

# Gli acceleratori di particelle

Come e perché acceleriamo le particelle

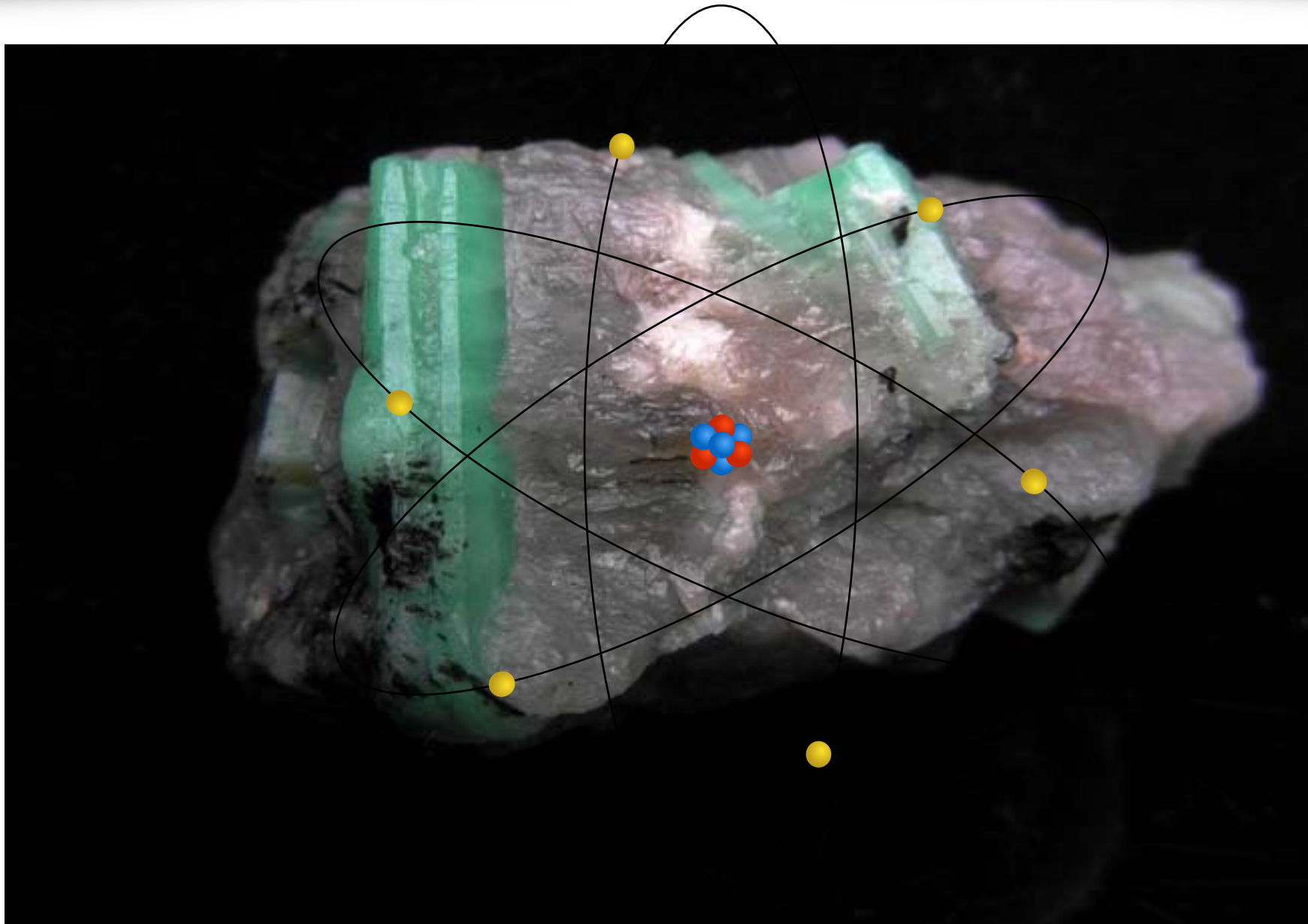
Andrea Messina — Sapienza Università di Roma

23 Febbraio 2016

# le domande fondamentali

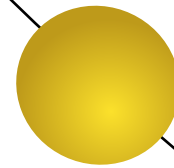
- 1. quali sono i componenti della materia**
- 2. quali sono le forze che determinano le loro interazioni**

# La materia ed i suoi costituenti



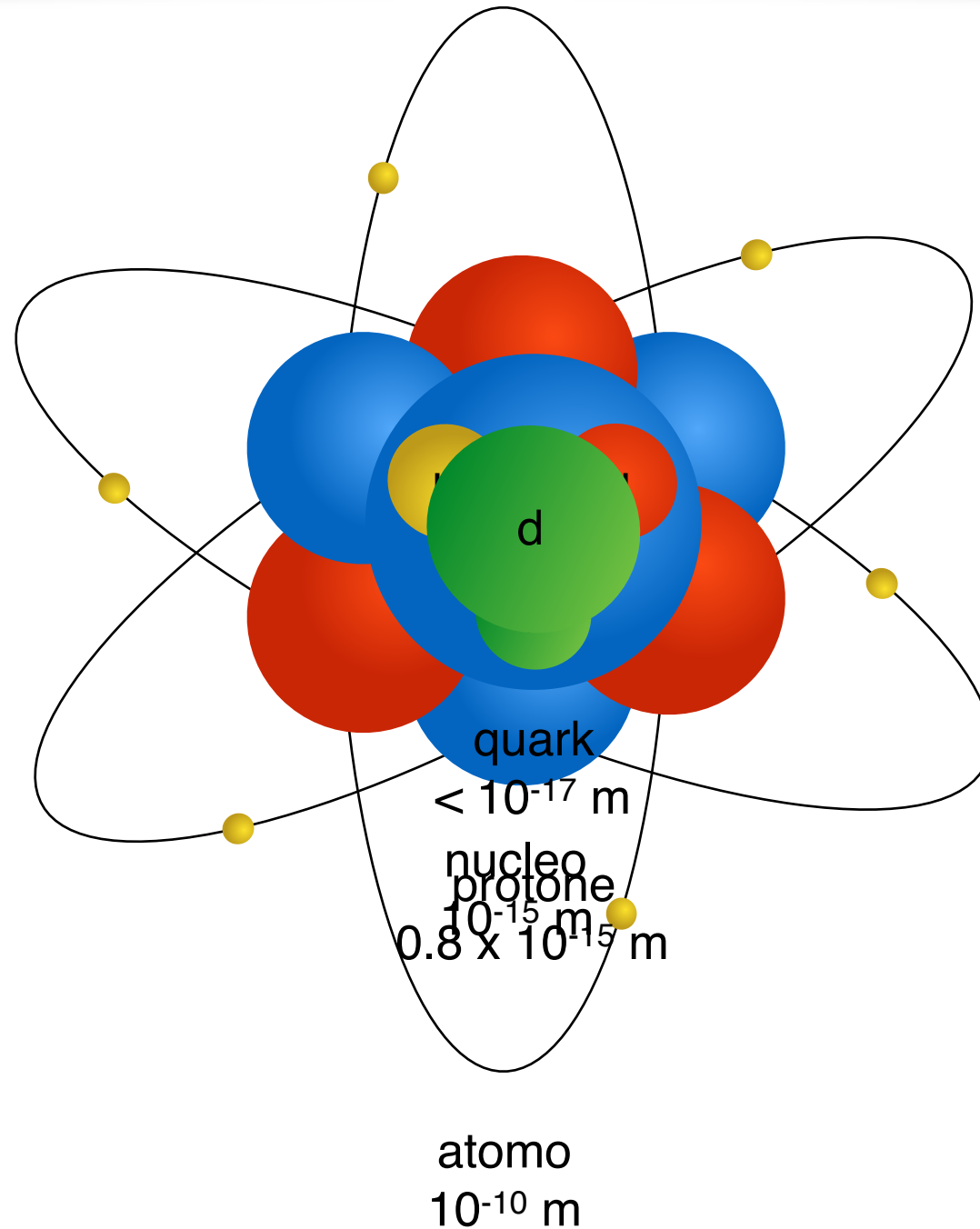
atomo  
 $10^{-10}$  m

# La materia ed i suoi costituenti

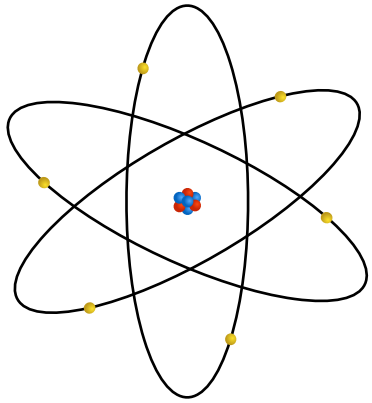


elettrone  
 $3 \times 10^{-15} \text{ m}$

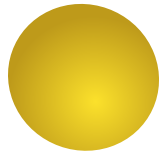
# La materia ed i suoi costituenti



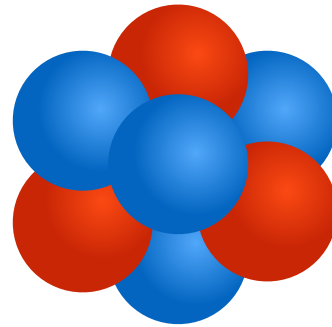
# La materia ed i suoi costituenti



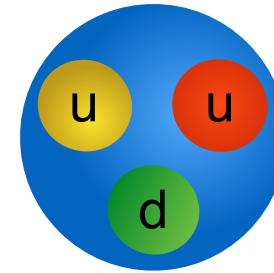
atomo  
 $10^{-10}$  m



elettrone  
 $3 \times 10^{-15}$  m



nucleo  
 $10^{-15}$  m



protone  
 $0.8 \times 10^{-15}$  m



quark  
 $< 10^{-17}$  m

# cos'è una particella elementare

Una particella che non ha, o di cui non conosciamo, la struttura, la chiamiamo elementare.

possiede delle  
caratterizzano



seche che la

vita media  
massa

# le particelle elementari



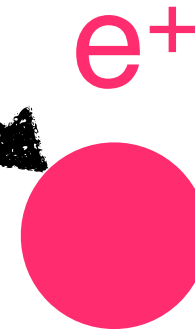
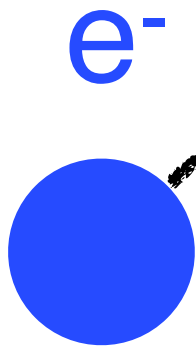
**materia di cui siamo costituiti**



# materia e anti-materia

materia

anti-materia



$$q=-1$$

$$s=1/2$$

$$m=10^{-30}\text{kg}$$

$$q=+1$$

$$s=1/2$$

$$m=10^{-30}\text{kg}$$

# Anti-materia



15 anti-elettroni  
al secondo



4000 anti-elettroni  
al secondo

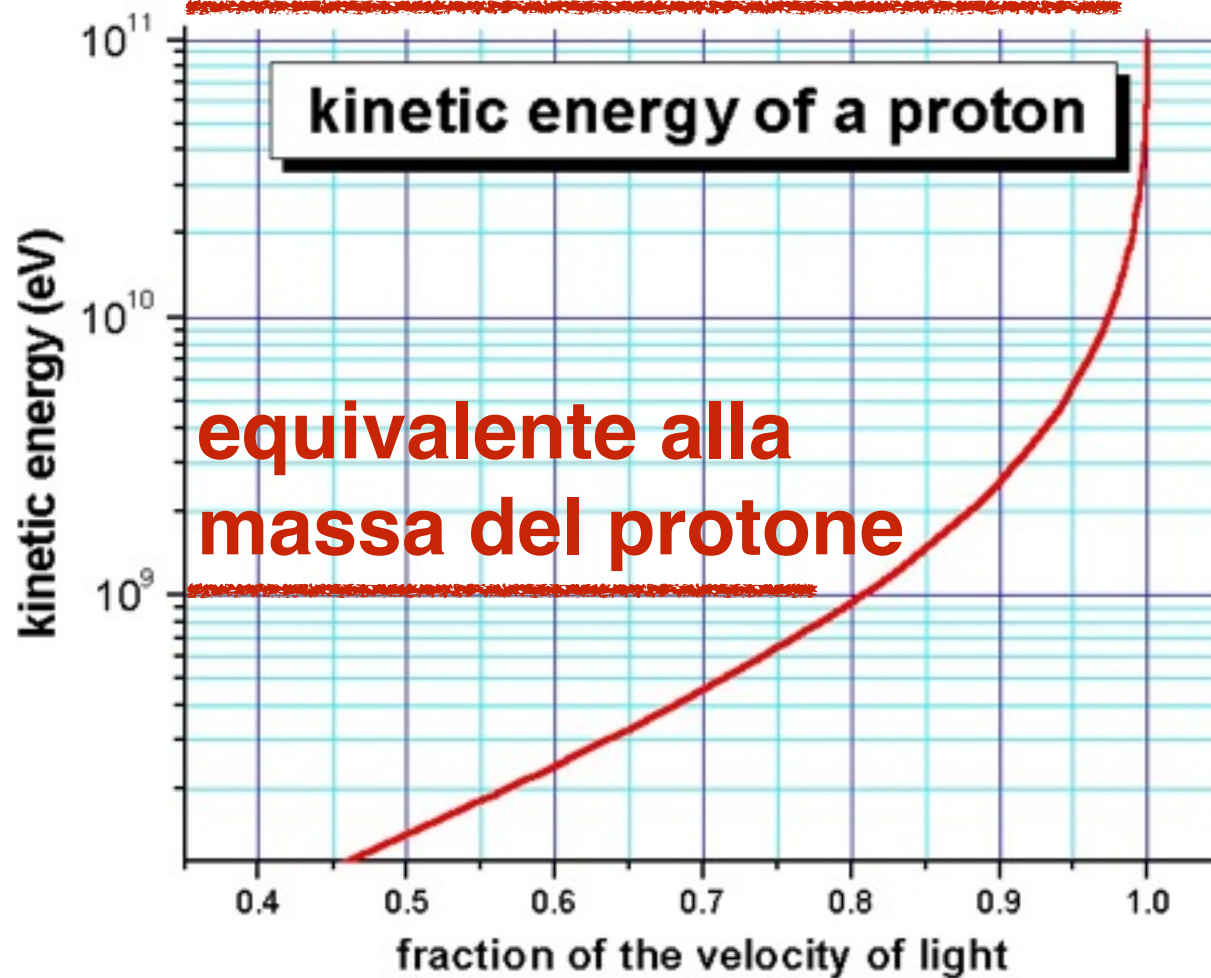
# annichilazione materia anti-materia





# energia e velocità

**equivalente alla massa  
di 100 protoni**

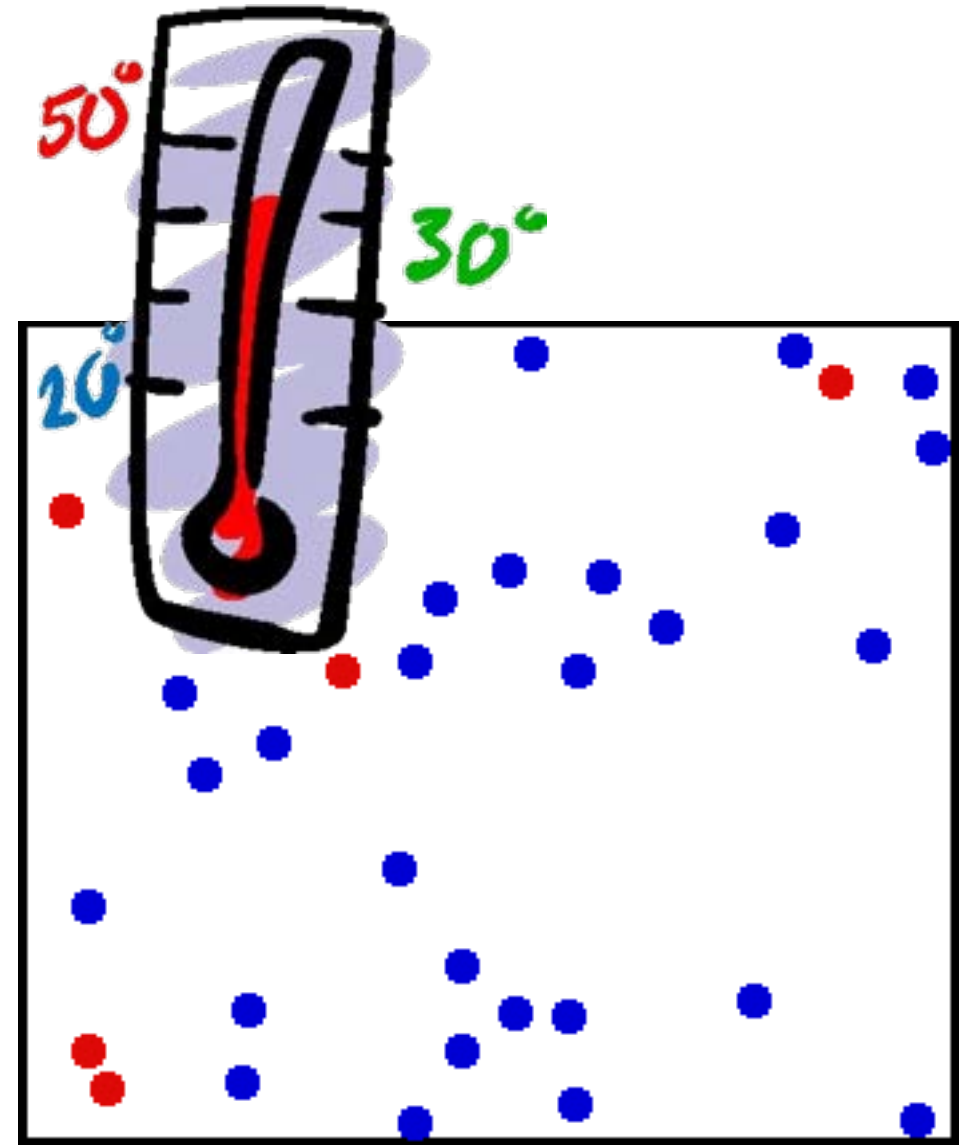


# temperatura e energia cinetica

la velocità di una molecola di idrogeno a 300 °K è di 2.5 km/s  $\ll$  300'000 km/s

25 °C  $\sim$  25 meV

2 centesimi di miliardesimo della massa del protone



e nel nucleo del sole?

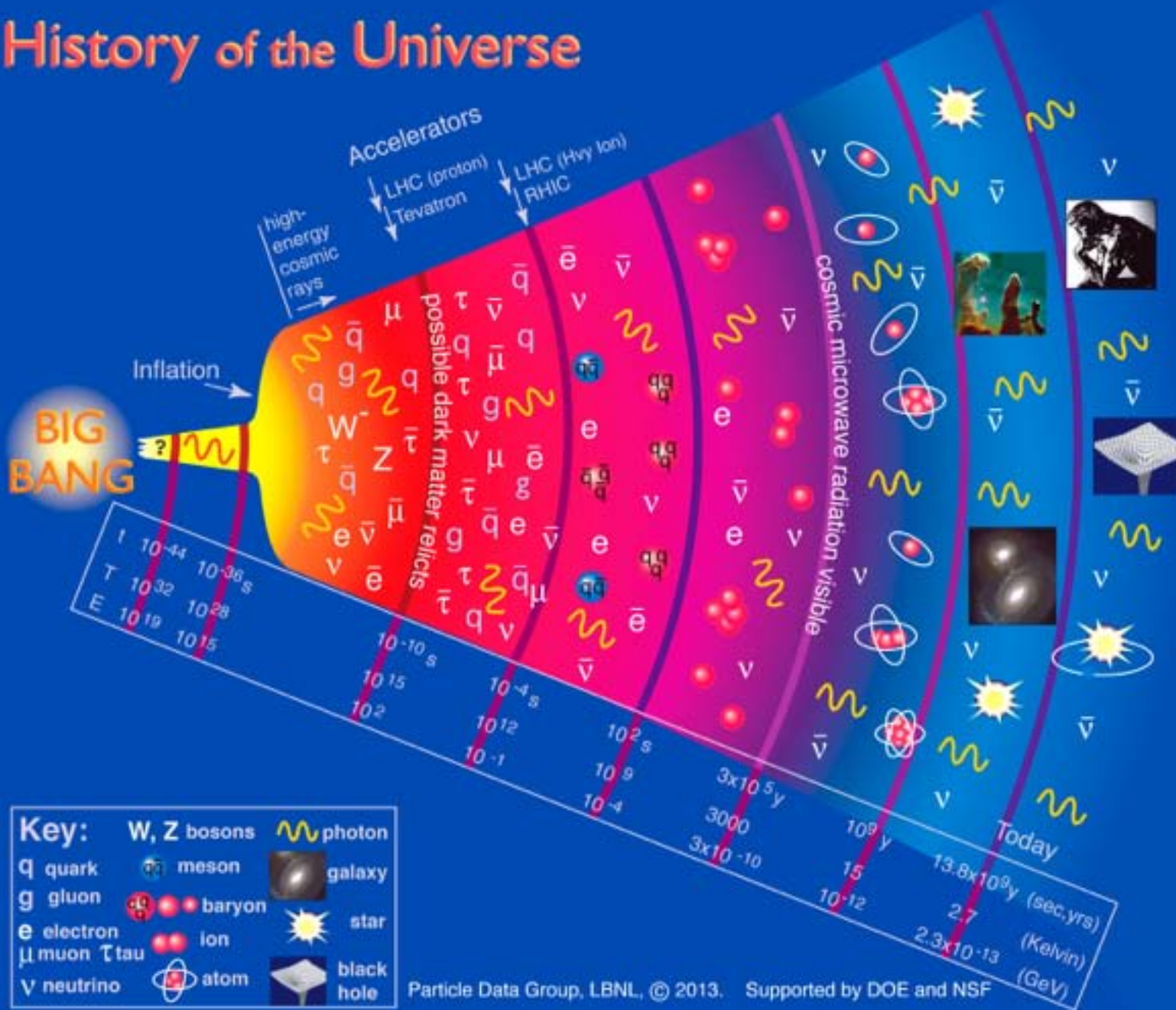
$T = 15'000'000 \text{ } ^\circ\text{K}$

$v = 560 \text{ km/s}$

**energia di un  
milionesimo  
della massa del protone**

# storia dell'universo

## History of the Universe



Particle Data Group, LBNL, © 2013. Supported by DOE and NSF



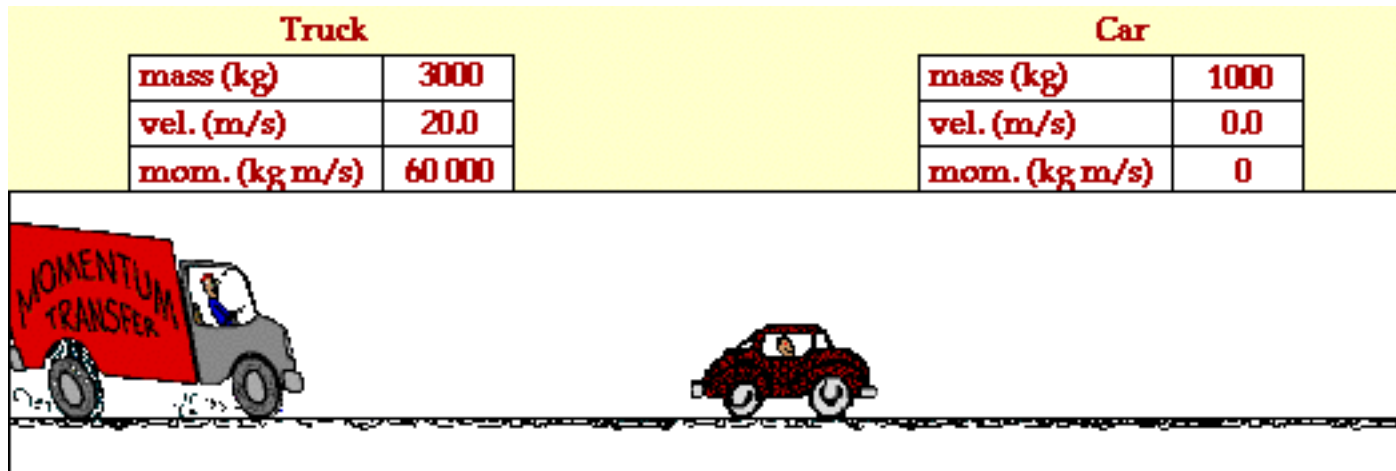
# Gli urti come strumento di indagine



# Gli urti come strumento di indagine

si conserva

l'energia e la quantità di moto

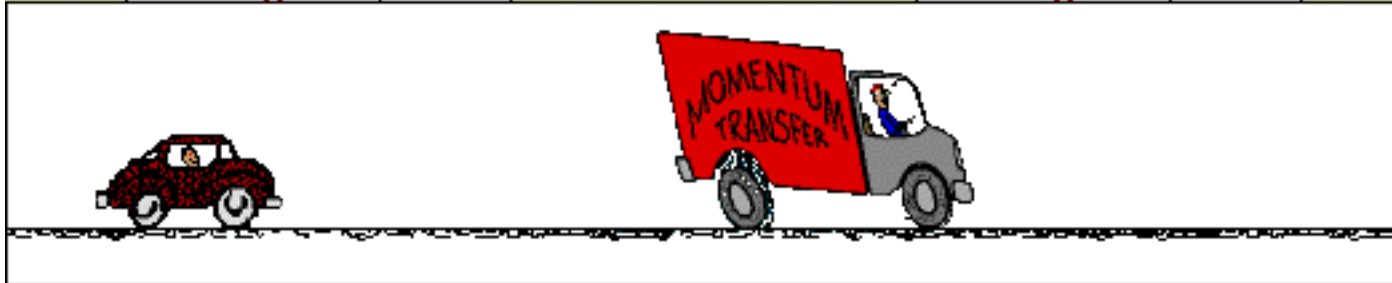


# Gli urti come strumento di indagine

si conserva

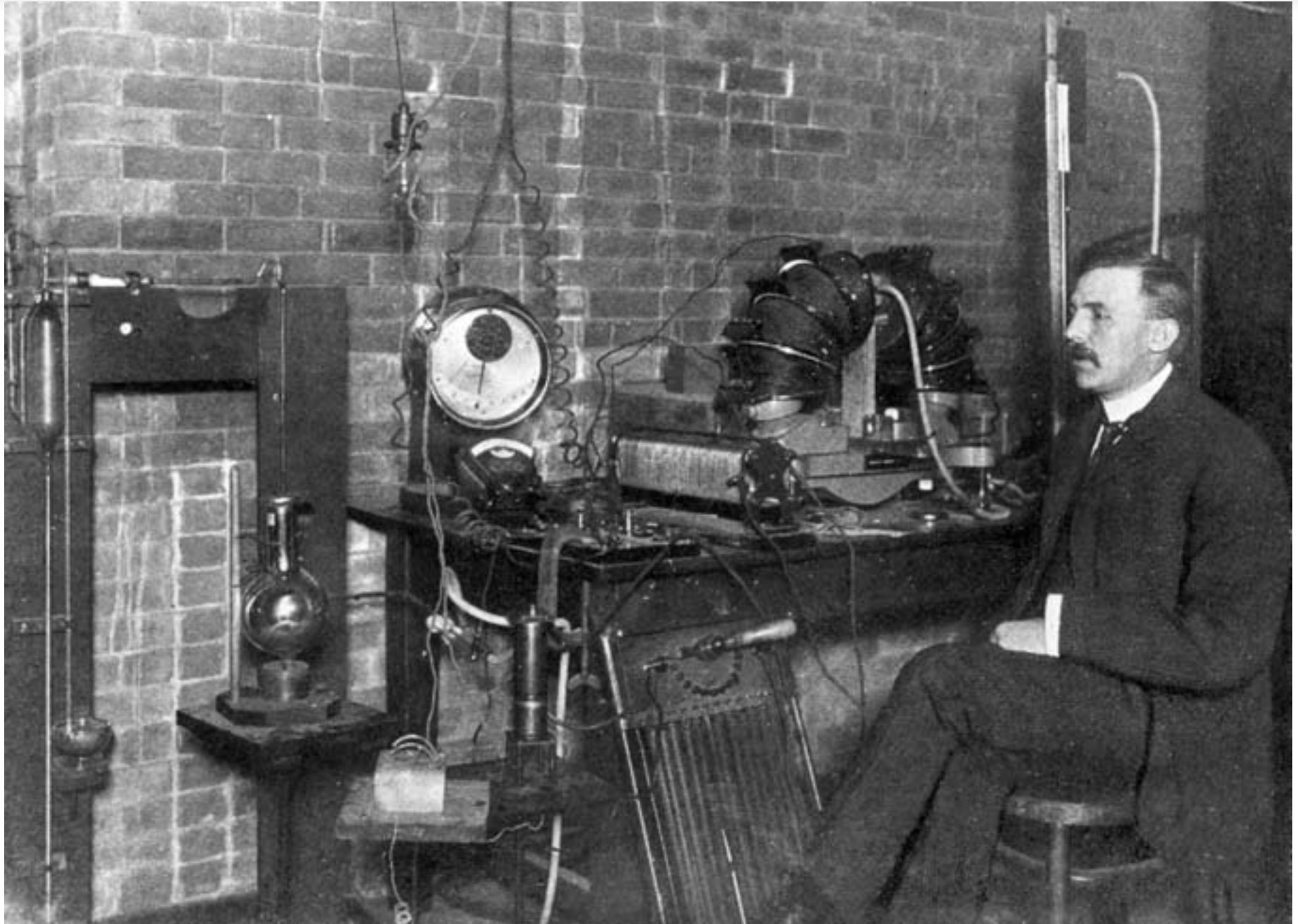
l'energia e la quantità di moto

Car		Truck	
mass (kg)	1000	mass (kg)	3000
vel. (m/s)	20.0	vel. (m/s)	0.0
mom. (kg m/s)	20 000	mom. (kg m/s)	0

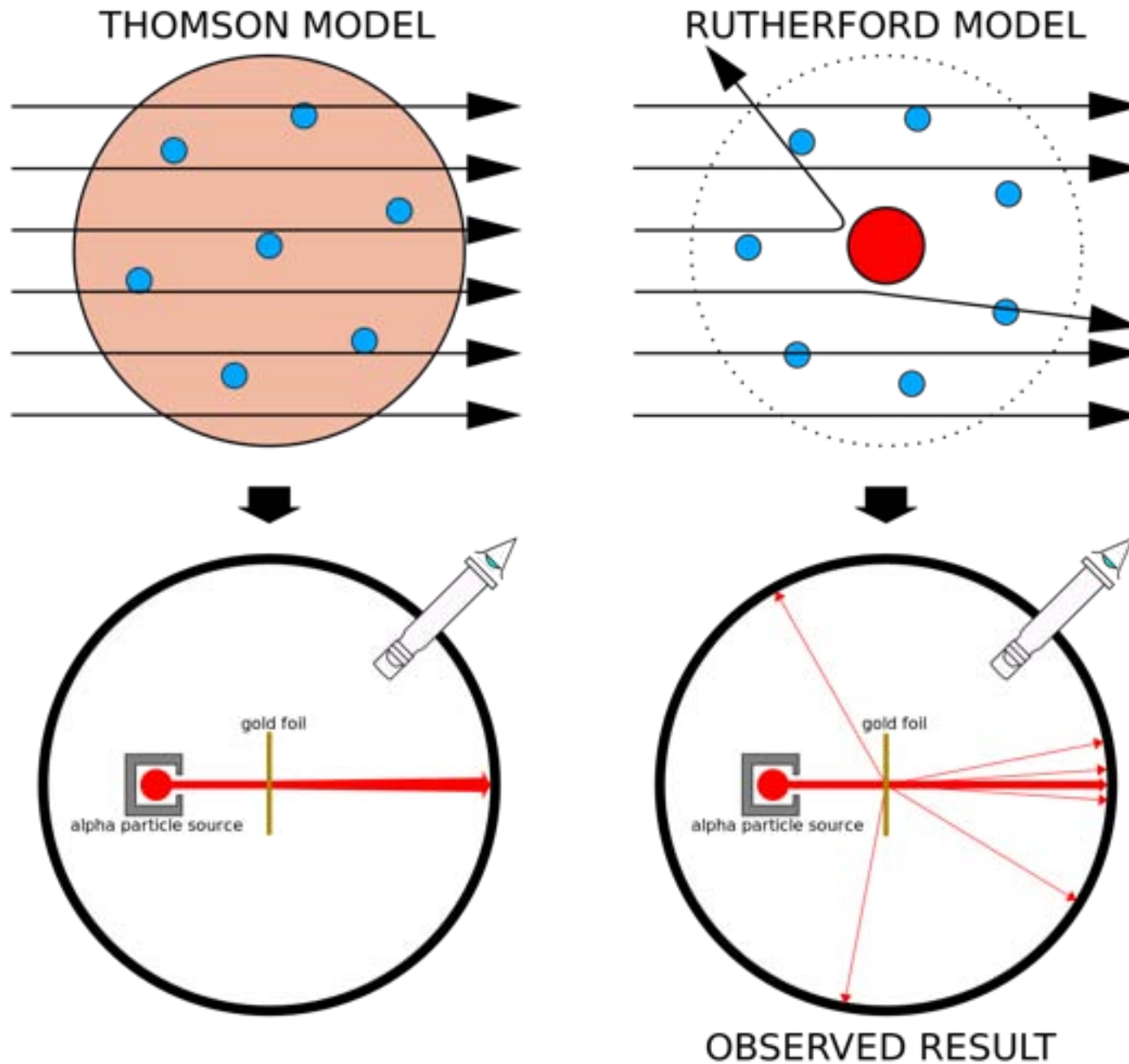


The diagram shows a car and a truck on a road. The car is on the left, and the truck is on the right. A red sign on the truck says "MOMENTUM TRANSFER".

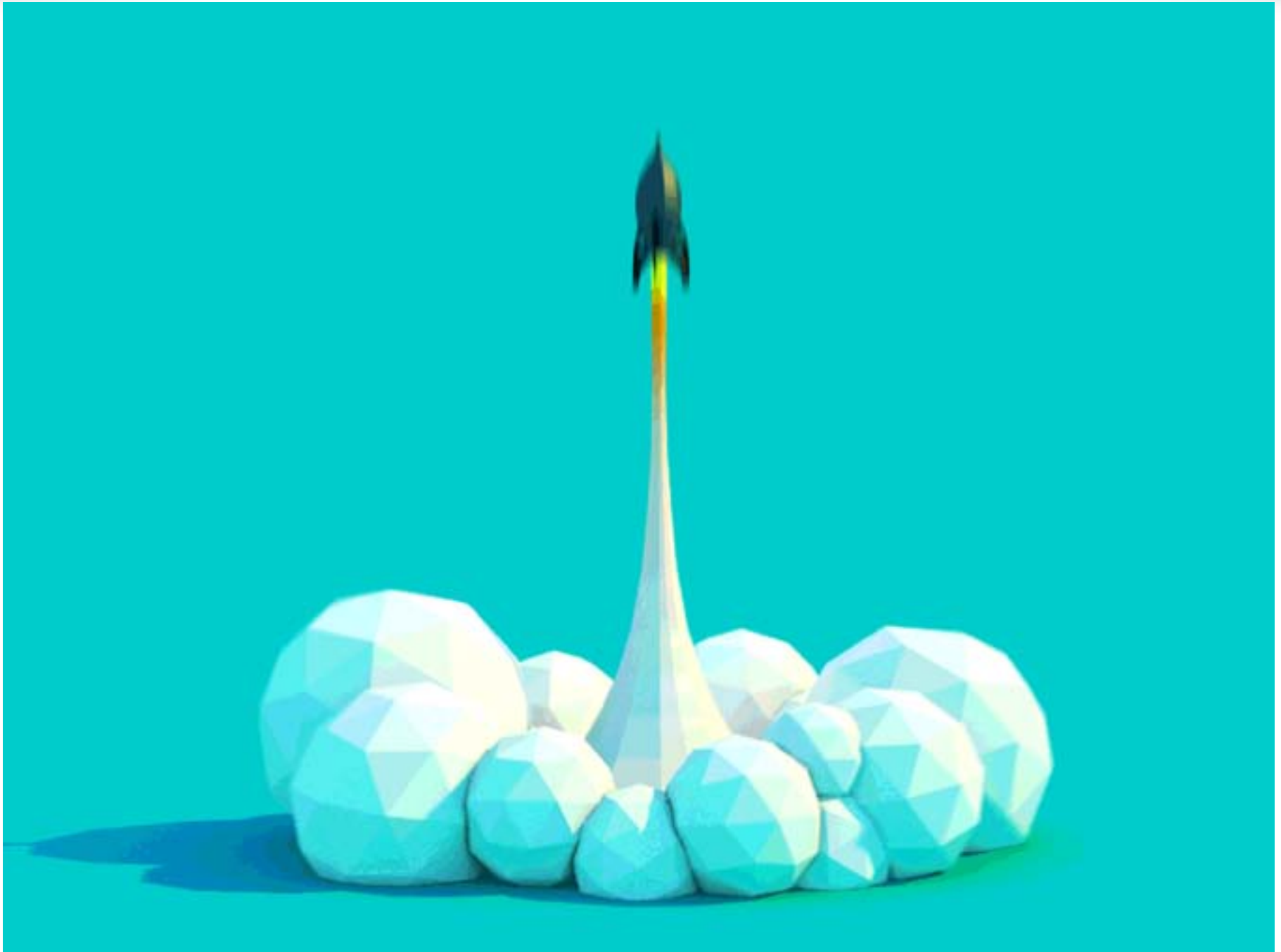
# esperimento di Rutherford



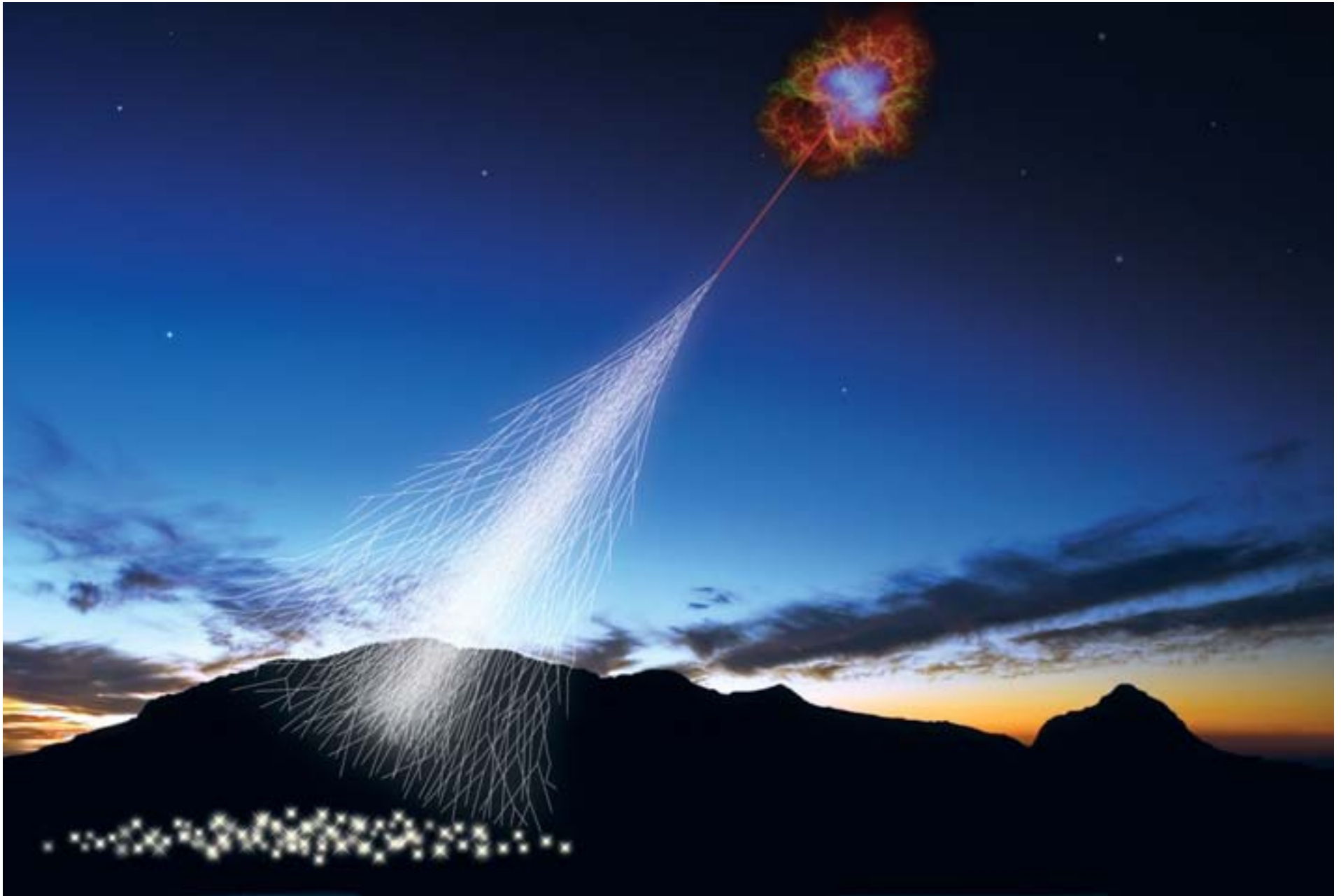
# esperimento di Rutherford



# come acceleriamo le particelle?



# universo, esplosioni stellari e raggi cosmici

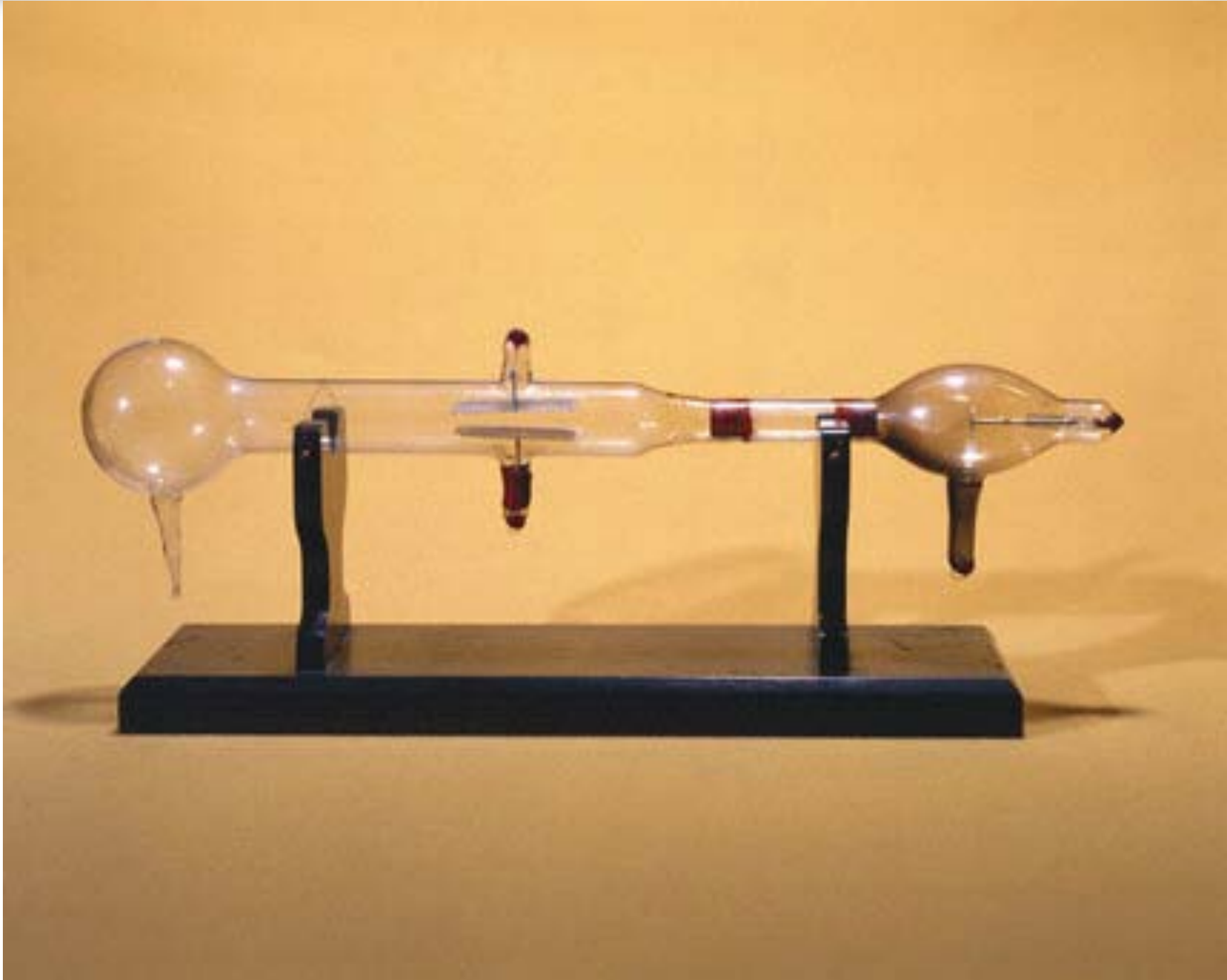


# innanzitutto delle particelle cariche

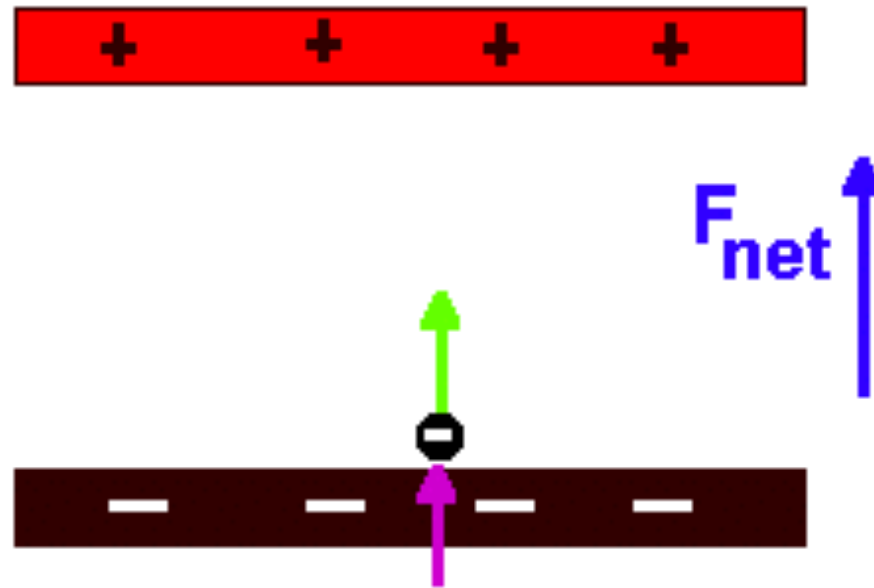




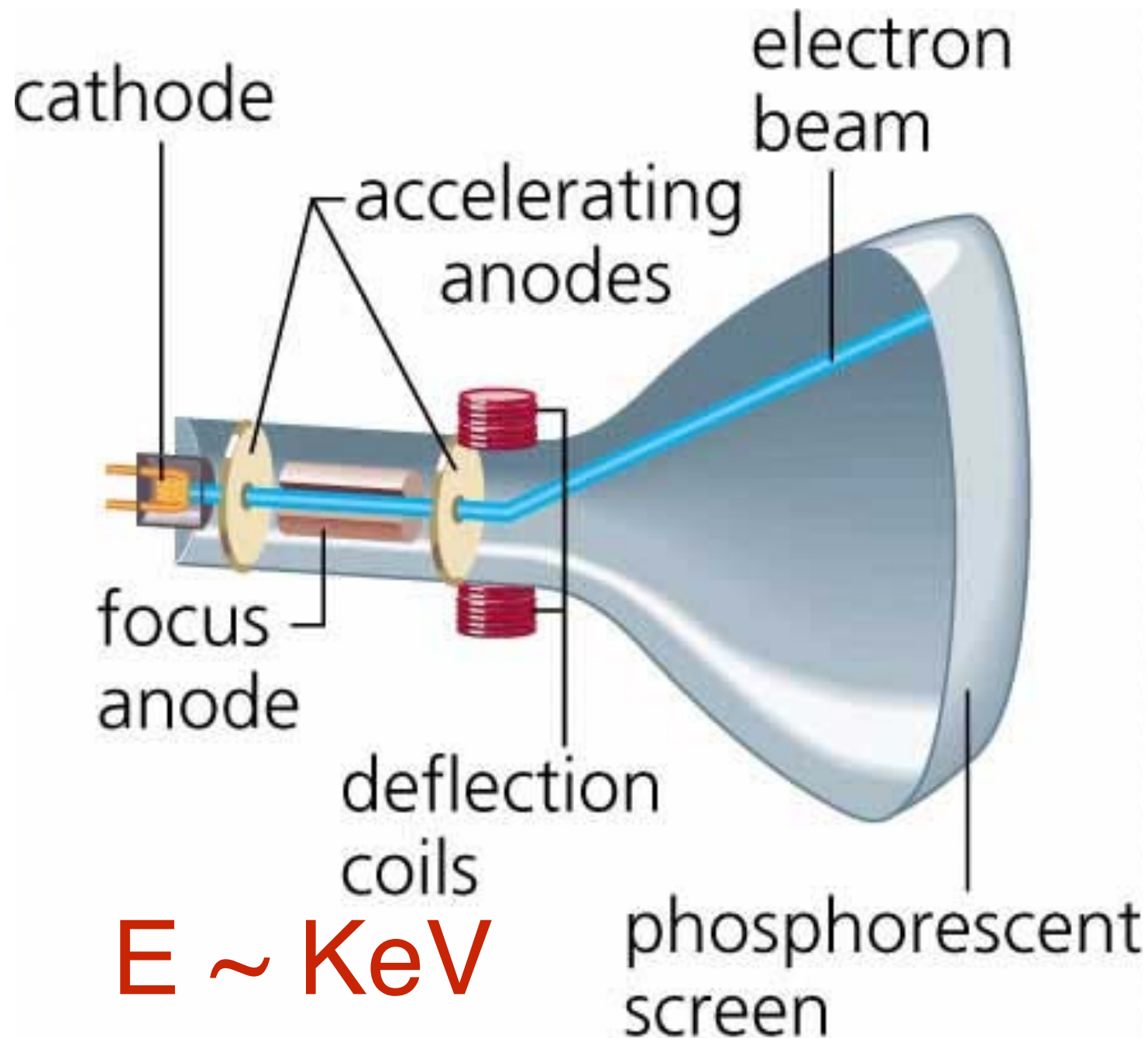
poi prendiamo un tubo a “vuoto”



quindi applichiamo un campo elettrico



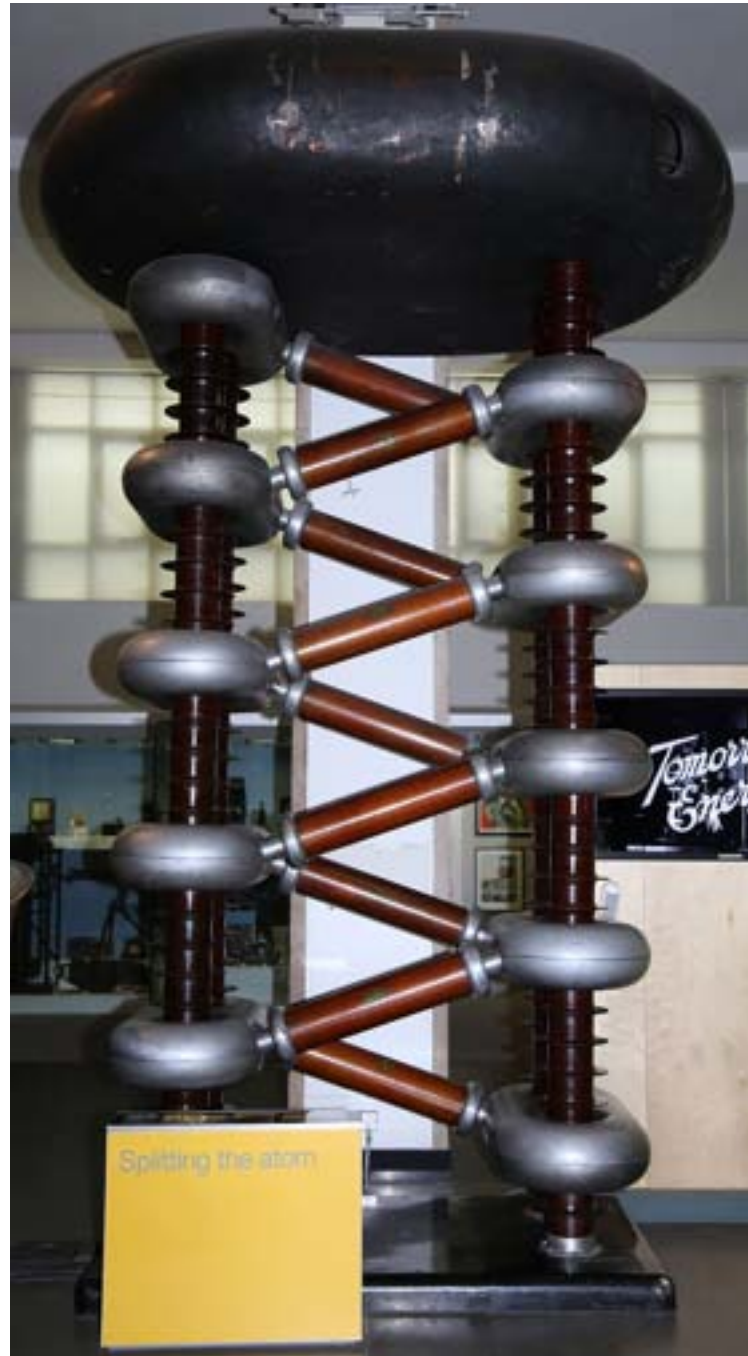
# l'acceleratore in ogni casa



# per aumentare l'energia

Cockcroft-Walton

$E \sim \text{MeV}$



# aumentiamo l'energia: linac

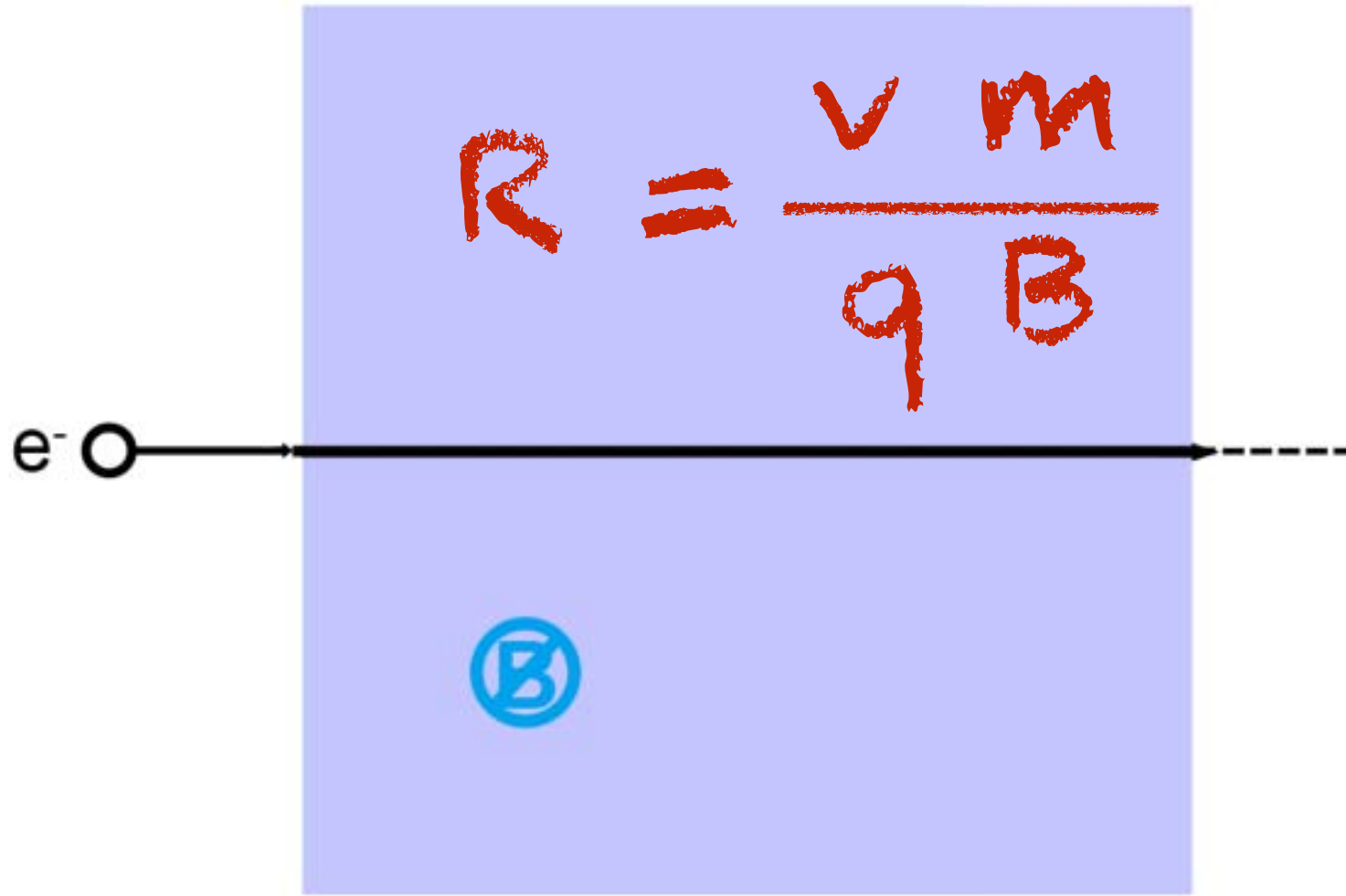


$E \sim 100 \text{ MeV}$

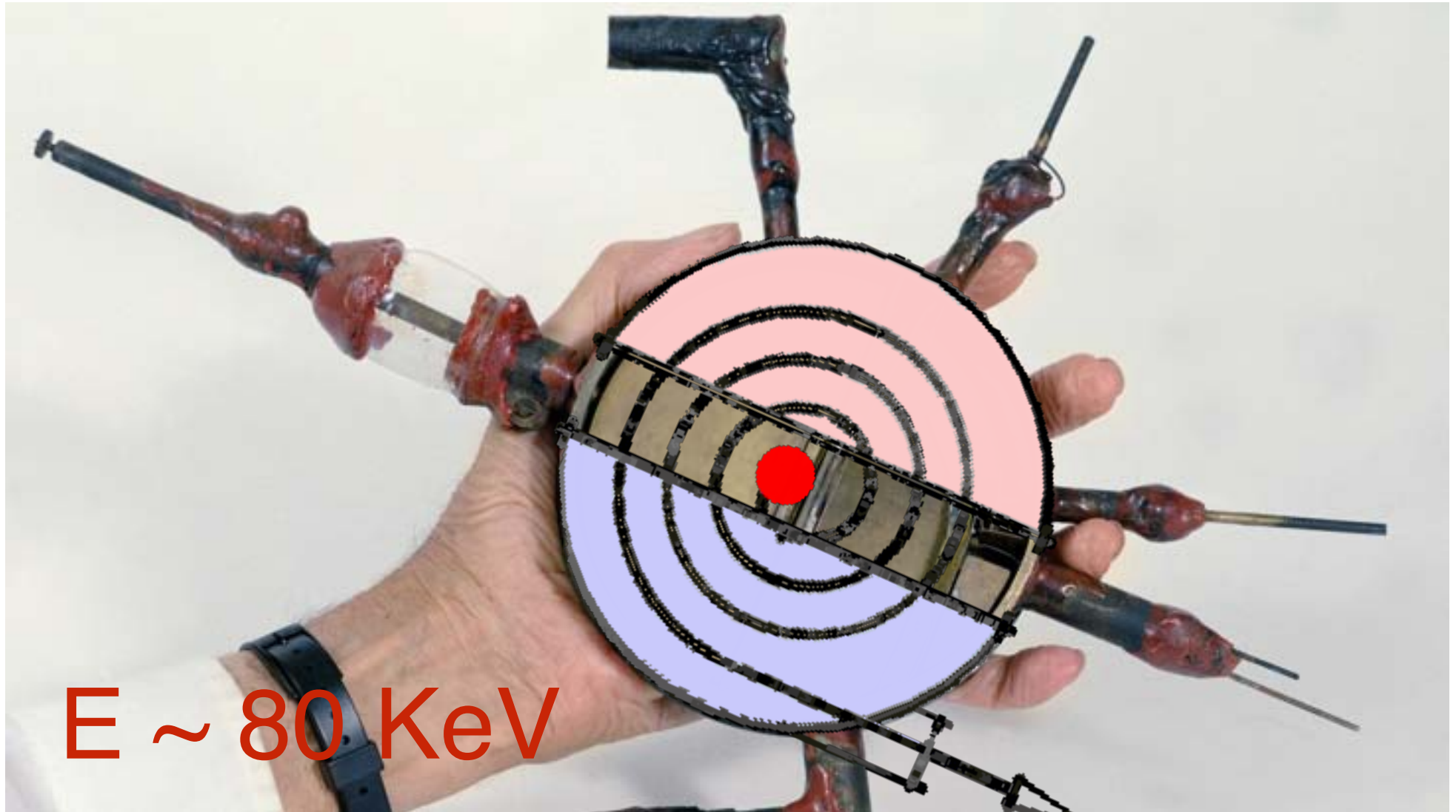
# riduciamo gli sprechi: acceleratori circolari



# la forza di Lorentz



# il ciclotrone



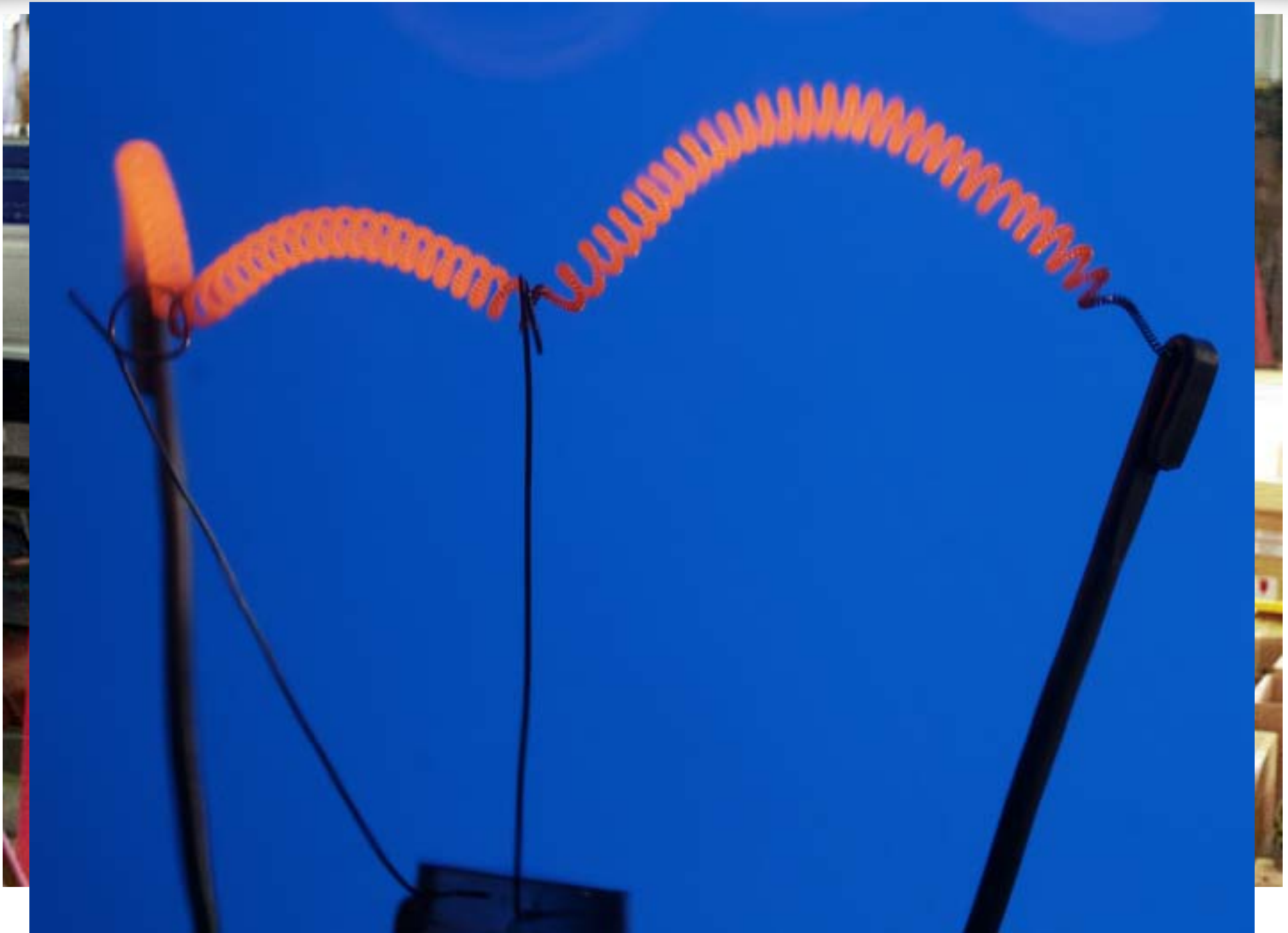
$E \sim 80 \text{ KeV}$



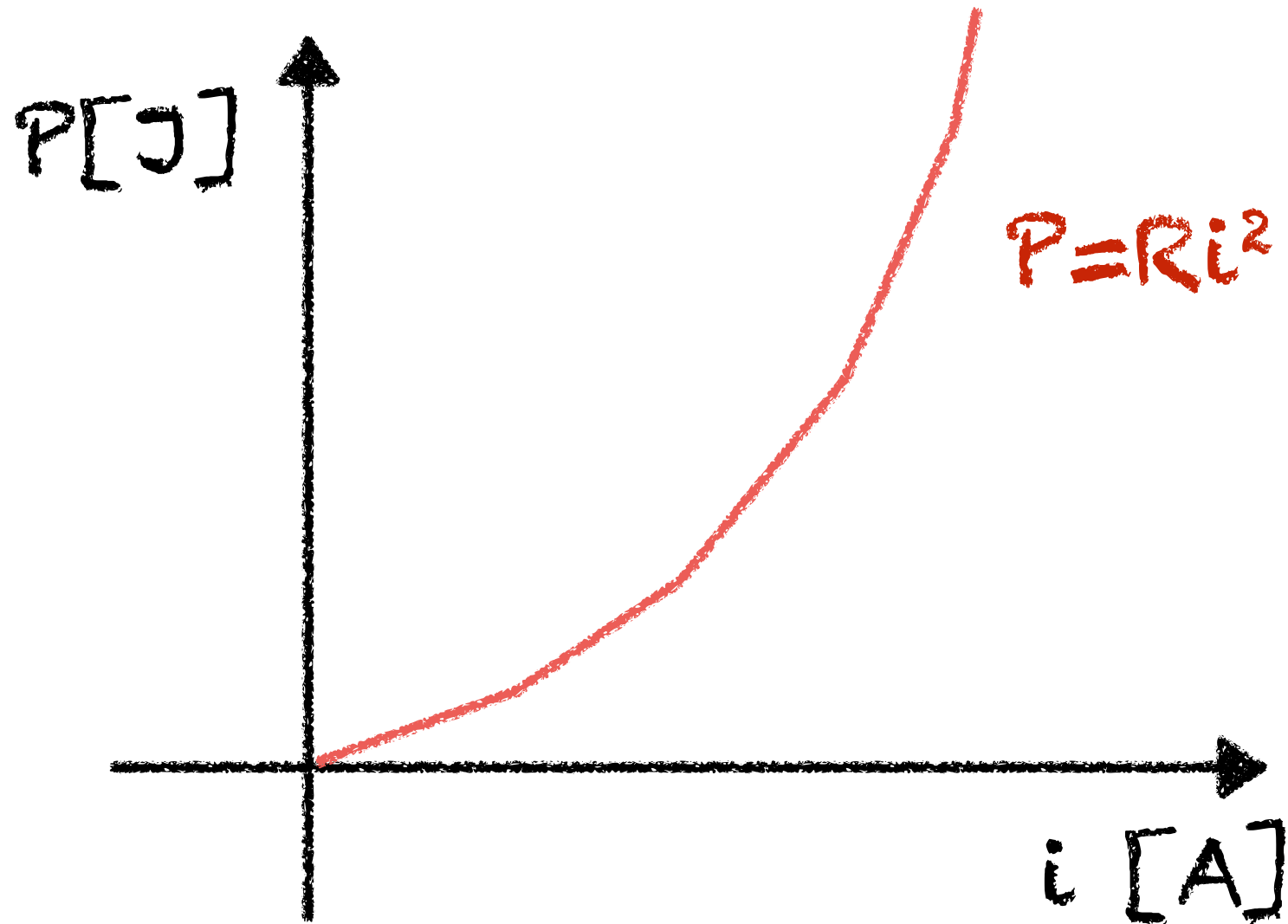
# i magneti



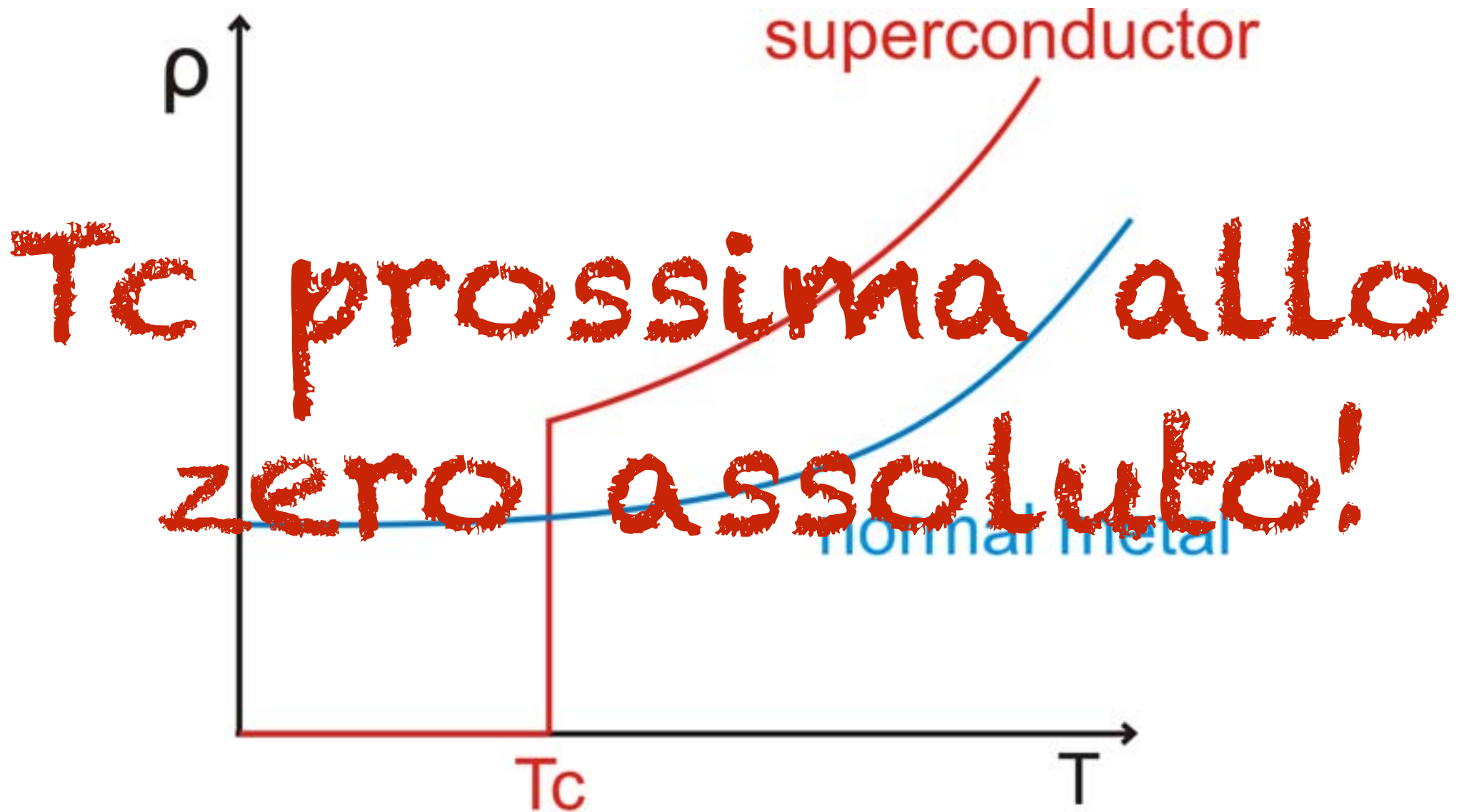
# dipolo



# la legge di Joule



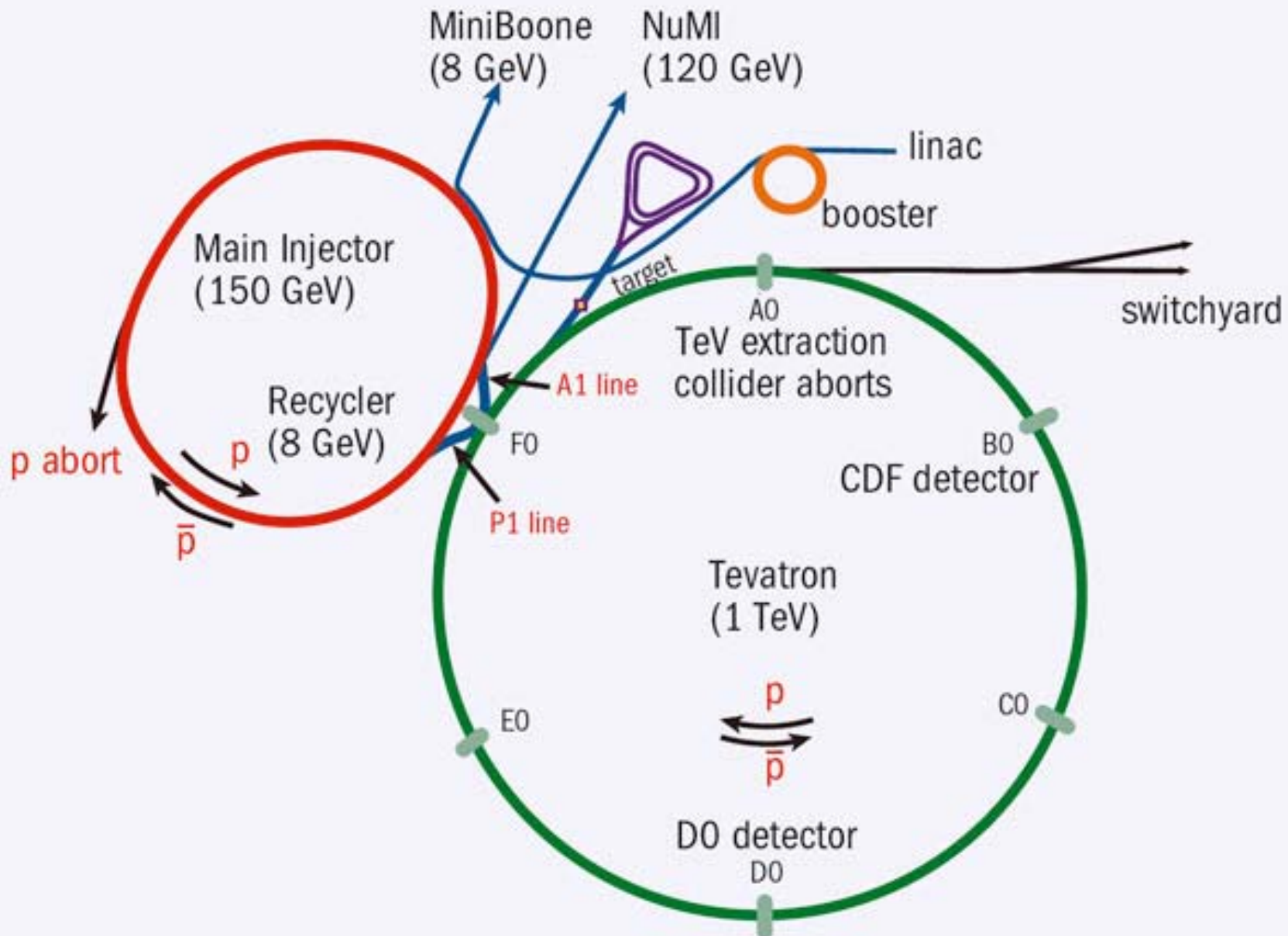
# i magneti superconduttori



# dipolo superconduttore



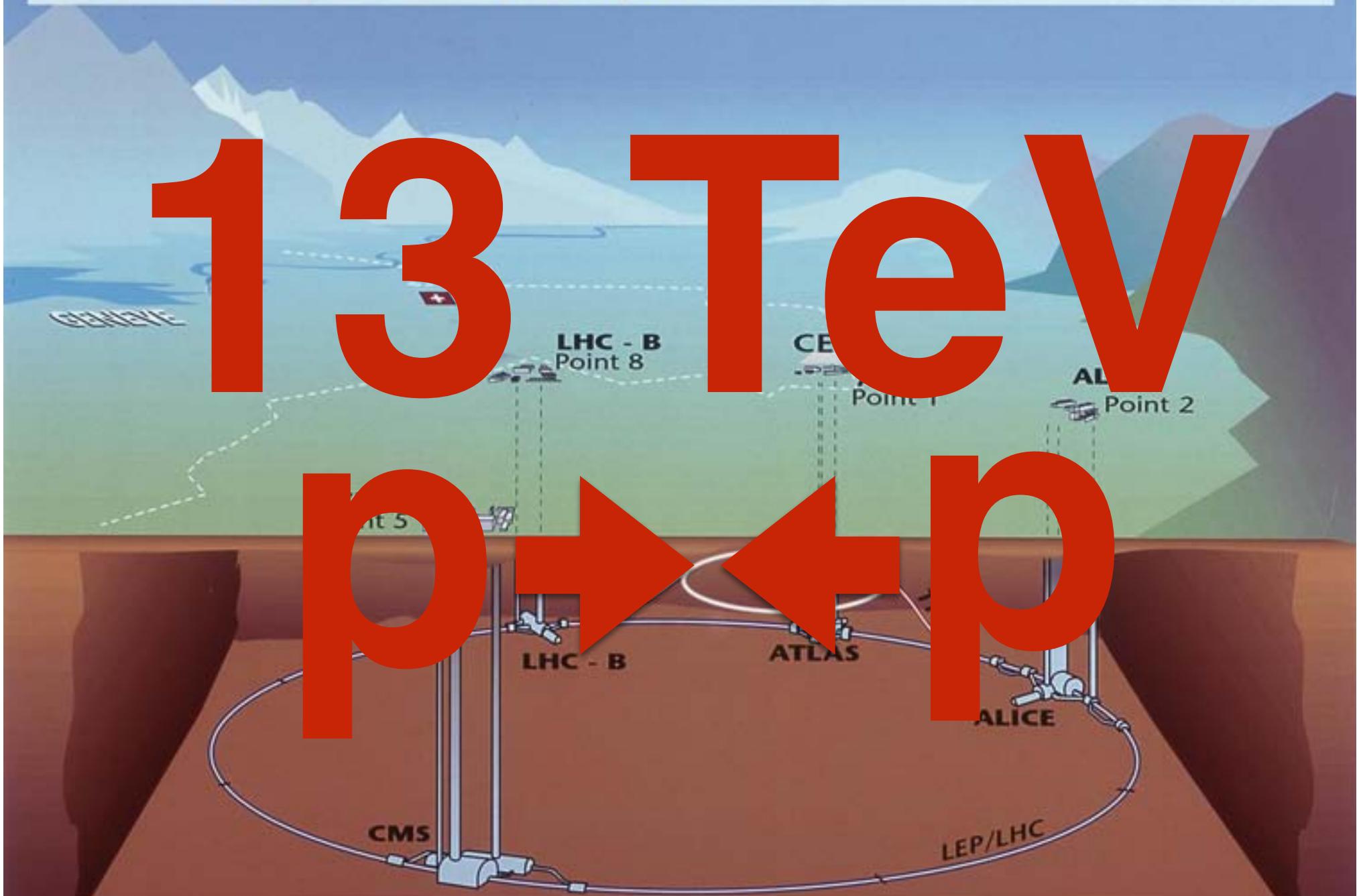
# gli acceleratori moderni



# LHC

Overall view of the LHC experiments.

13 TeV  
p → ← p



l'energia più elevata mai raggiunta

# 13 TeV

13'000'000'000'000 eV = 0.000002 Joule





# l'energia del fascio di protoni di LHC

362 MJ

An aerial photograph of the aircraft carrier USS George Washington (CVN-75) sailing on the open ocean. The ship's deck is visible with several aircraft parked. The number '75' is clearly visible on the superstructure. Overlaid on the image in large, bold, red font is the text '362 MJ', which represents the energy of the proton beam at the LHC.

magneti



# l'anello



**27 Km**

**1232 dipoli**

**12000 A**

il posto più freddo dell'universo



# Collisioni

 **ATLAS**  
EXPERIMENT  
<http://atlas.ch>

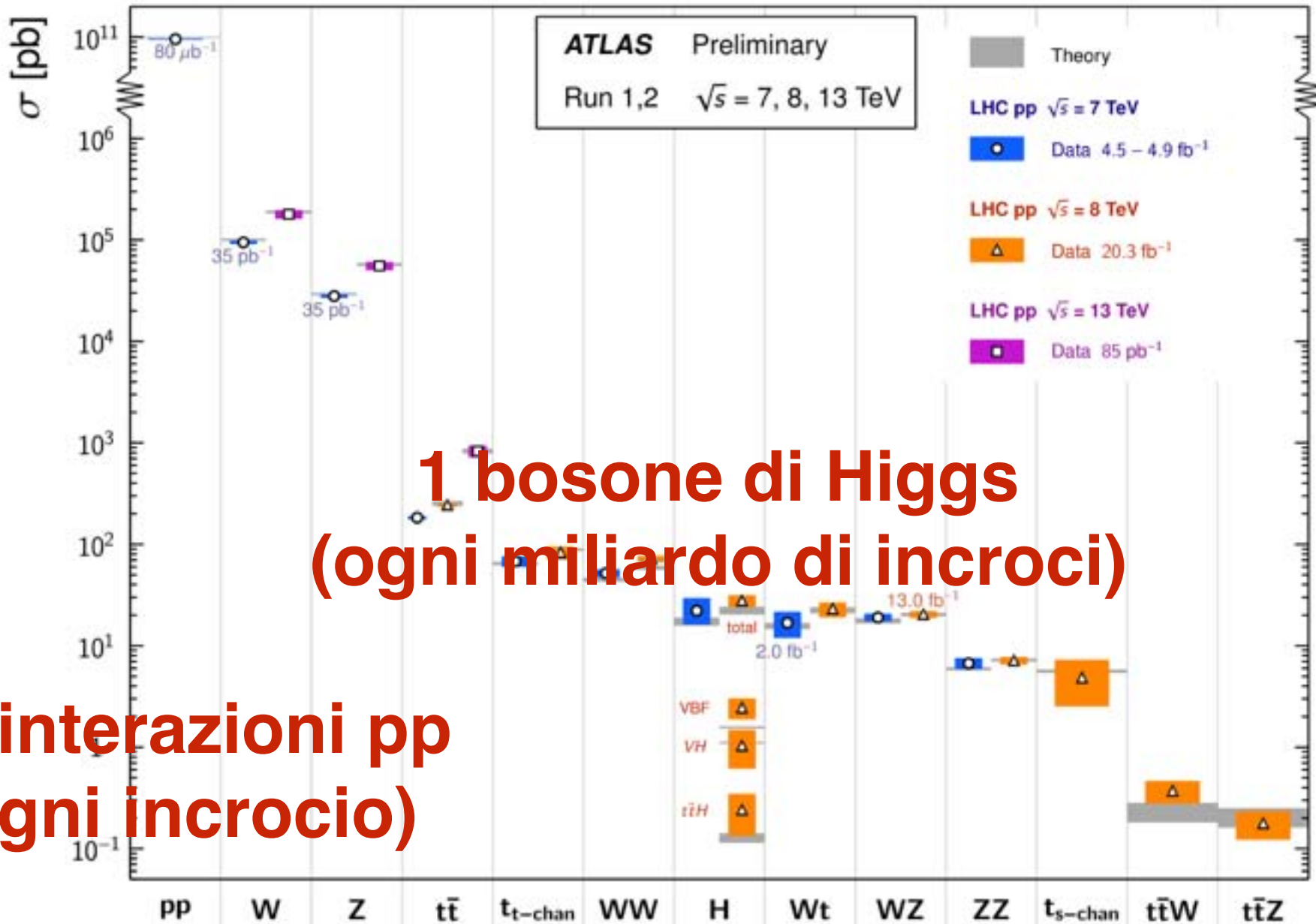
Run: 280464  
Event: 478442529  
2015-09-27 22:09:07 CEST

**40 milioni di incroci al secondo**  
**25 collisioni ad incrocio**



# Collisioni

Standard Model Total Production Cross Section Measurements Status: Nov 2015



# la sala di controllo



# LHC page 1

LHC Page1

Fill: 3607

E: 6500 GeV

10-04-15 00:53:06

## BEAM SETUP: RAMP

Energy:

6500 GeV

I(B1):

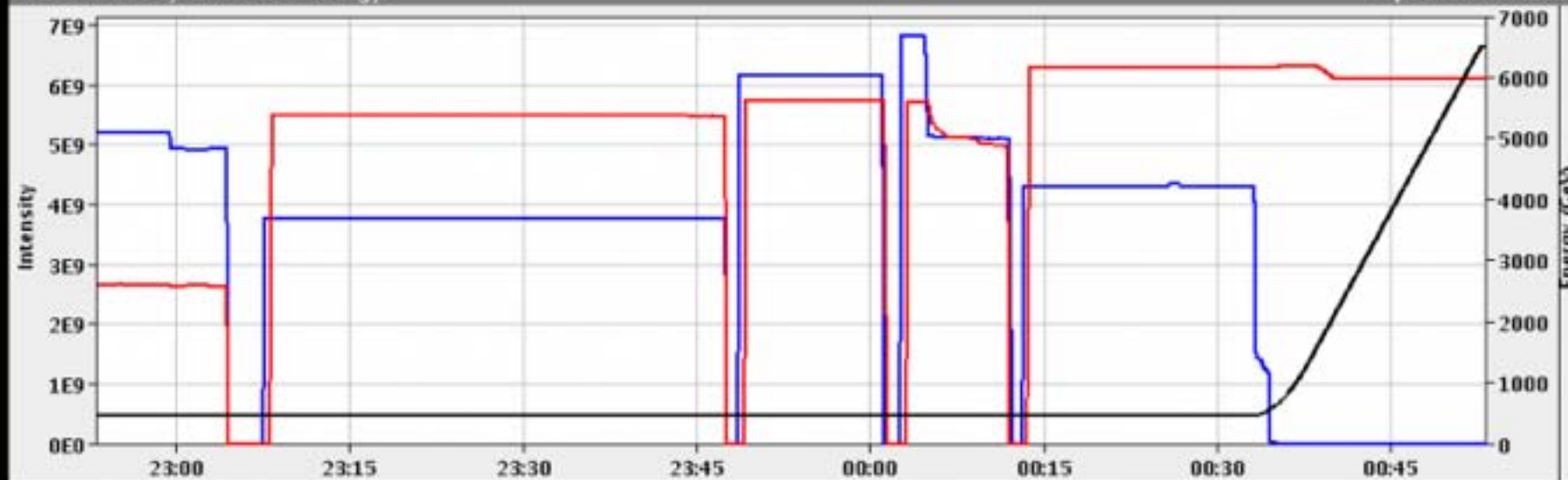
2.34e+09

I(B2):

6.16e+09

FBCT Intensity and Beam Energy

Updated: 00:53:05



Comments (10-Apr-2015 00:50:05)

first ramp

BIS status and SMP flags

B1 B2

Link Status of Beam Permits

false false

Global Beam Permit

true true

Setup Beam

true true

Beam Presence

false true

Moveable Devices Allowed In

false false

Stable Beams

false false

AFS: 150ns\_104b\_93\_8\_93\_8bpl

PM Status B1

ENABLED

PM Status B2

ENABLED



filmينو su LHC