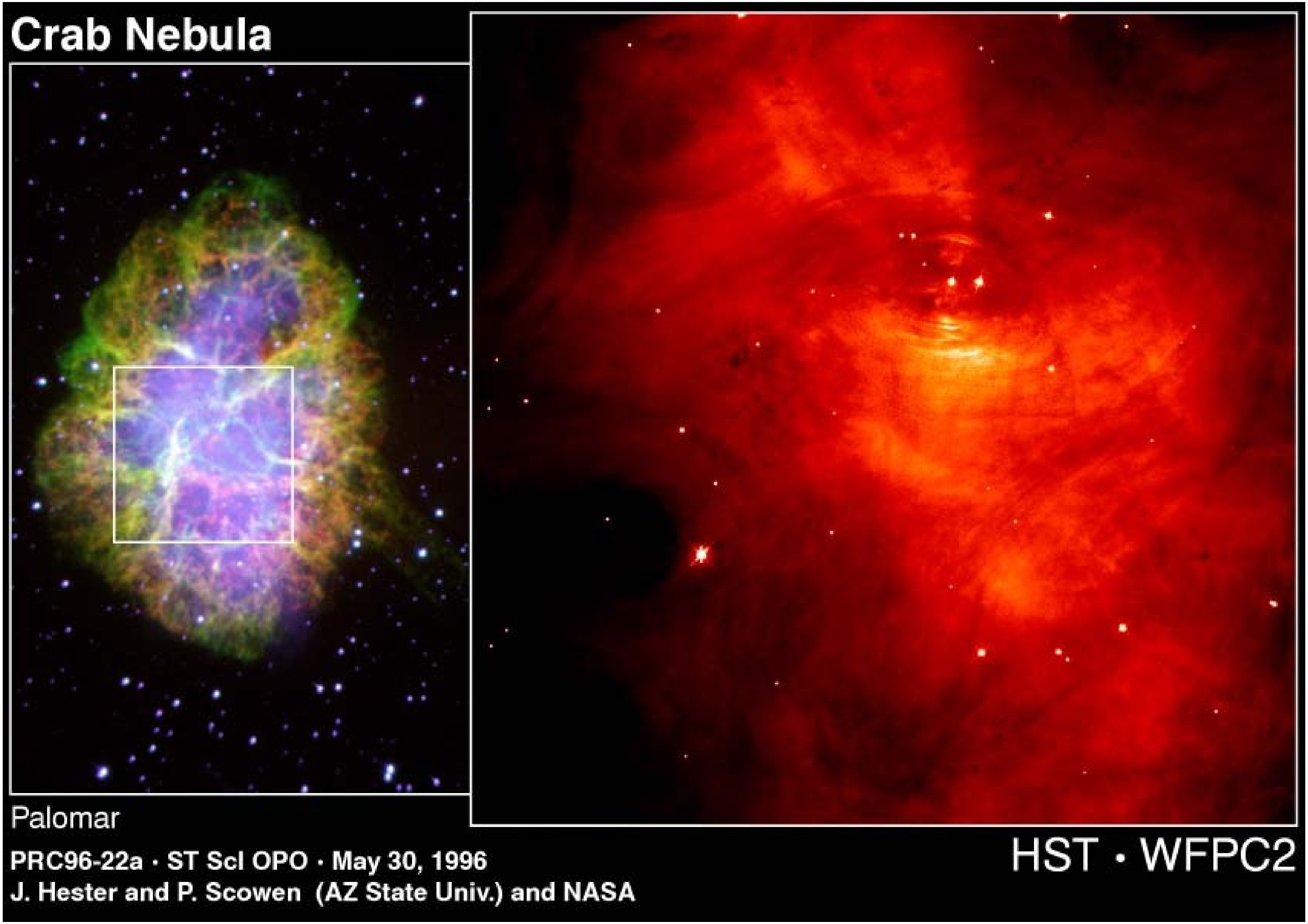
- $E_p > 5\times10^{19}$eV
- $E_\gamma \approx 1$meV

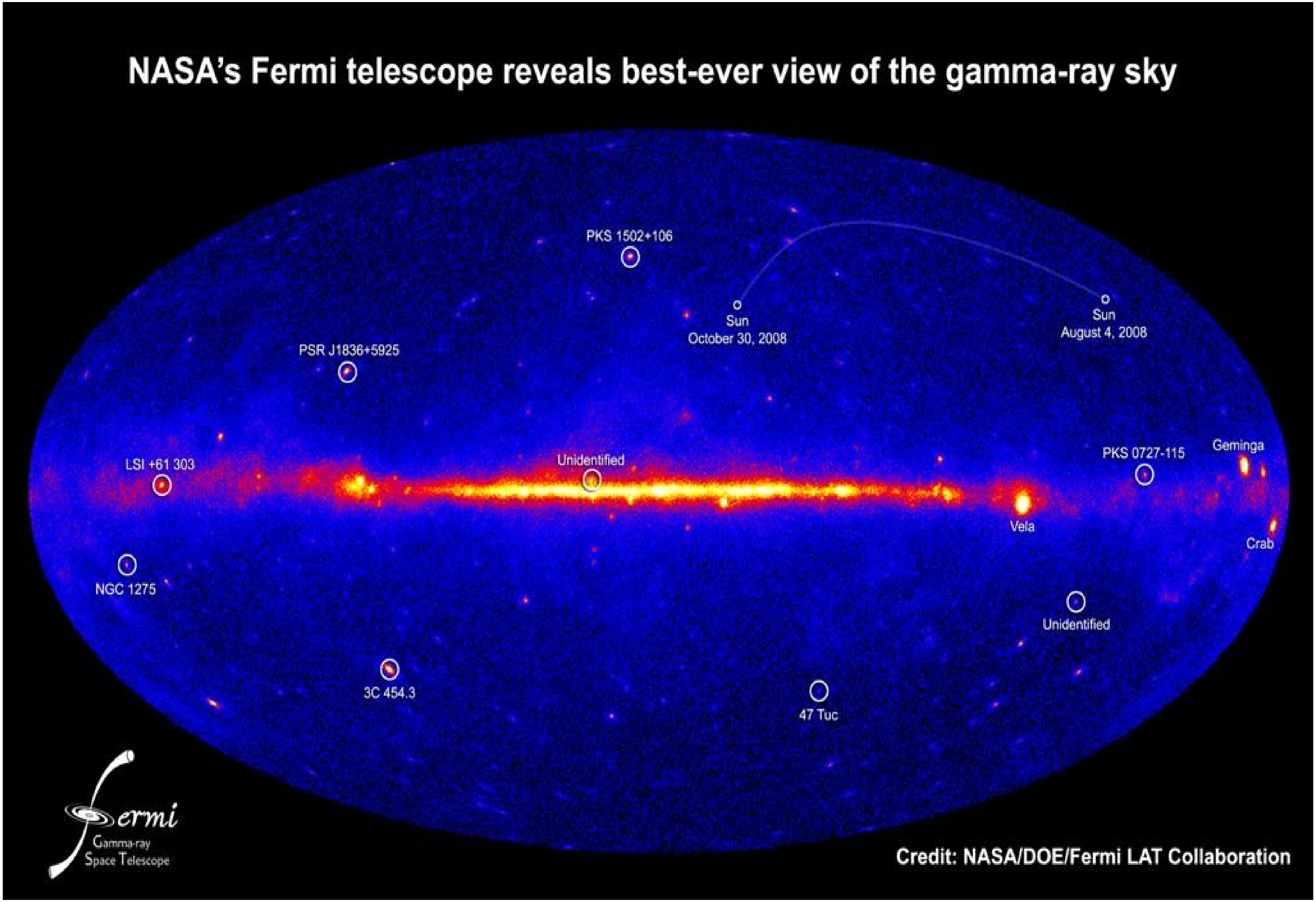
$$p + \gamma \rightarrow \Delta^+ \rightarrow \begin{cases} p + \pi^0 \\ n + \pi^+ \end{cases}$$



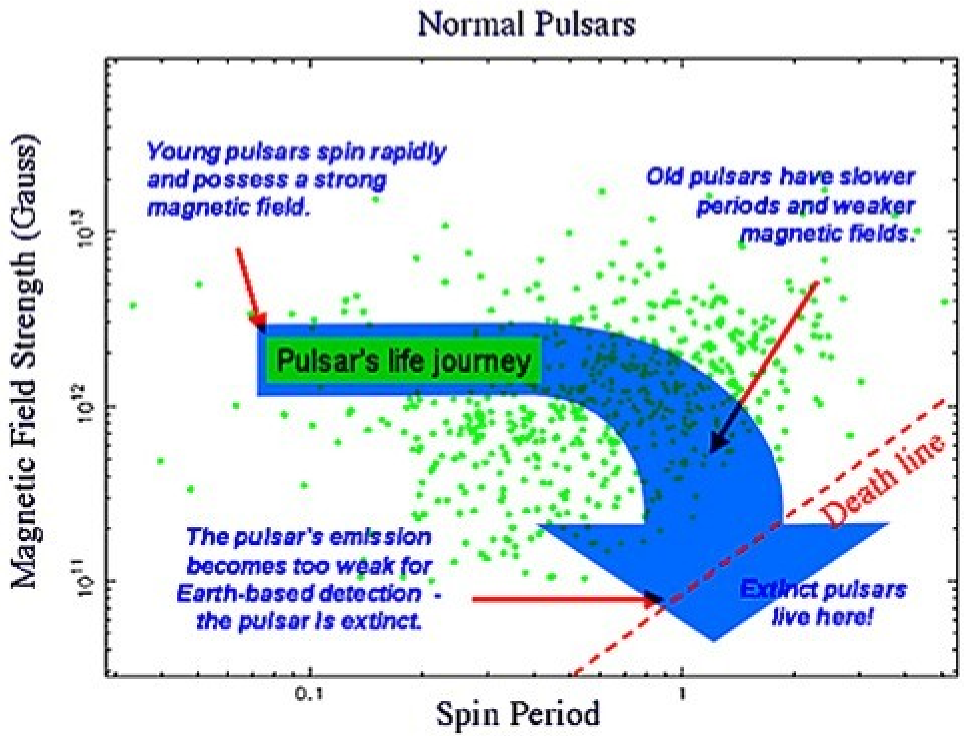
Limit asi na 50 MPc.



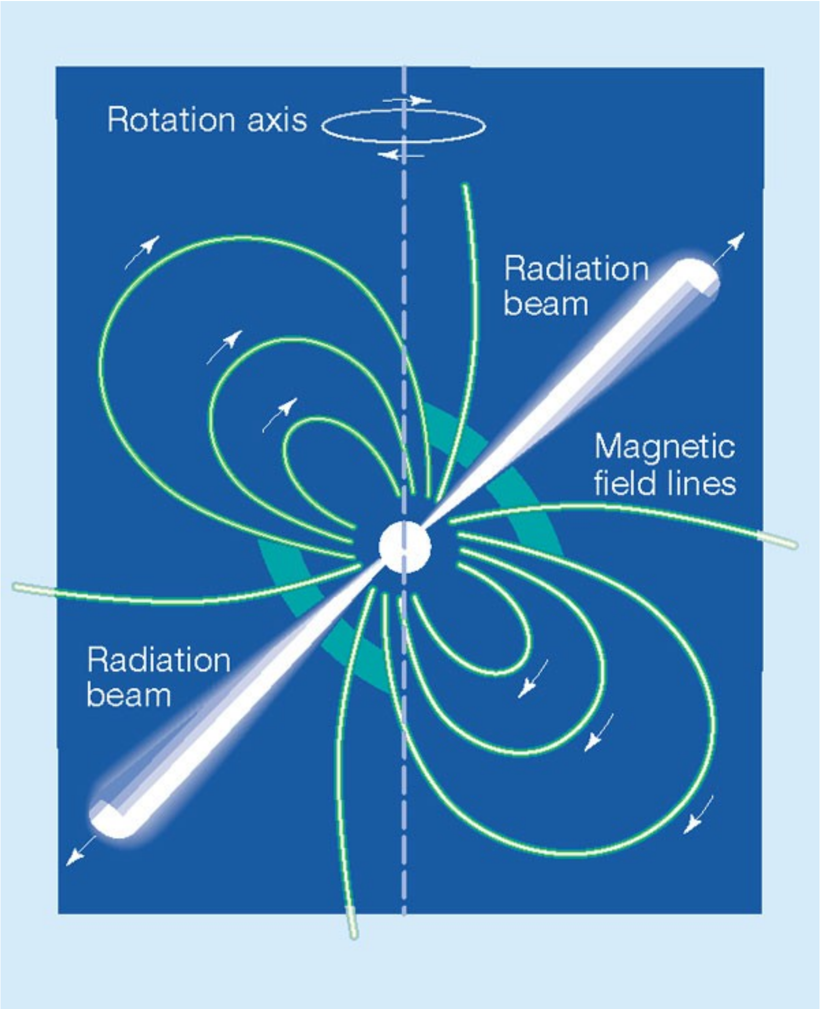

Crab Nebula
Palomar
PRC96-22a · ST ScI OPO · May 30, 1996
J. Hester and P. Scowen (AZ State Univ.) and NASA
HST · WFPC2


NASA's Fermi telescope reveals best-ever view of the gamma-ray sky
PKS 1502+106
Sun
October 30, 2008
Sun
August 4, 2008
PSR J1836+5925
LSI +61 303
Unidentified
PKS 0727-115
Geminga
Vela
Crab
NGC 1275
Unidentified
3C 454.3
47 Tuc
Fermi
Gamma-ray
Space Telescope
Credit: NASA/DOE/Fermi LAT Collaboration

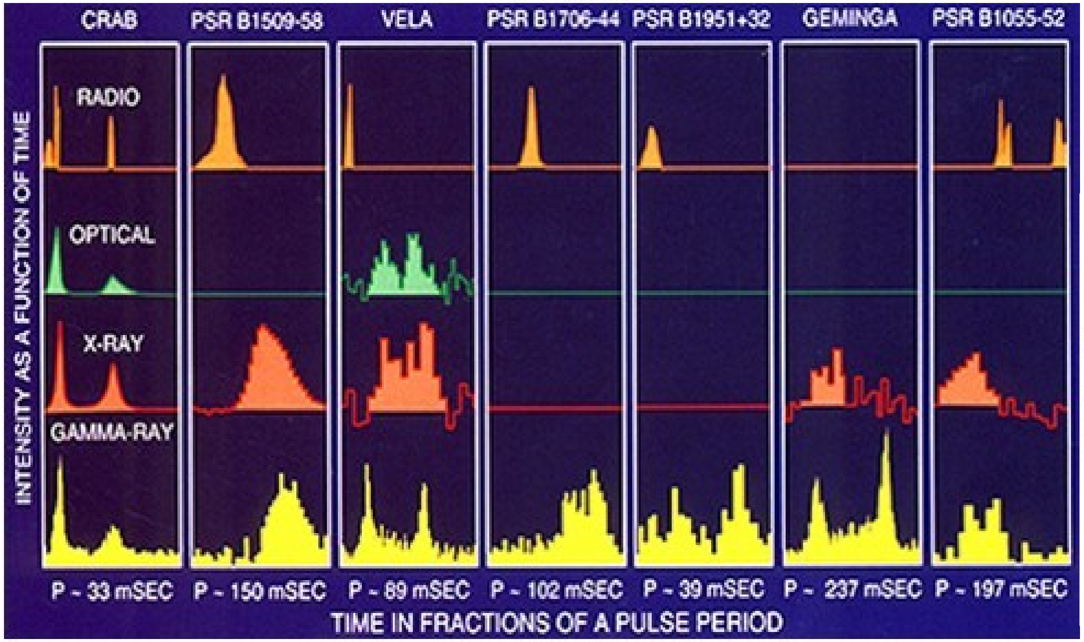
Pulsars



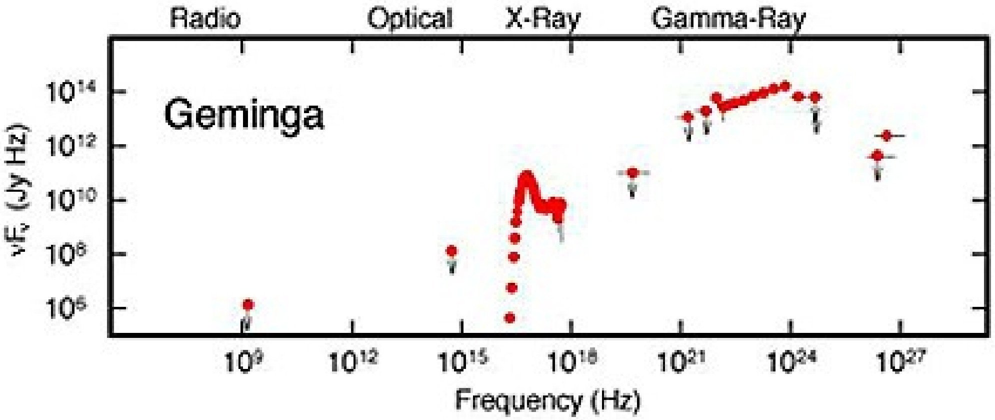
Normal Pulsars
Young pulsars spin rapidly and possess a strong magnetic field.
Old pulsars have slower periods and weaker magnetic fields.
Pulsar's life journey
Death line
The pulsar's emission becomes too weak for Earth-based detection - the pulsar is extinct.
Extinct pulsars live here!
Magnetic Field Strength (Gauss)
Spin Period



Rotation axis
Radiation beam
Magnetic field lines
Radiation beam

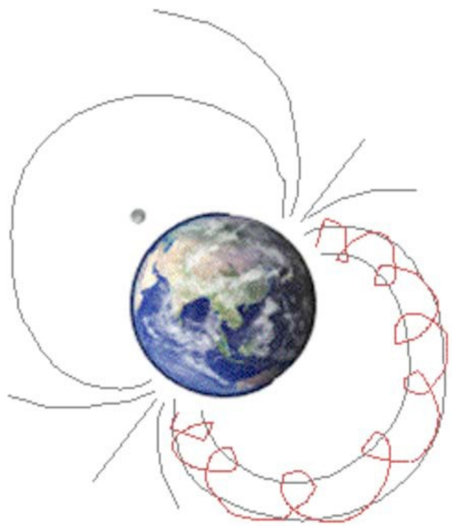


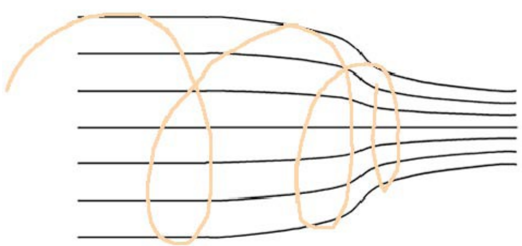
CRAB
PSR B1509-58
VELA
PSR B1706-44
PSR B1951+32
GEMINGA
PSR B1055-52
RADIO
OPTICAL
X-RAY
GAMMA-RAY
INTENSITY AS A FUNCTION OF TIME
P ~ 33 mSEC
P ~ 150 mSEC
P ~ 89 mSEC
P ~ 102 mSEC
P ~ 39 mSEC
P ~ 237 mSEC
P ~ 197 mSEC
TIME IN FRACTIONS OF A PULSE PERIOD

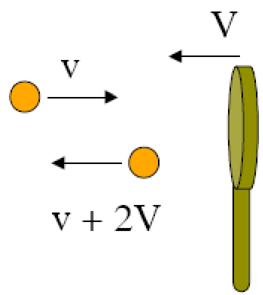


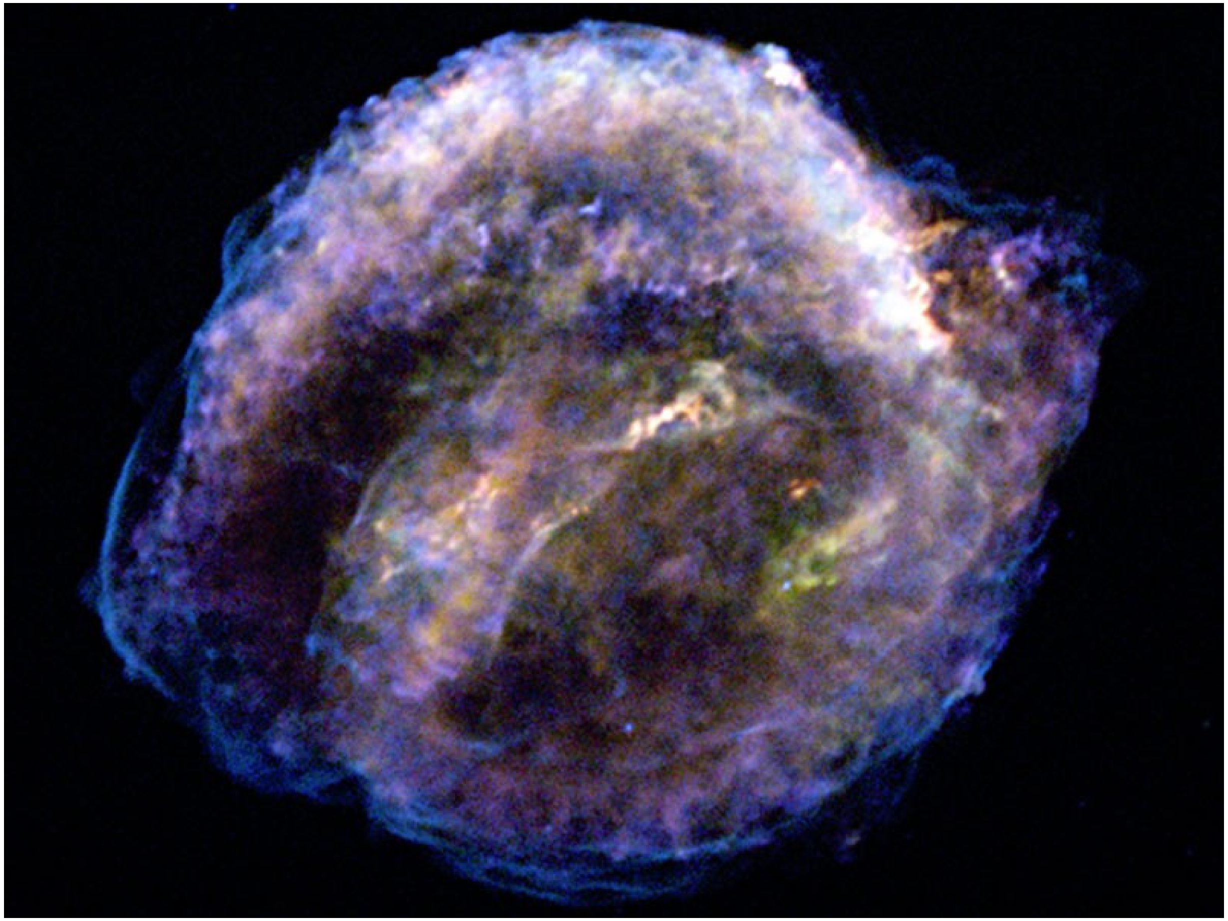
Radio
Optical
X-Ray
Gamma-Ray
Geminga
νFν (Jy Hz)
Frequency (Hz)

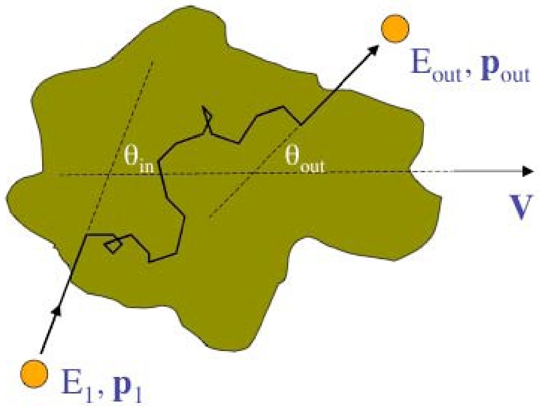
Fermi acceleration

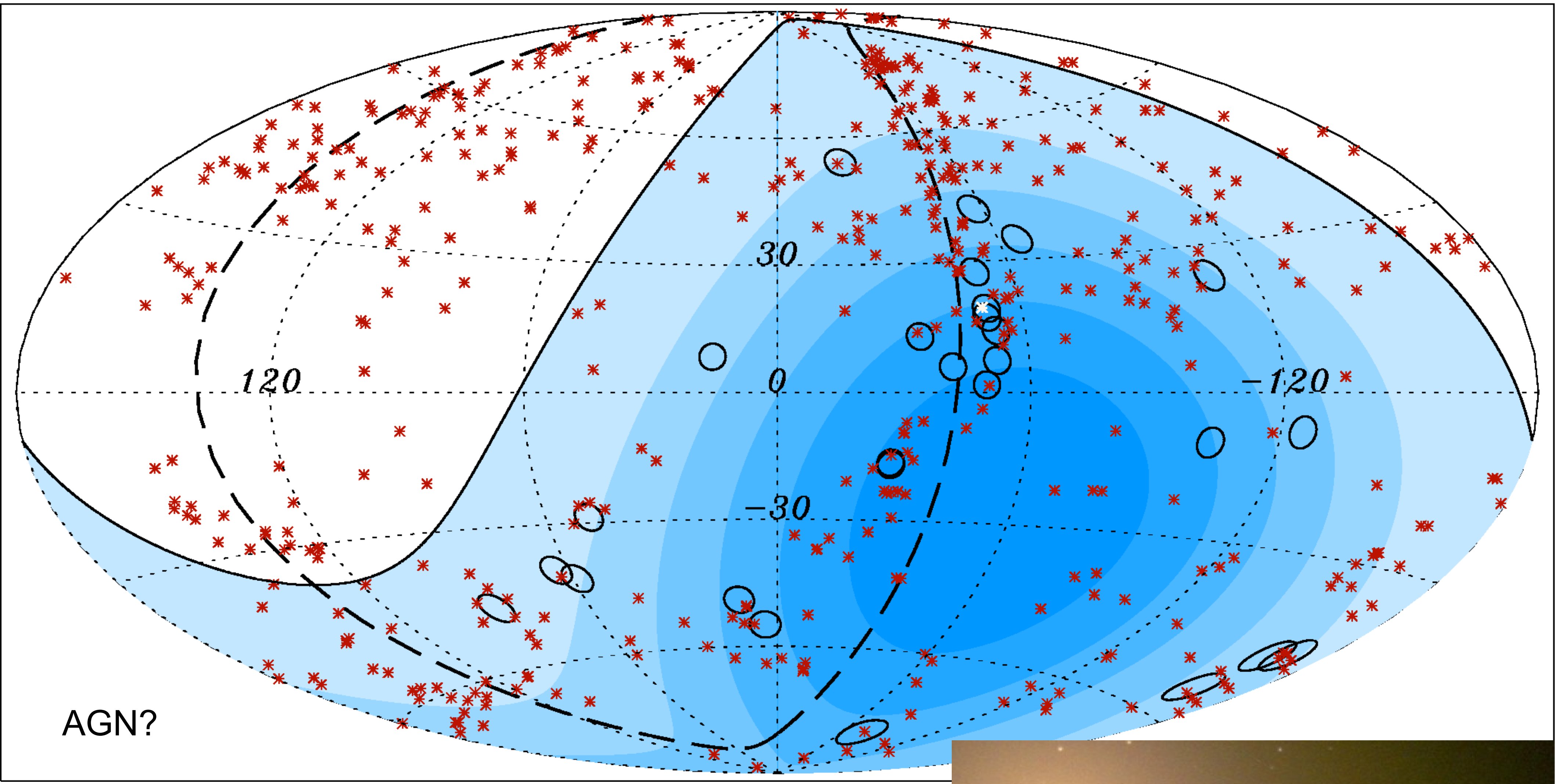








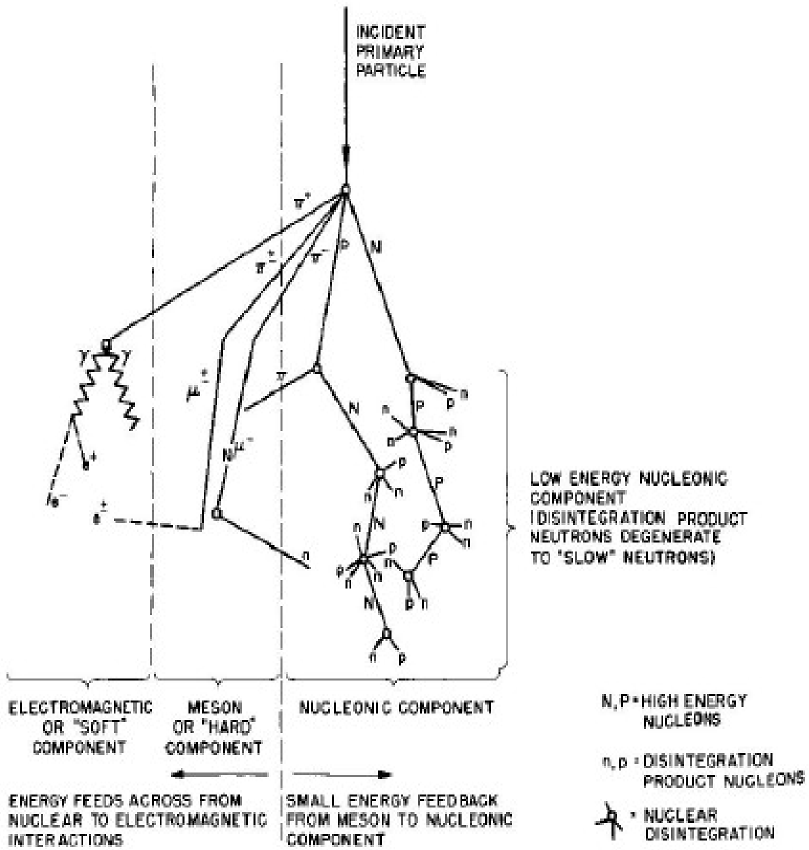


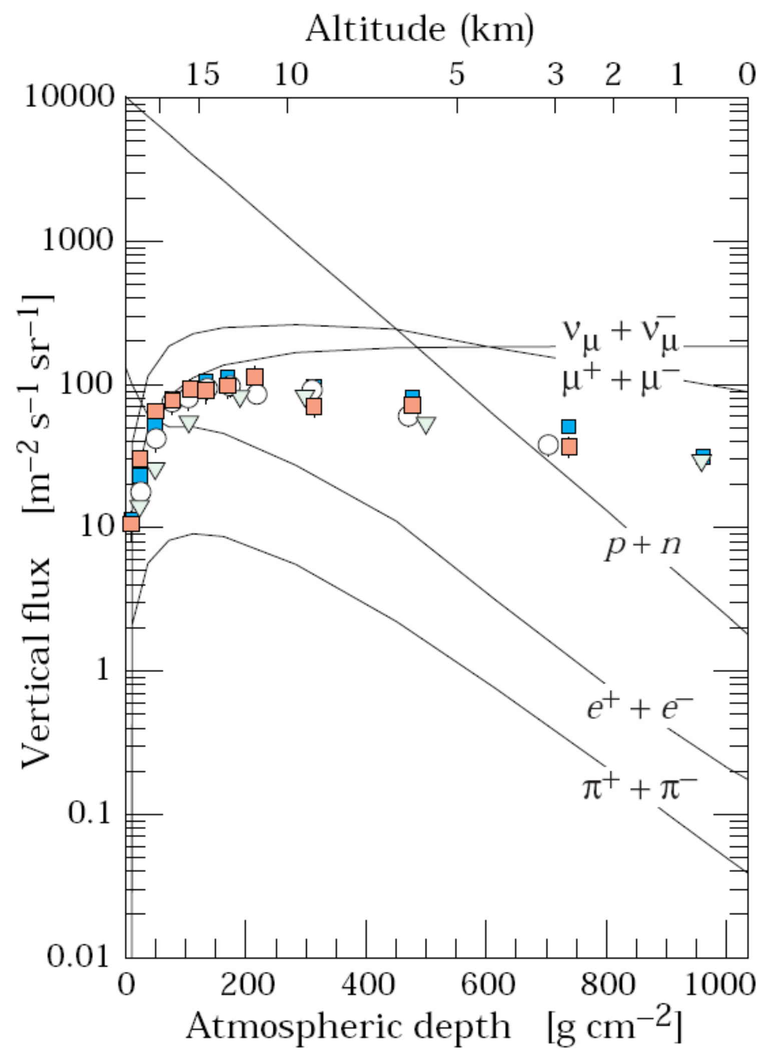


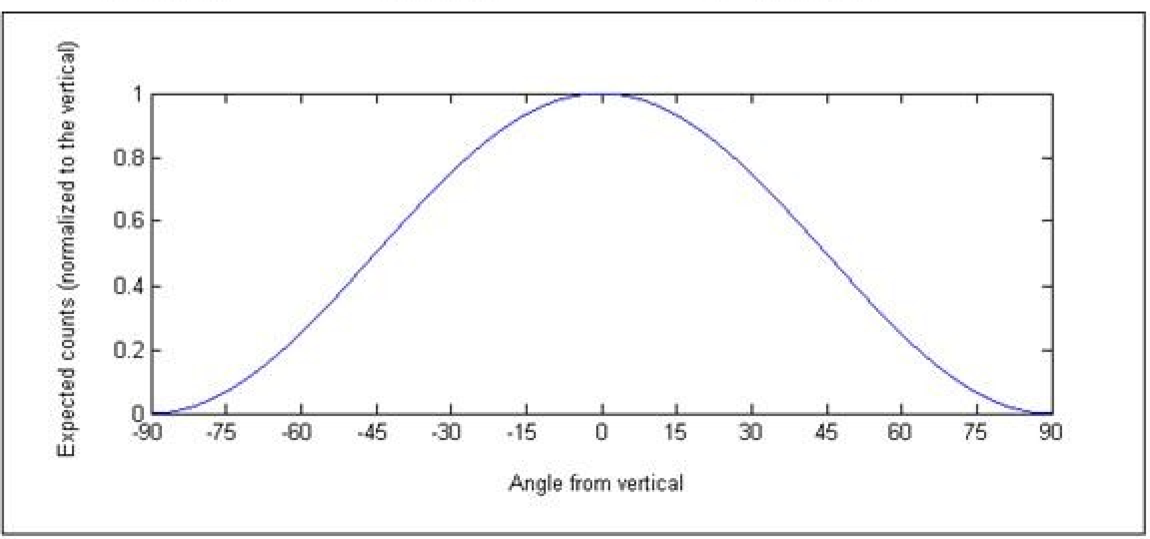
Pierre Auger experiment, 2007

Secondary CR

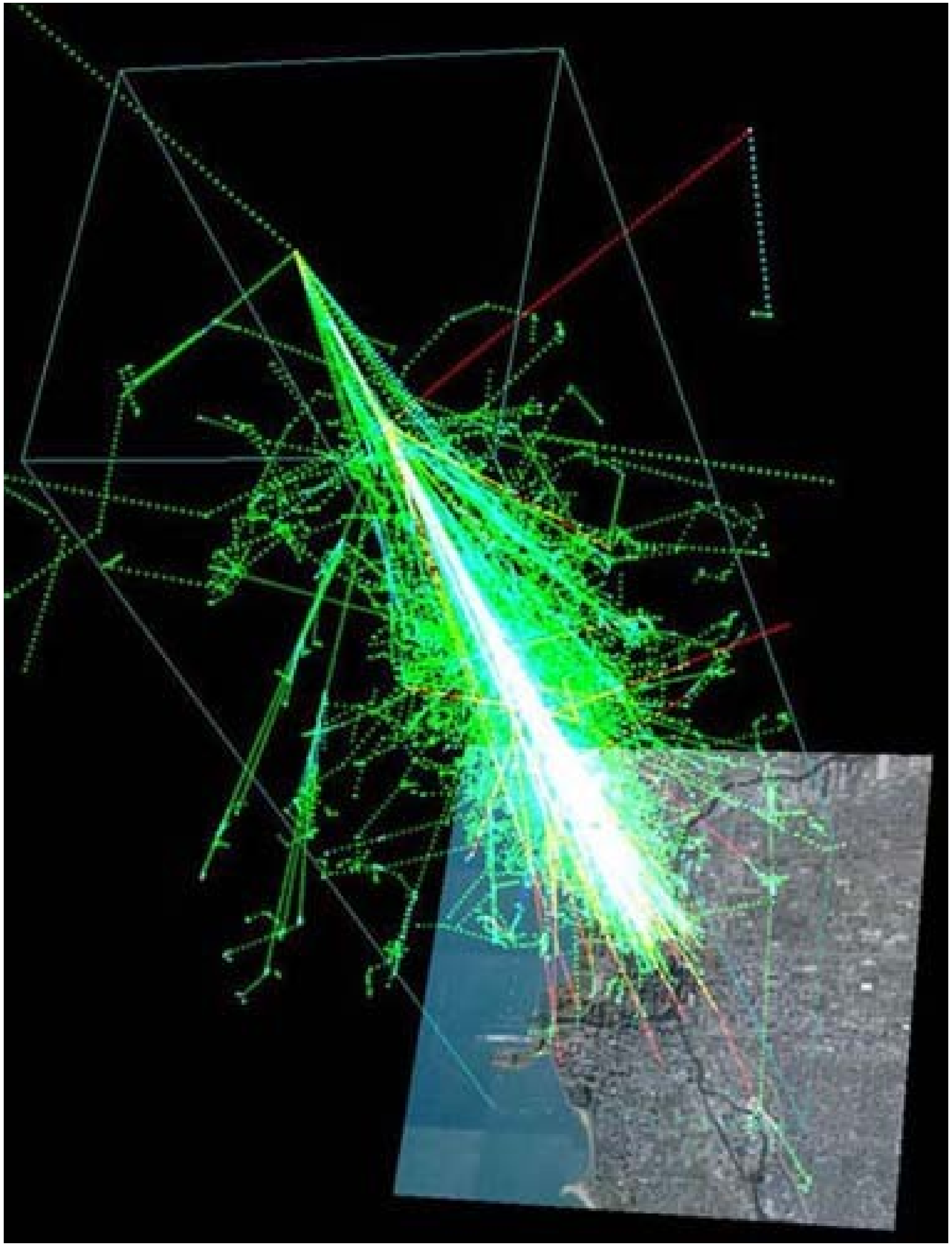
Atmospheric cascade





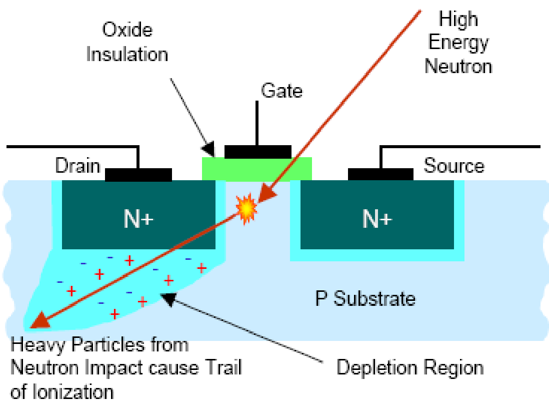


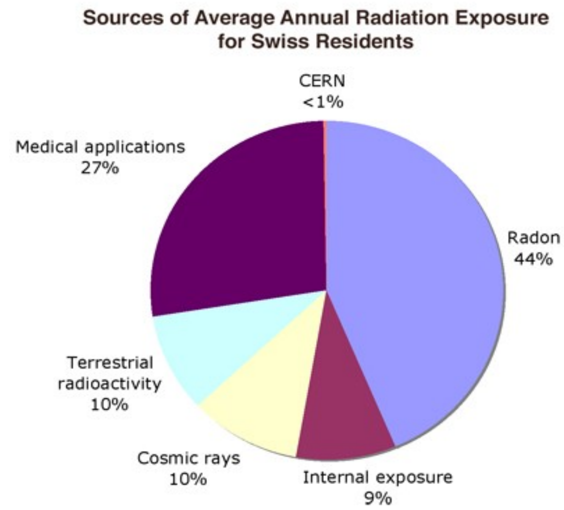
stredenie



CR on the ground

- Background radiation
- Effects on electronics (soft, hard)
- Space travel



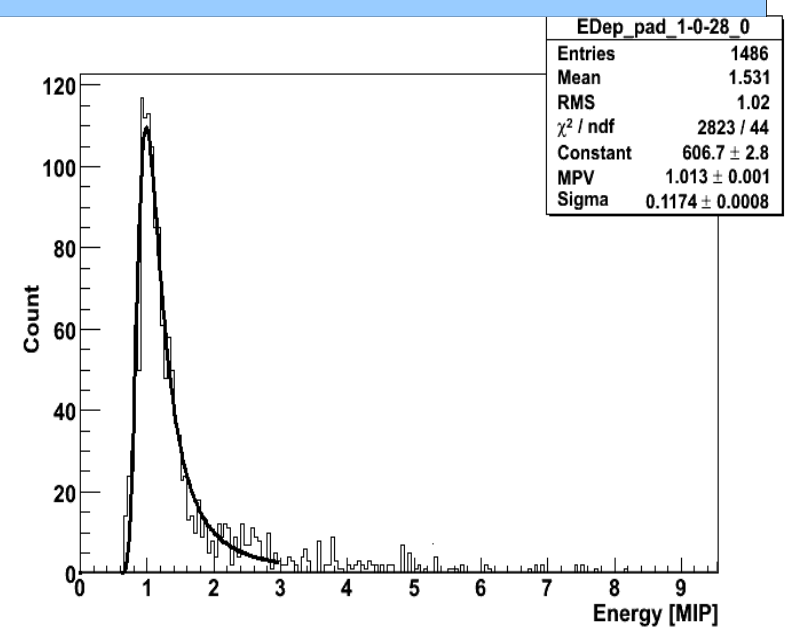


Radiation Exposure Limits for Astronauts and the General Public (in Sv)				
Type of person	Time period	Organs (Sv)	Eye (Sv)	Skin (Sv)
Astronauts	30-day	0.25	1.0	1.5
	Annual	0.5	2.0	3.0
	Career	1.0-4.0	4.0	6.0
Occupational Exposure	Annual	0.05	0.15	0.5
General Public	Annual	0.001	0.015	0.05

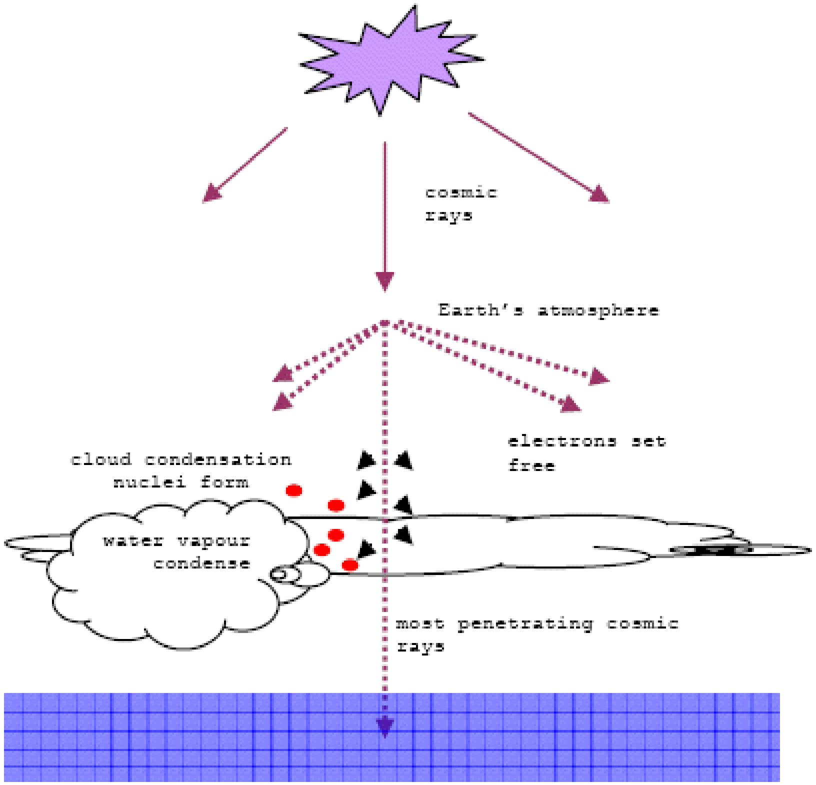
British Airways

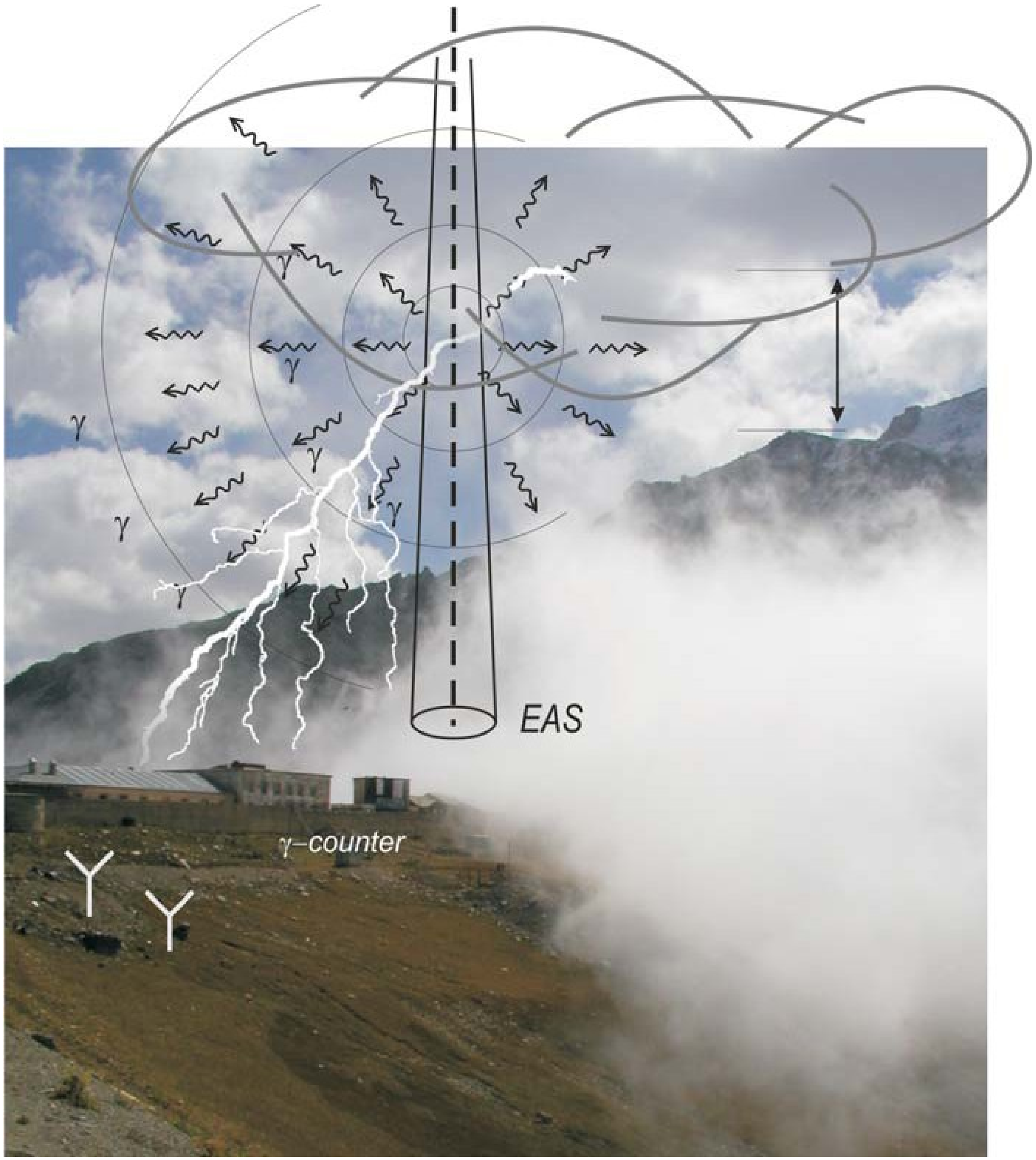
Concorde, 12-15 μSv (microsieverts) per hour;
Long haul aircraft, 5 μSv (microsieverts) per hour;
Short haul aircraft, 1-3 μSv (microsieverts) per hour dependent on the altitude reached.

```
volatile int x = 0;
volatile int y = 0;
while (1) if (x != y) {
    printf("Cosmic ray detected\n");
    y = x;
}
```



- Lightning
- Climate change?





EOF