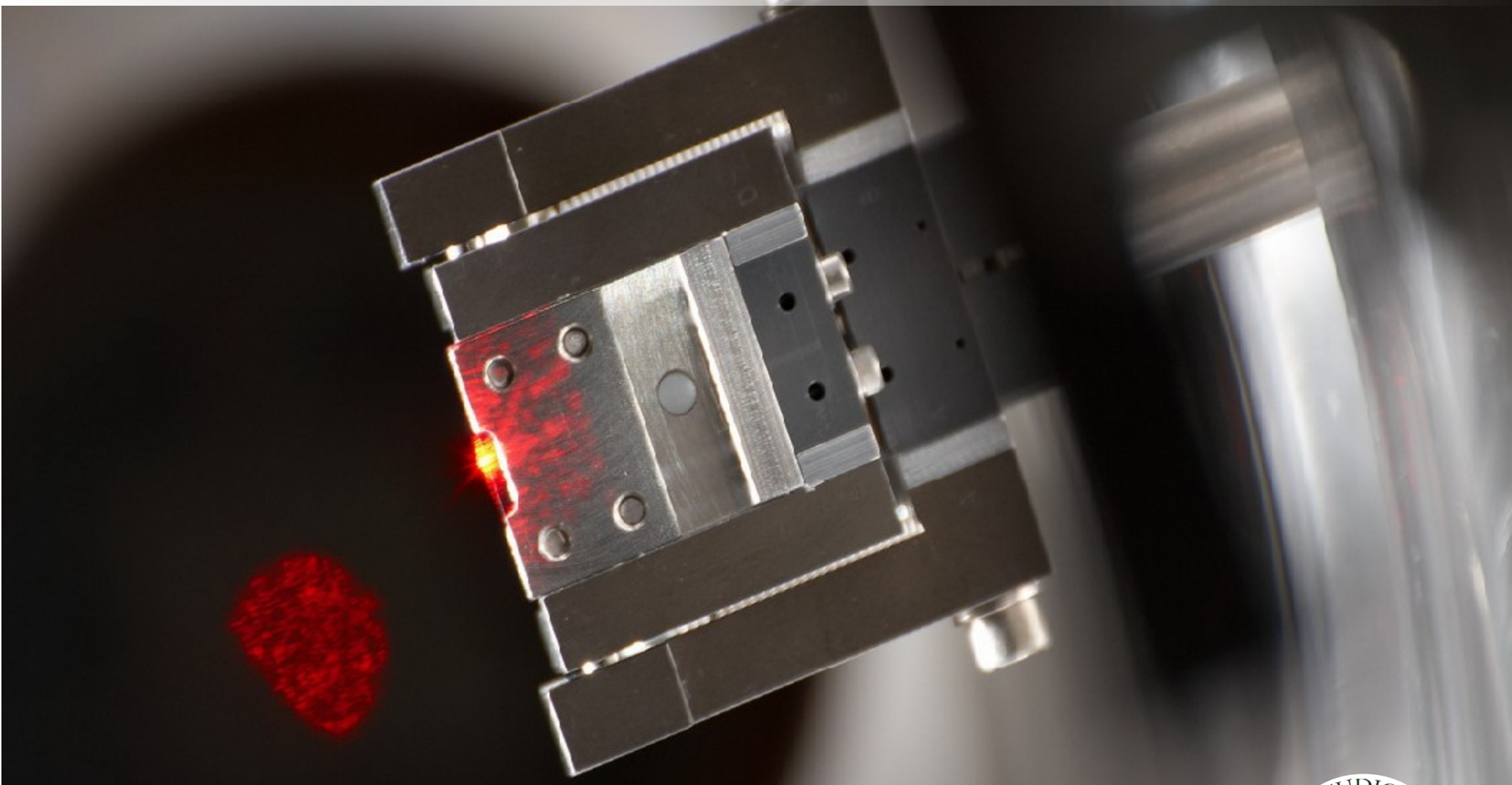


Cristalli curvi, le ultime novità



Said Hasan

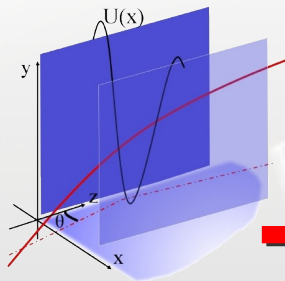
Università degli studi dell'Insubria

Seminario di dottorato (XXIII ciclo)



Di cosa parleremo:

➡ **Introduzione:**



Il channeling e fenomeni connessi

Aspetti sperimentali:

➡ **Deflessione**

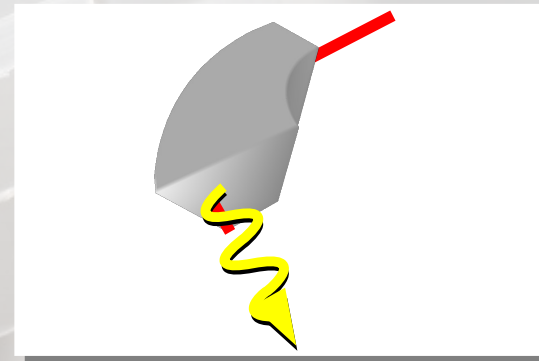
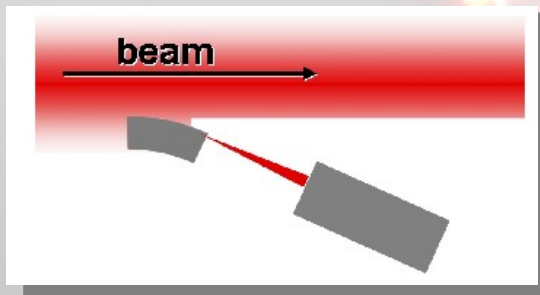
➡ **Emissione di radiazione**

applicazioni: ➡ **Collimazione**

➡ **Sorgente di fotoni**

esperimenti: ➡ **UA9**

➡ **Insurad**





Introduzione: channeling &Co.

In un mezzo amorfo

↳ Serie di urti non correlati con gli atomi del bersaglio



*Interazione con:
Nuclei, elettroni*



Scattering multiplo

Diffusione a grande angolo

Radiazione di bremsstrahlung

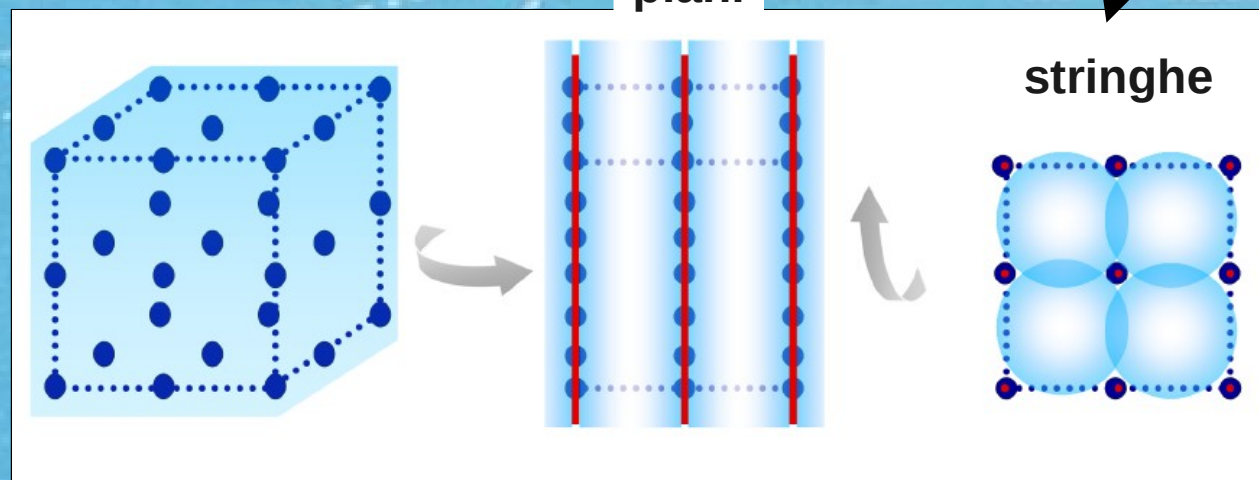
Perdita di energia per ionizzazione



The LHC collimation

In un cristallo

- ↳ Gli atomi sono disposti in un reticolo!
- A seconda dell'orientazione, appaiono disposti:

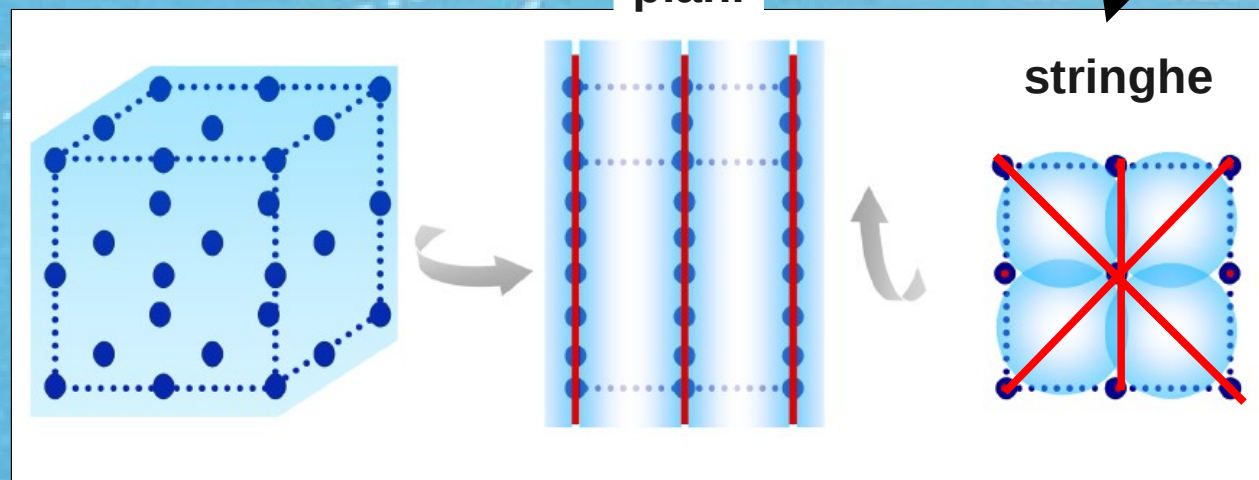




The LHC collimation

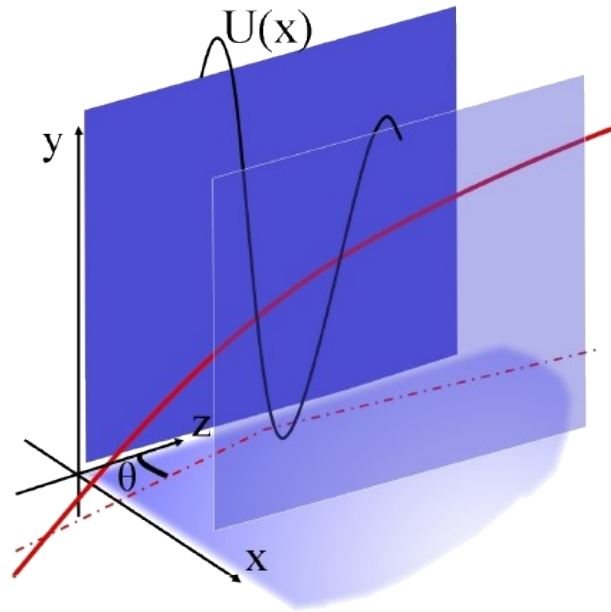
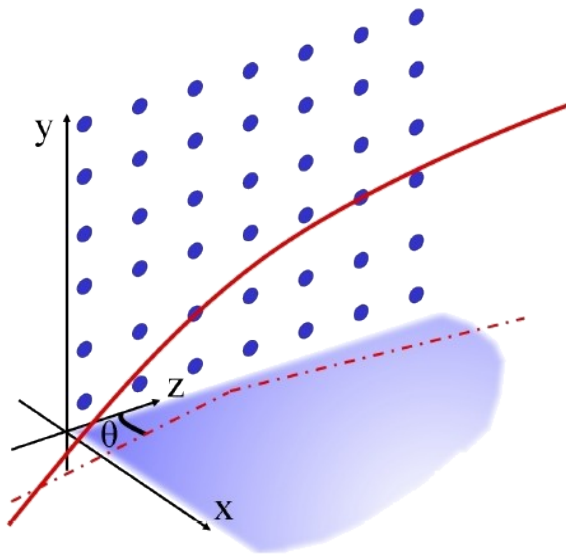
In un cristallo

- ↳ Gli atomi sono disposti in un reticolo!
- ⇒ A seconda dell'orientazione, appaiono disposti:



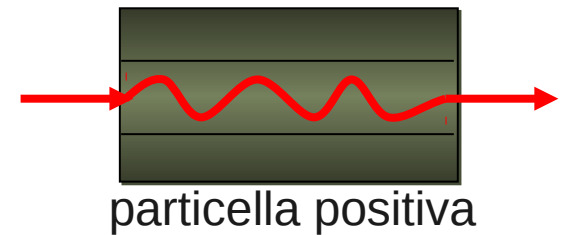


Allineamento planare



$$\theta_p < \theta_c = \sqrt{\frac{2U_{\max}}{pv}}$$

$\sim 10 \mu\text{rad}$ @ 400 GeV/c



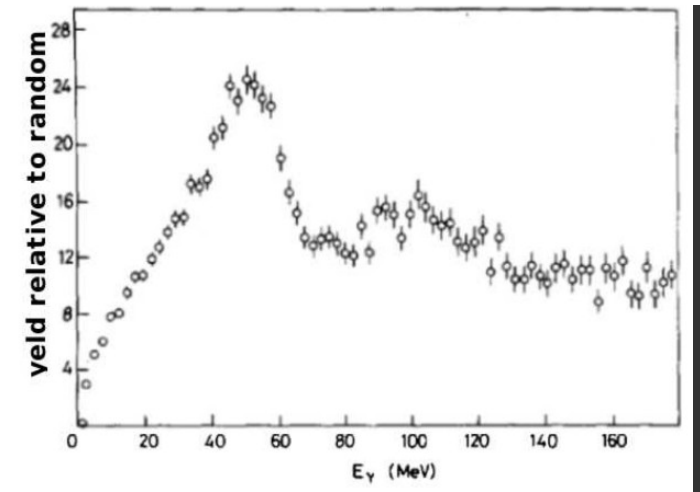
Channeling



Confinamento

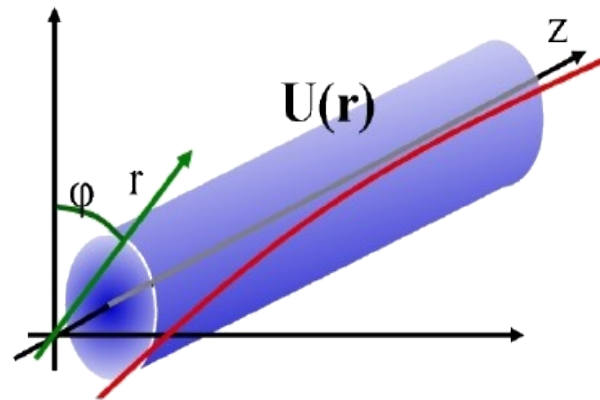
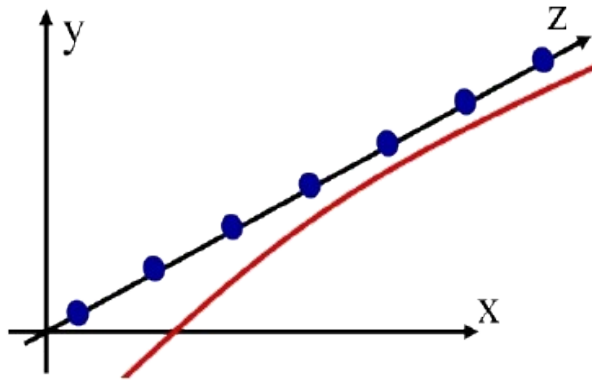
Soppressione delle collisioni a piccolo parametro di impatto

Ridotta perdita di energia per ionizzazione
Emissione di radiazione di channeling



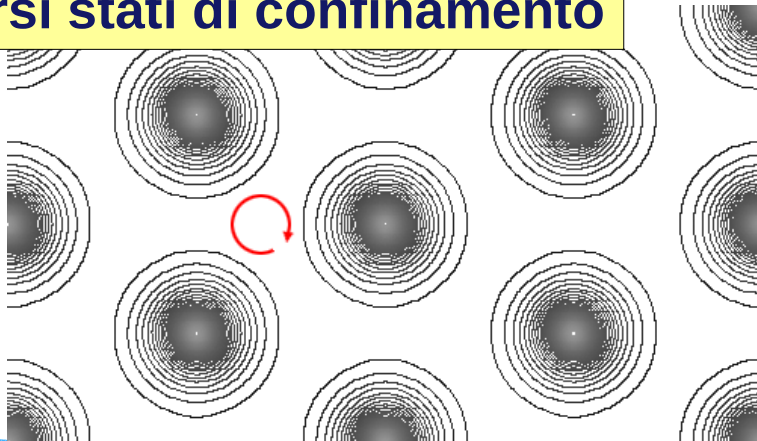


Allineamento assiale

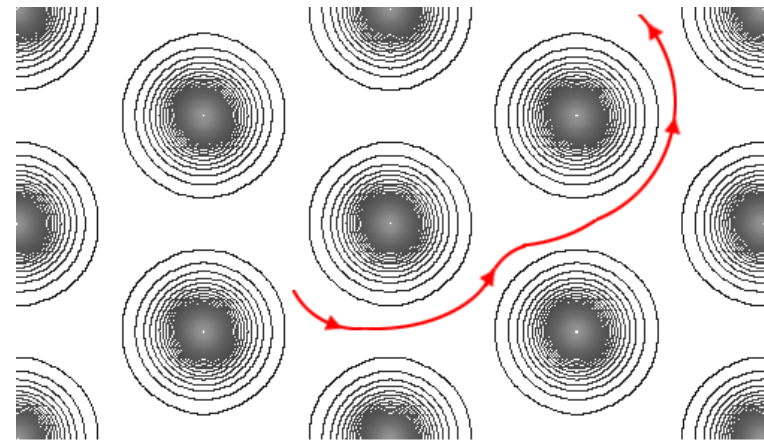


L'angolo critico è più grande che nel caso planare tuttavia la probabilità di dechanneling (o migrazione al caso planare) è più alta a causa della forma del potenziale

Diversi stati di confinamento



Hyperchanneling



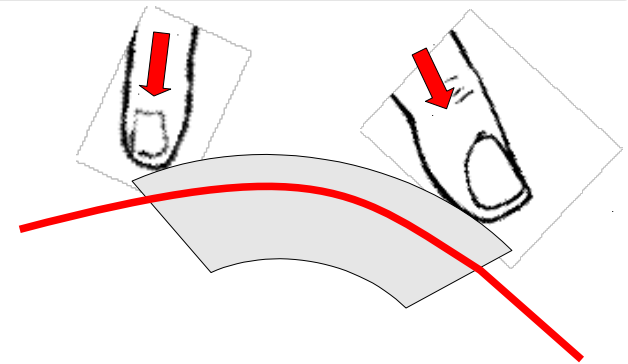
Doughnut scattering



Cristalli curvi, l'idea

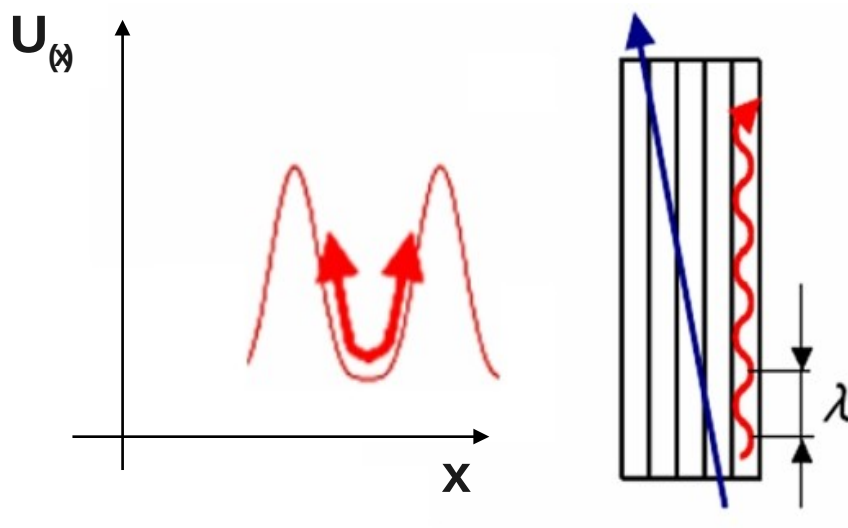
Usare il potere di confinamento per:

Devviare fasci ultrarelativistici di particelle
(1976 Tsyganov)



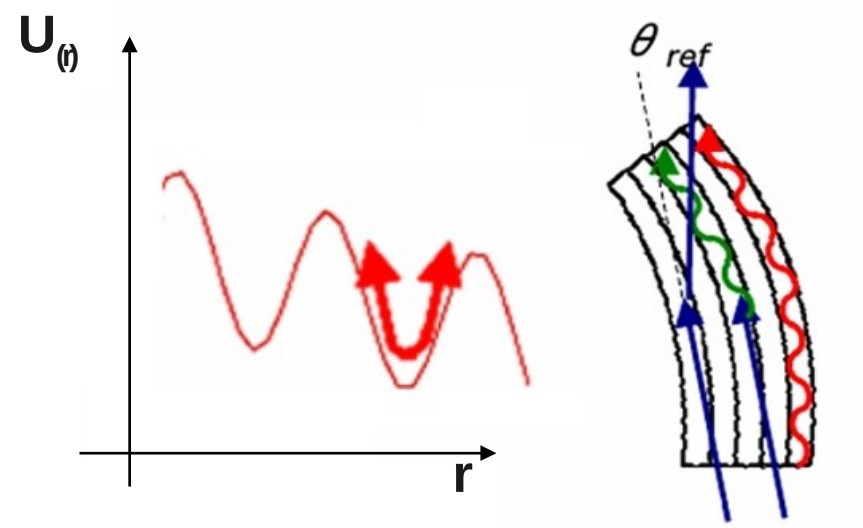
► Cristallo dritto

*Potenziale interplanare:
Campo elettrico prodotto dagli atomi*



► Cristallo curvo

*Potenziale efficace:
campo elettrico + forza centrifuga*

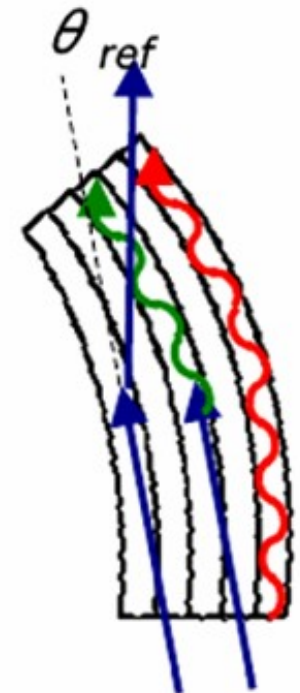
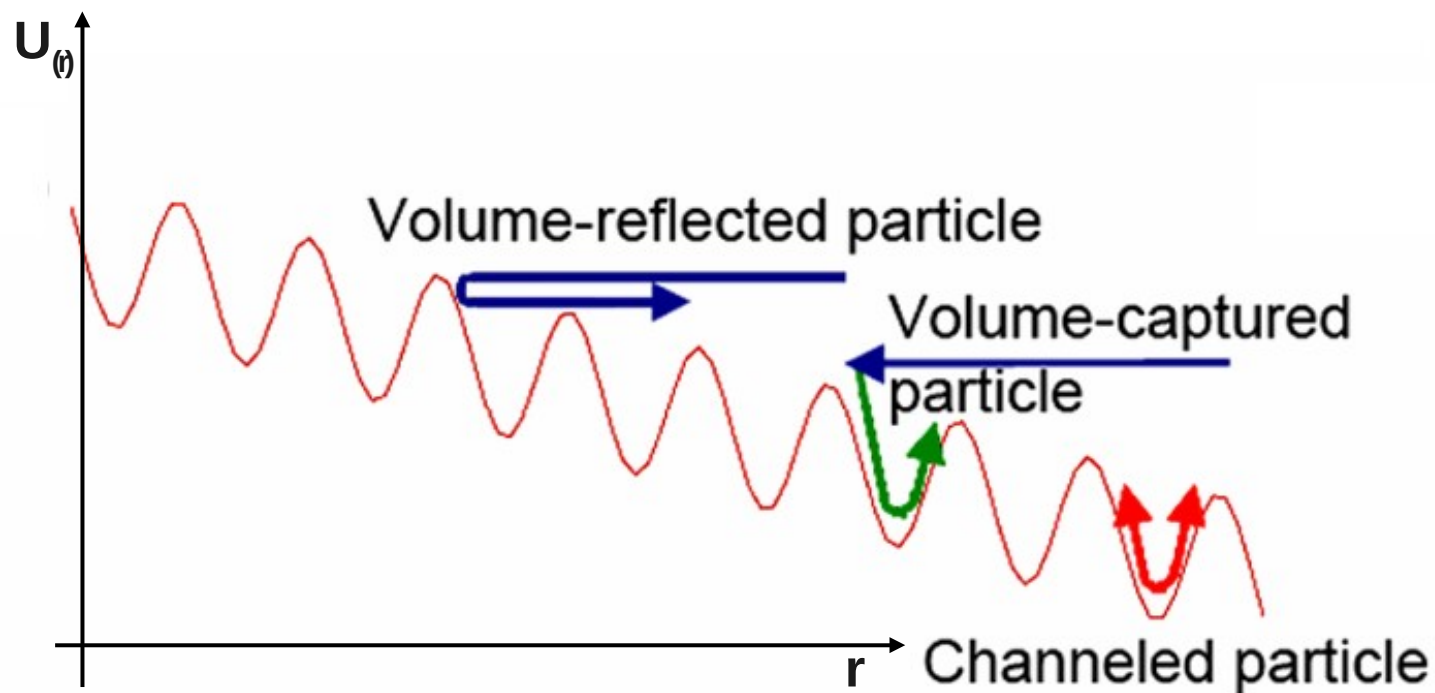
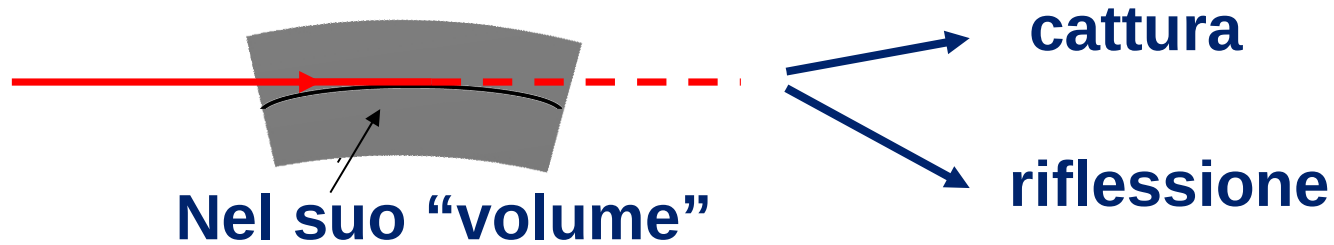


curvatura limite:
raggio di Tsyganov $\sim 5\text{cm} \times P(\text{GeV})$
(silicio)

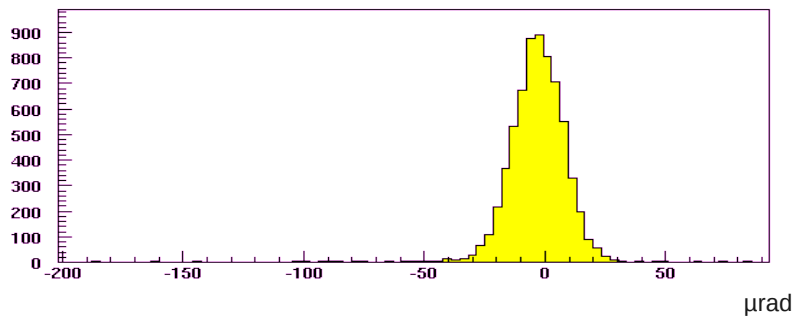
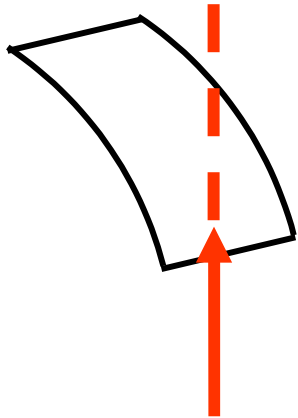


Cristalli curvi, gli imprevisti

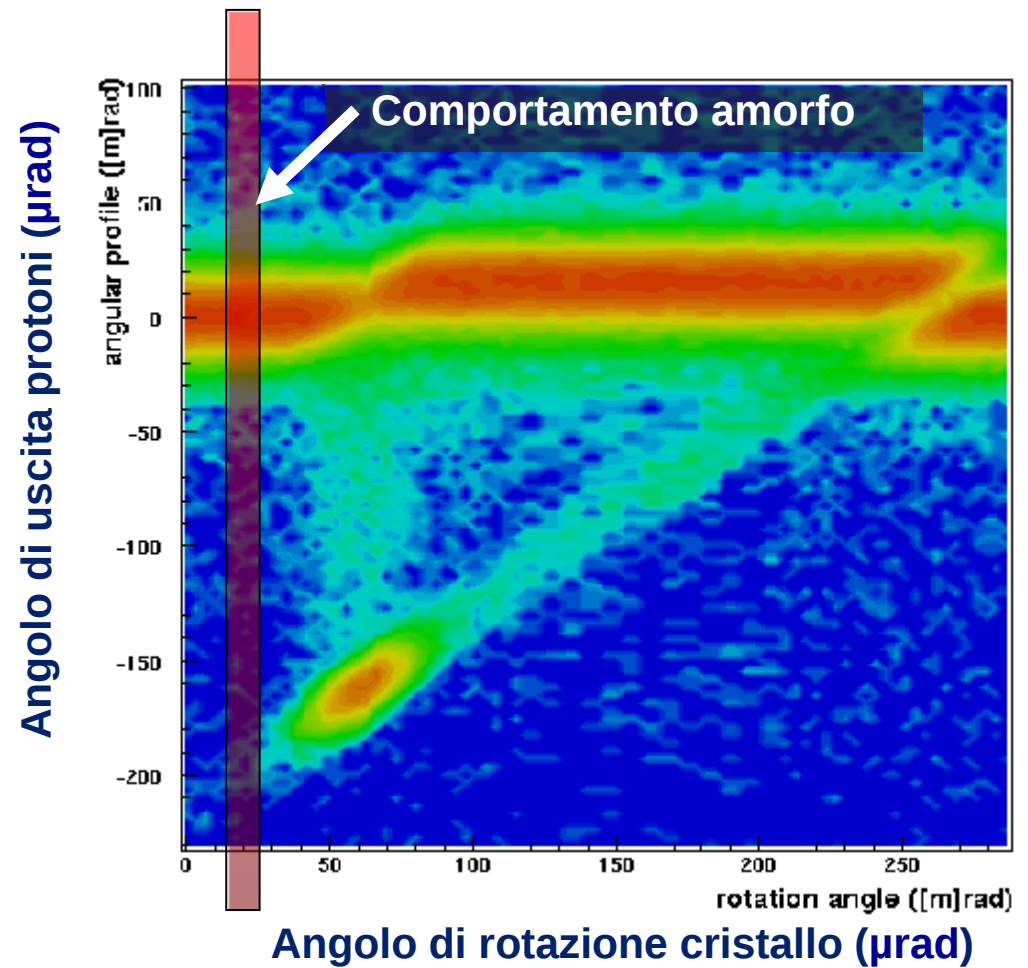
- Il punto di tangenza con il canale può essere nel cristallo



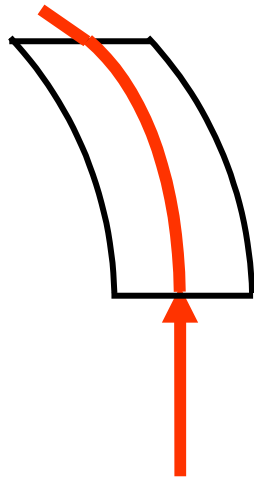
Cristallo disallineato: Comportamento amorfo



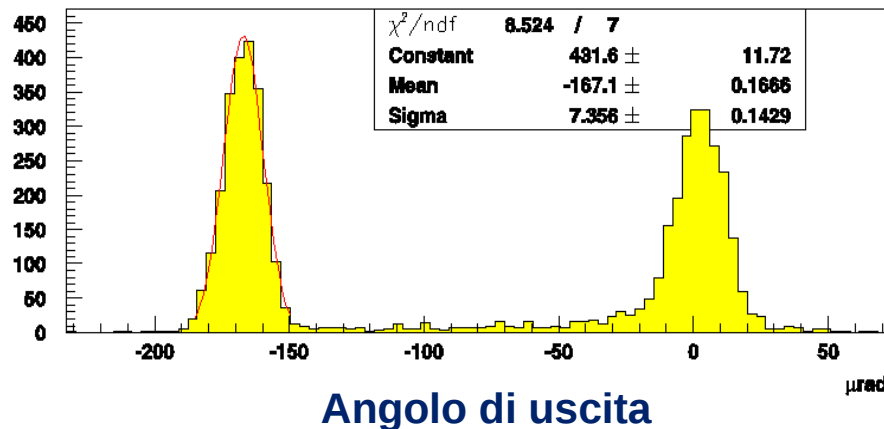
Angolo di uscita



Cristallo allineato: Channeling

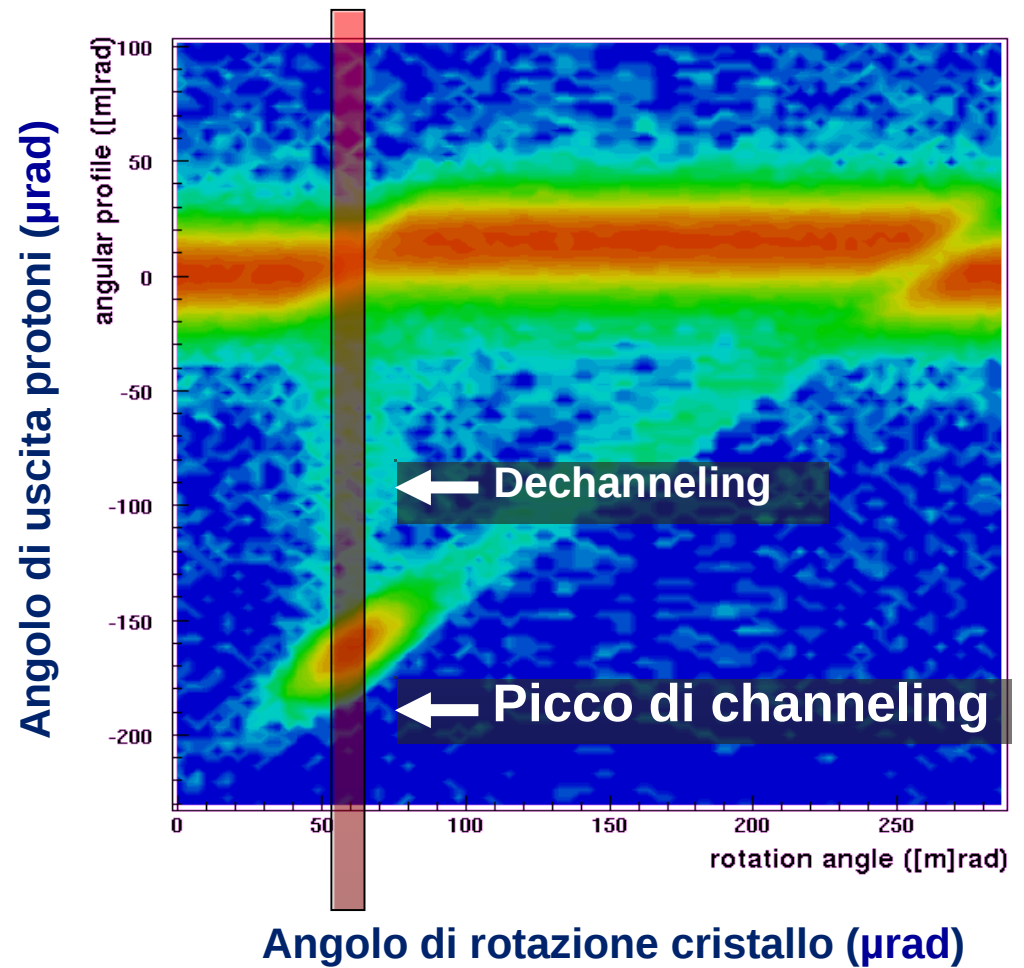


$$\theta_c = \frac{L}{R}$$



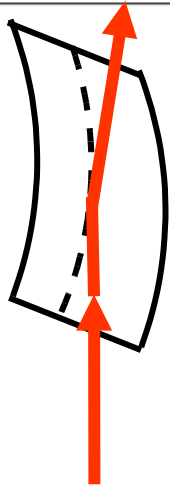
Angolo di channeling: 162 μrad

Equivale a 72 Tesla!

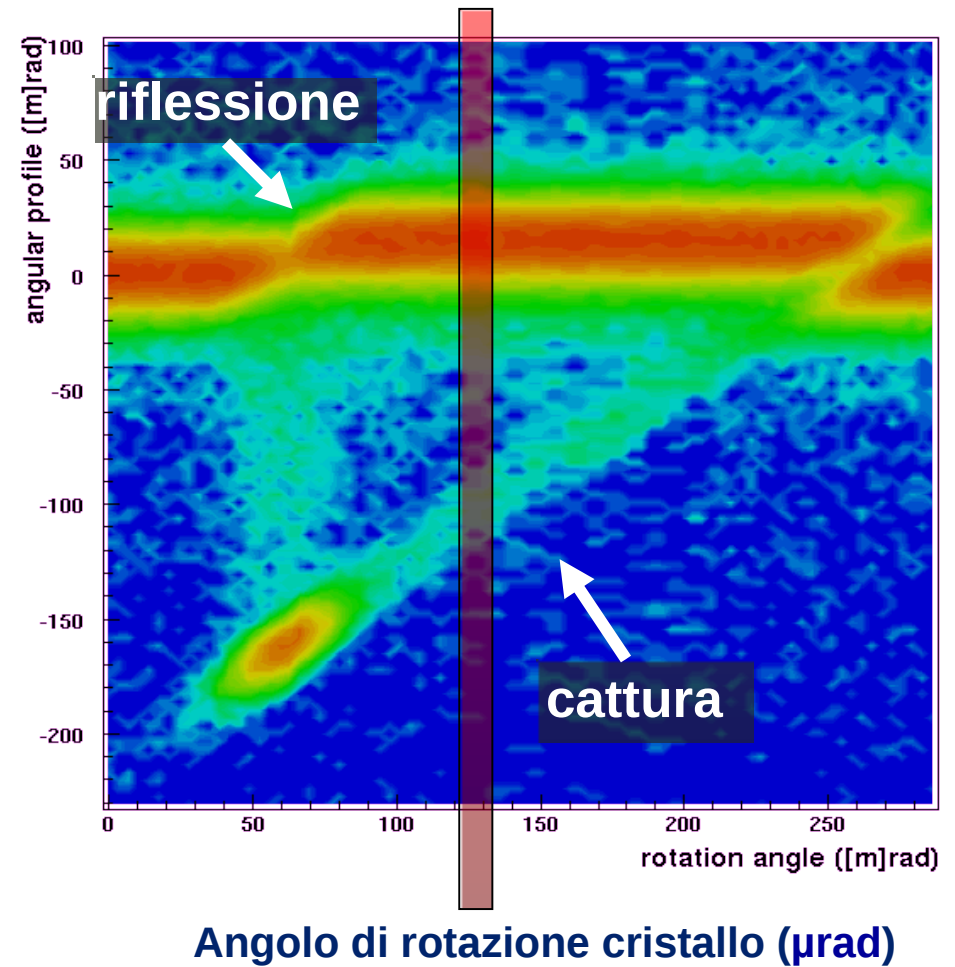
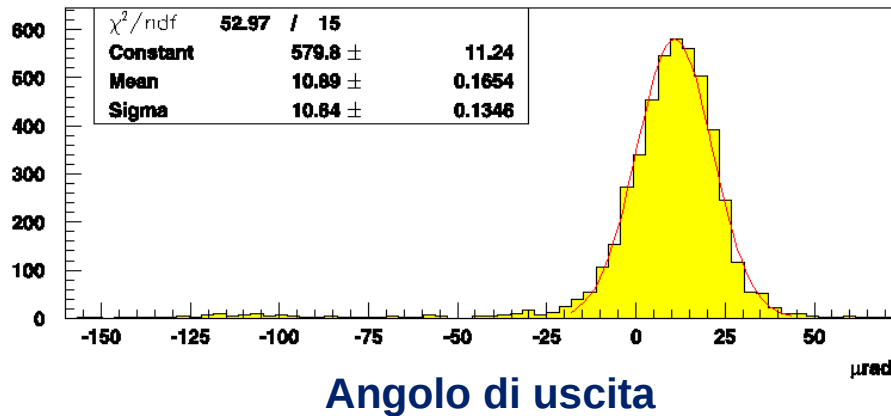


DATI 2006

Ruotando ulteriormente: Volume Reflection



$$\theta_r = 1.50c$$



angolo di riflessione: 13.8 μrad

Cristalli singoli:

2 classi sviluppate per ottenere:

Curvature regolari e spessori sottili nella direzione del fascio

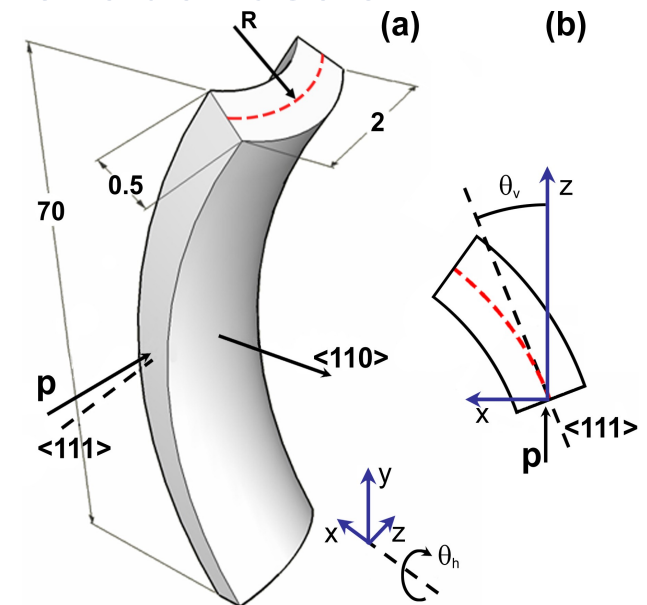
● Cristalli strip

Principio:
Curvatura anticlastica

Superfici regolari
ma con
dimensioni limitate



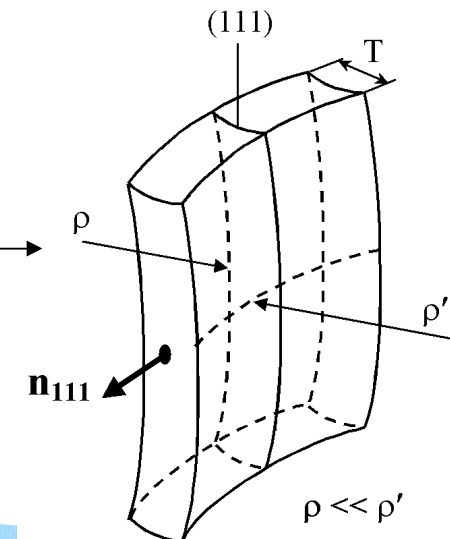
~10cm



● Cristalli quasimosaici

Principio:
Curvatura quasimosaica
(anisotropia del cristallo)

Grandi superfici
ma con
irregolarità





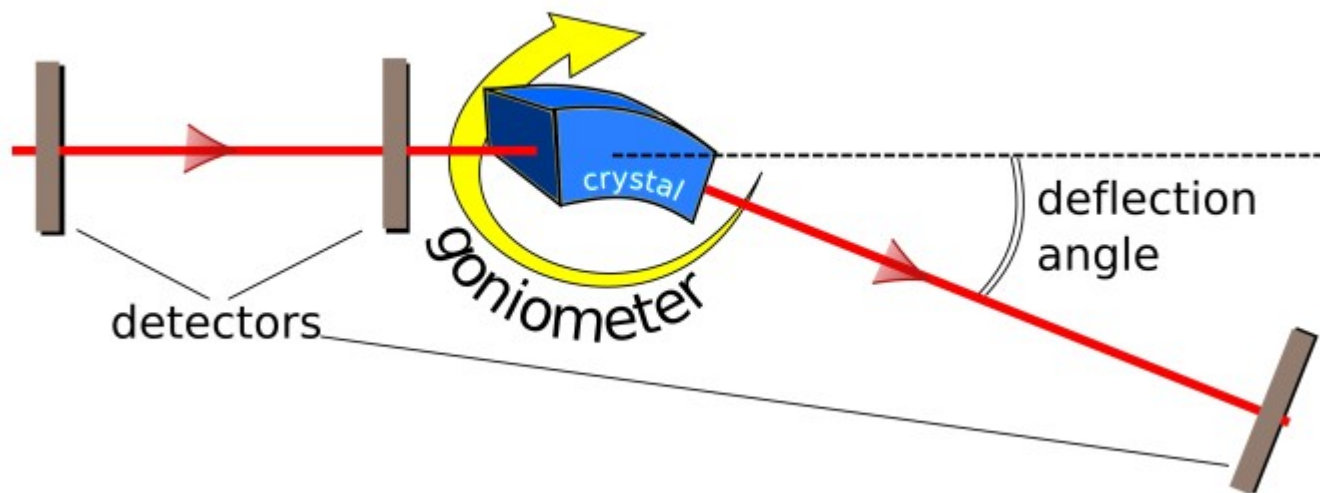
Setup sperimentale

Osservabili misurate:

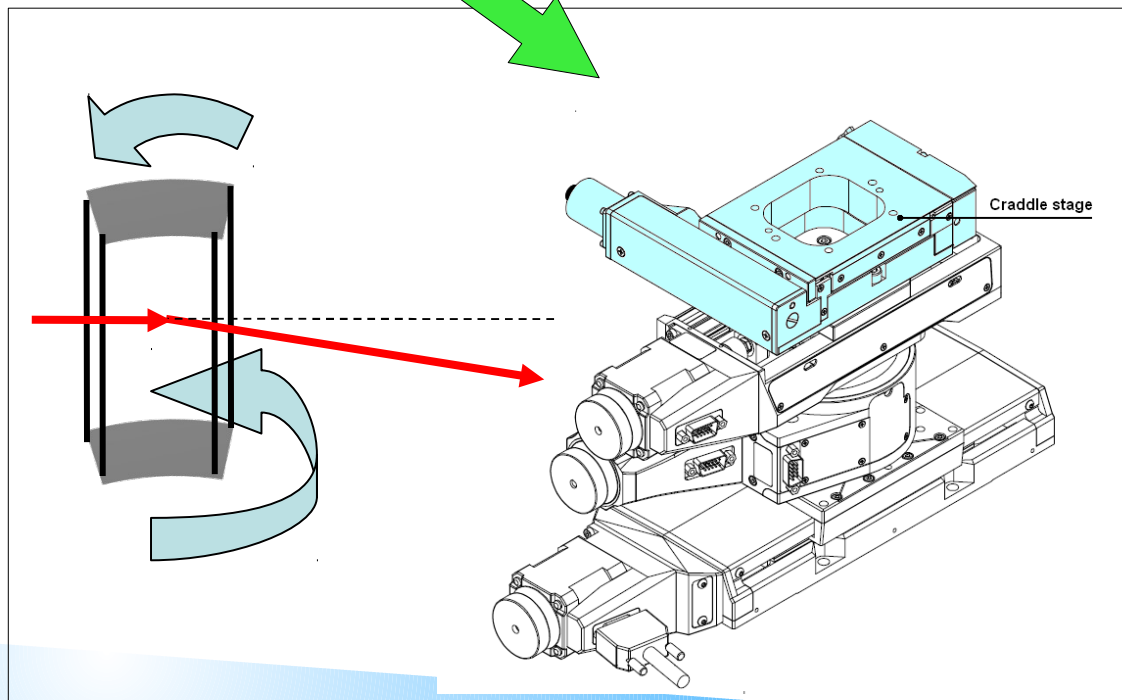
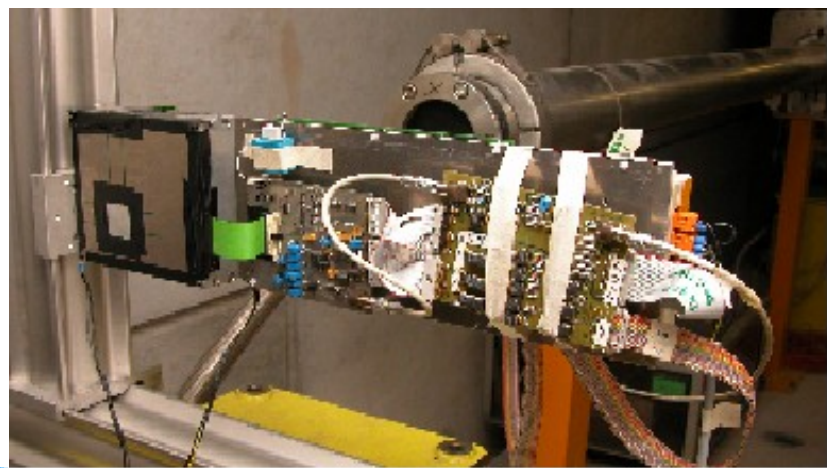
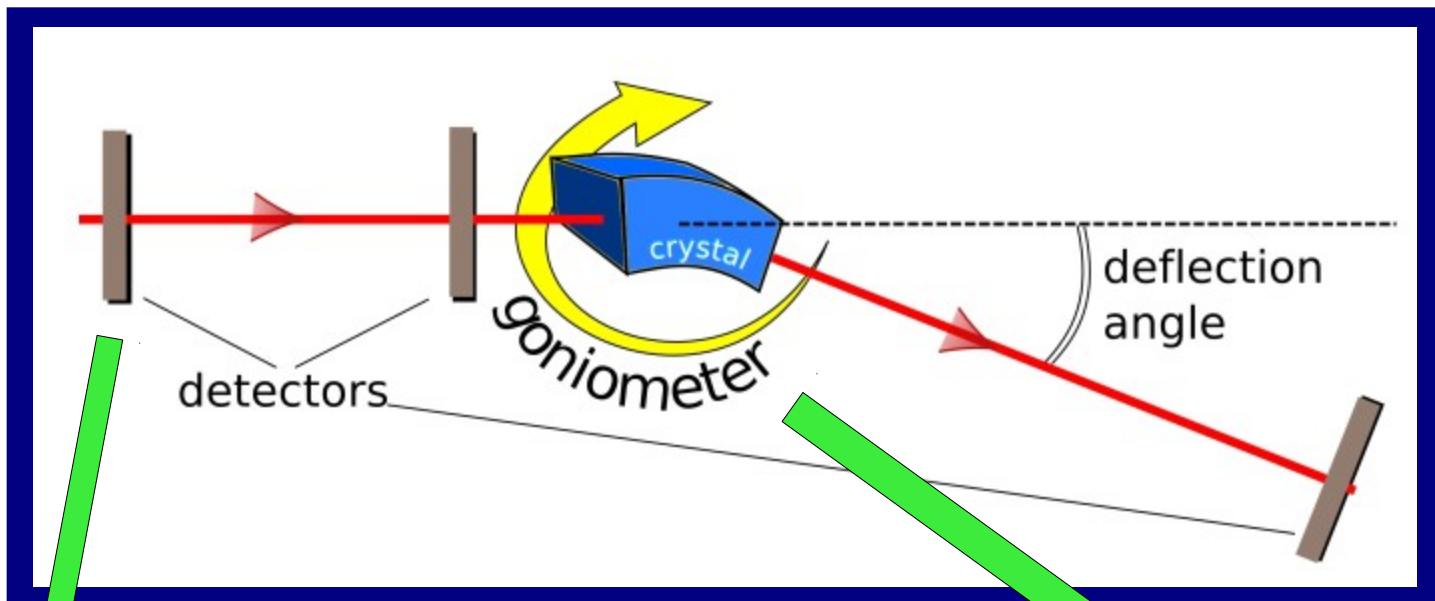
- angolo di deflessione
- angolo di ingresso
- posizione di impatto sul cristallo

Risoluzione angolare:

- Determinata dal multiple scattering del 2° rivelatore e dallo stesso cristallo



Setup sperimentale



Setup sperimentale

Caratteristiche:

Affidabilità

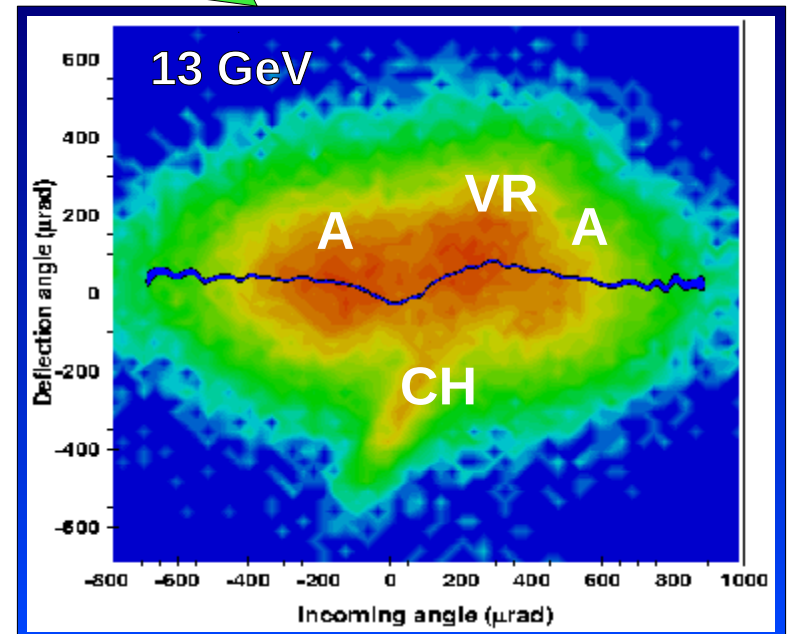
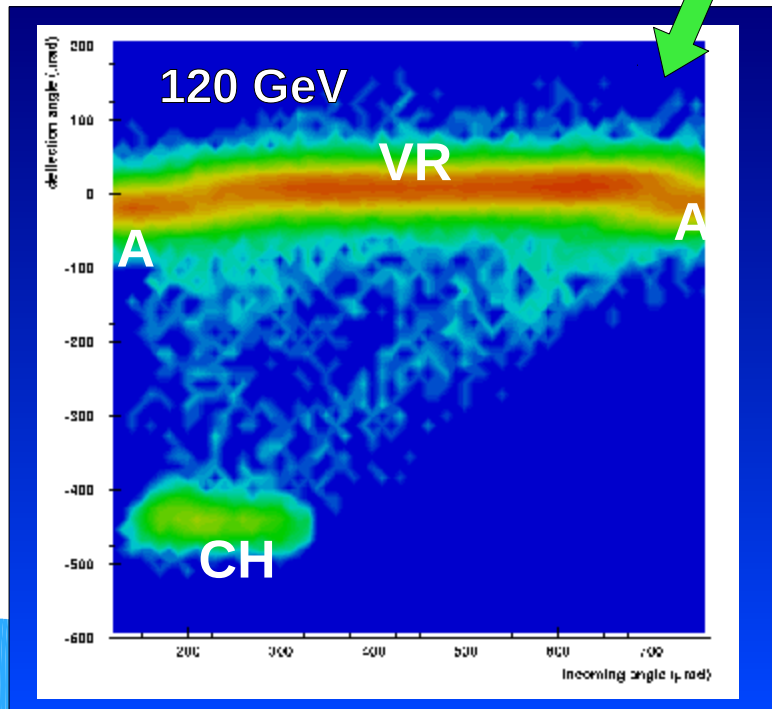
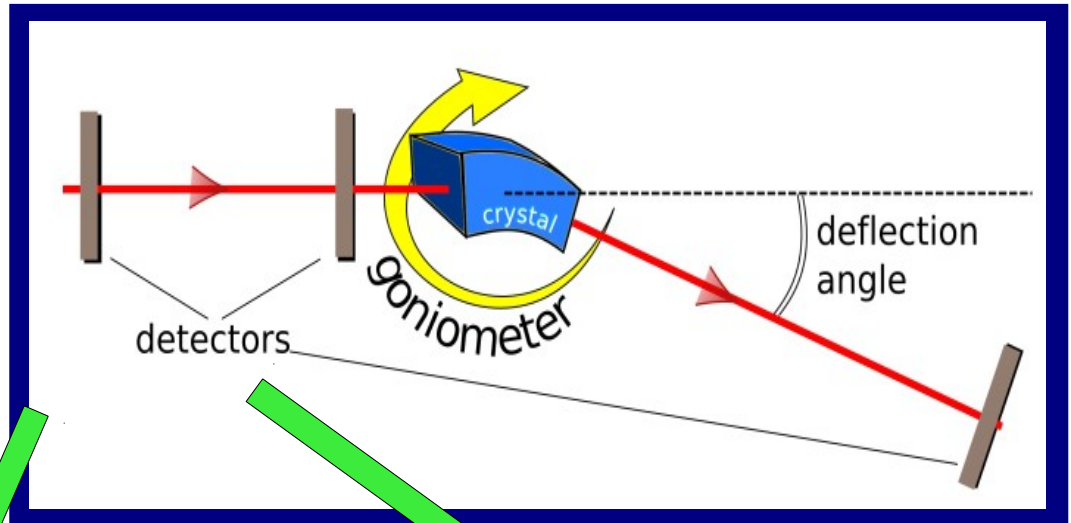
~4 mesi di presa dati tra il 2007 e il 2009!

Velocità

feedback istantaneo

Versatilità

tracciatore di singola particella





Setup sperimentale

Caratteristiche:

Affidabilità

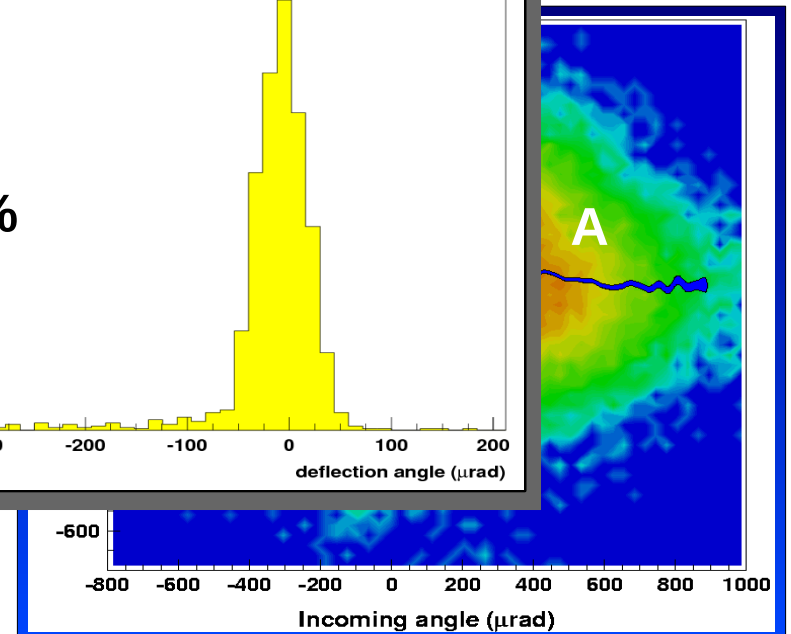
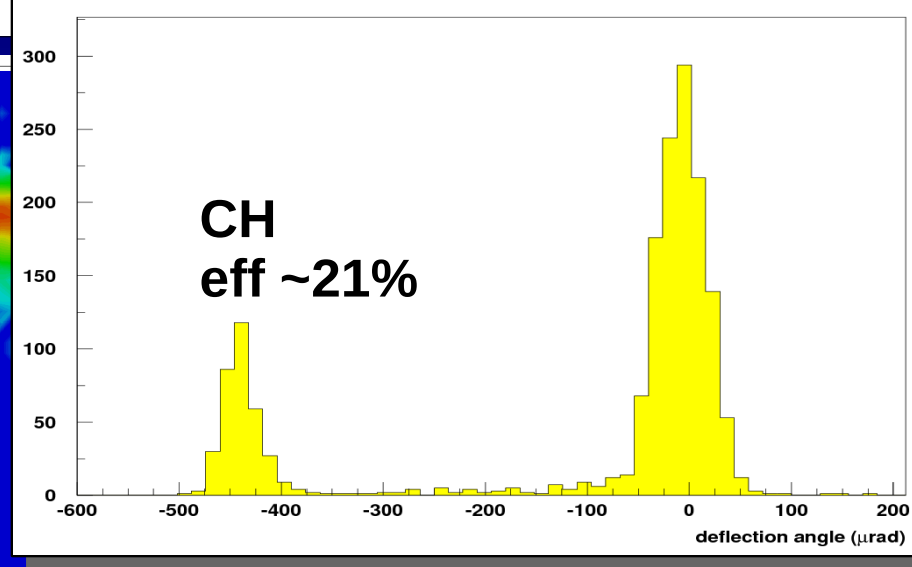
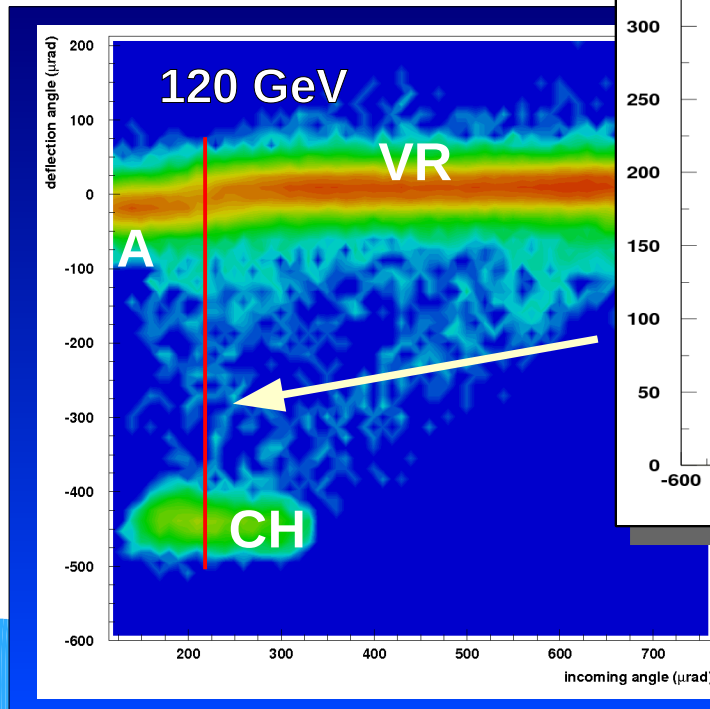
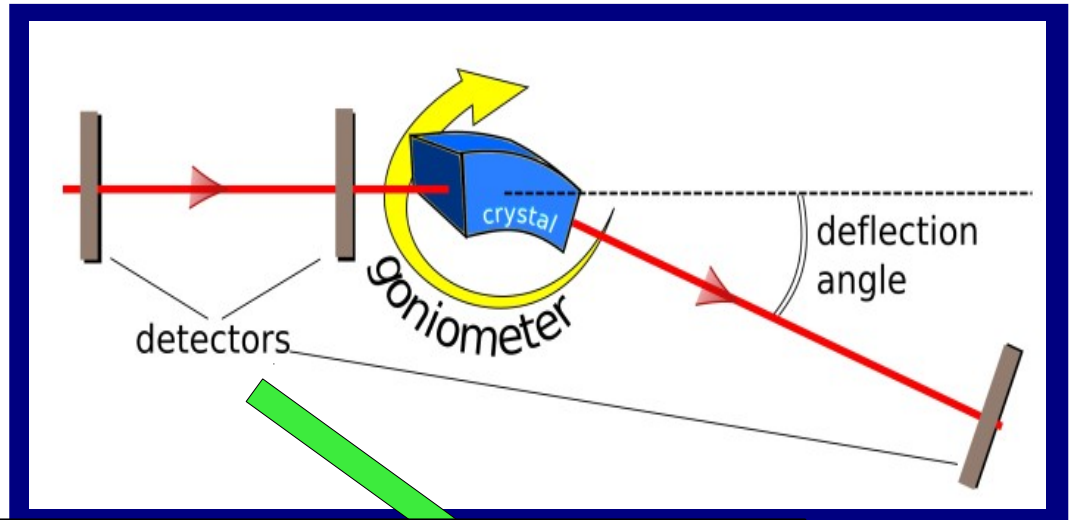
~4 mesi di presa dati tra il 2007 e il 2009!

Velocità

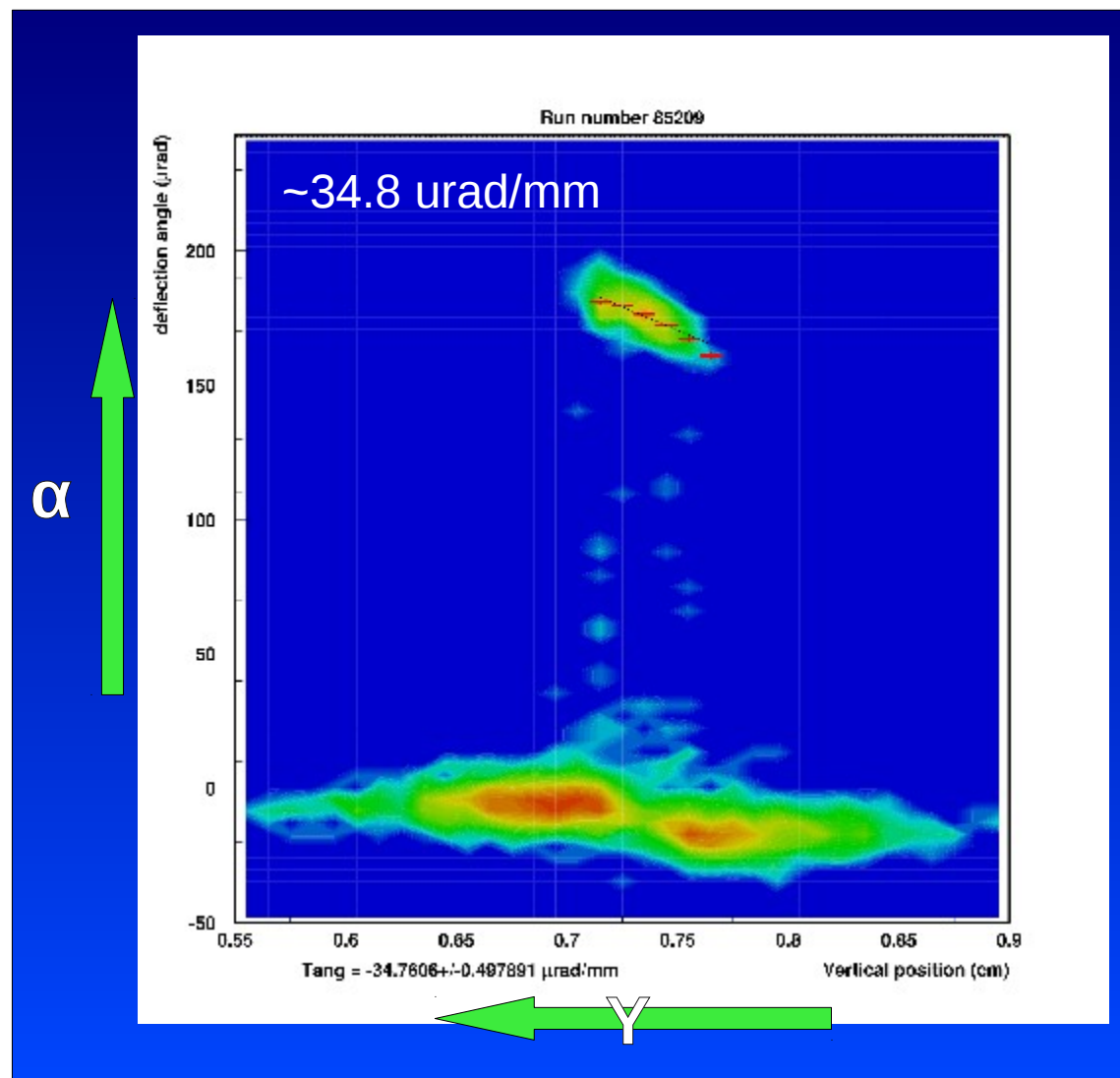
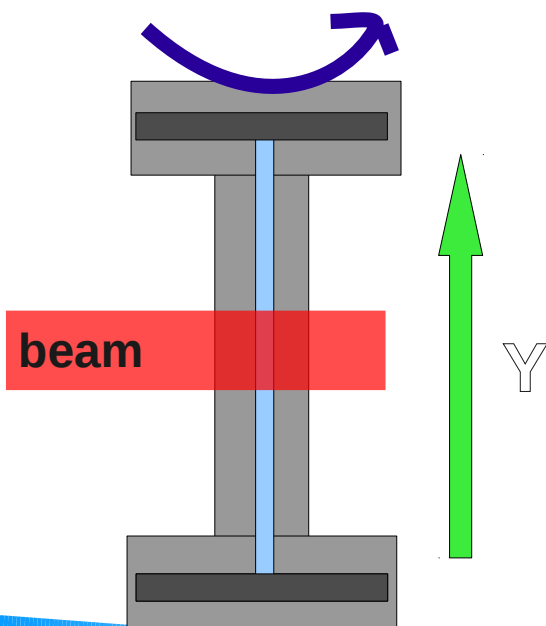
feedback istantaneo

Versatilità

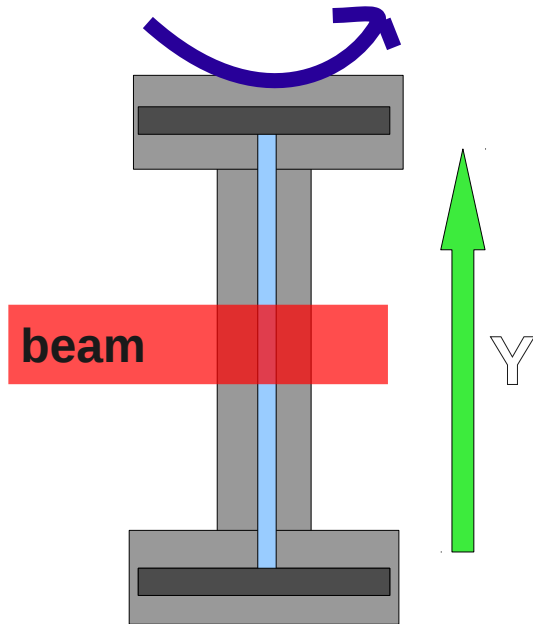
tracciatore di singola particella



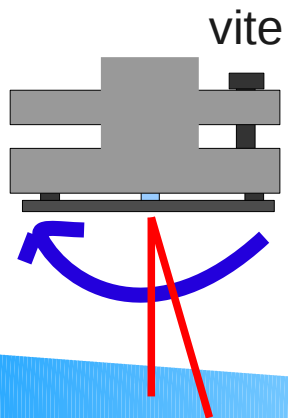
Efficienza di channeling e torsione



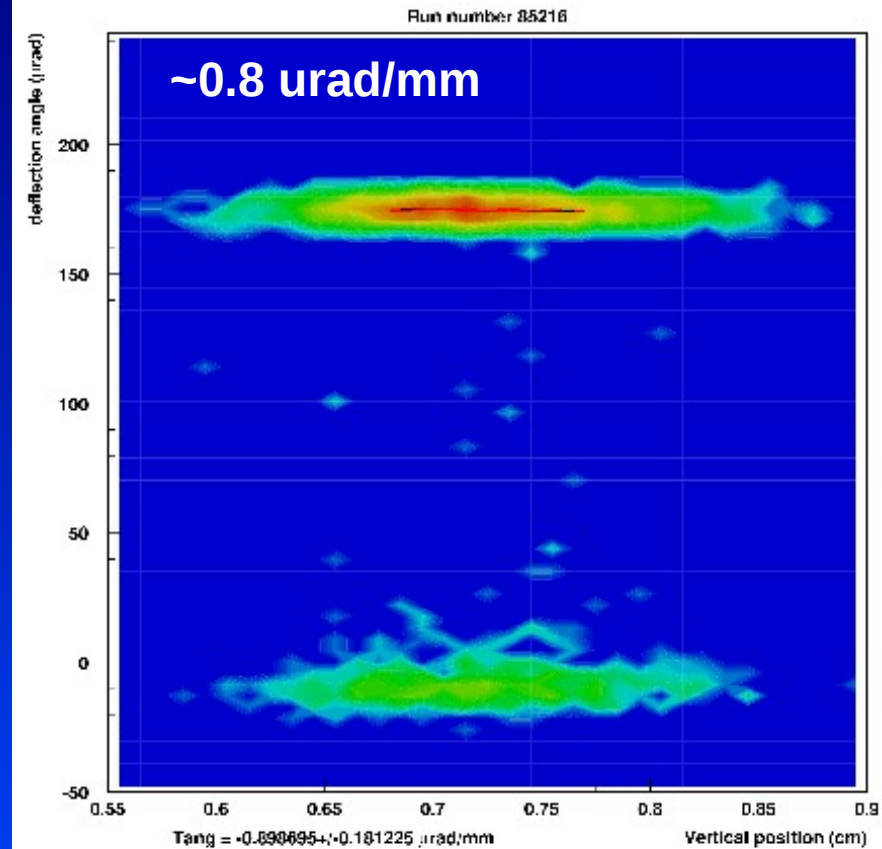
Efficienza di channeling e torsione



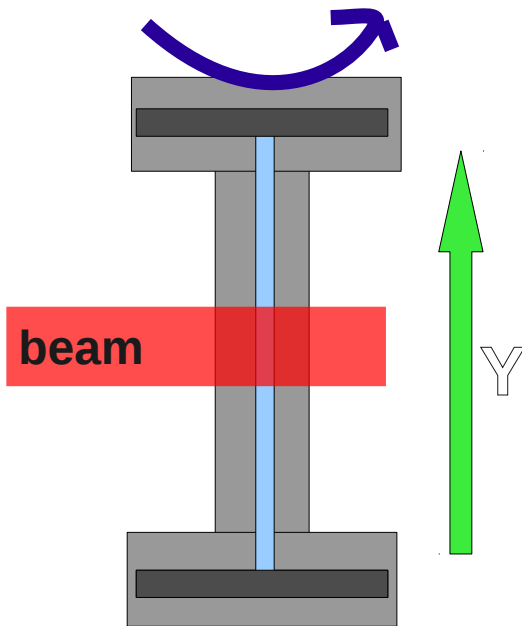
Top view



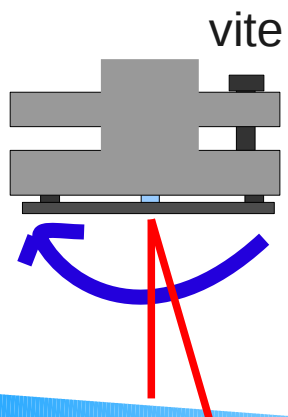
feedback laser



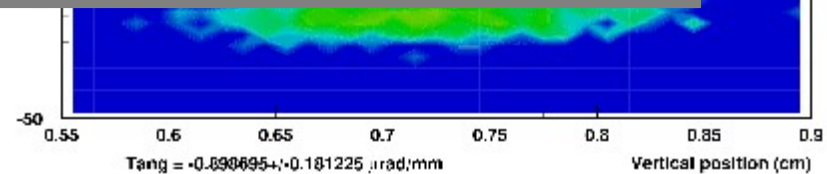
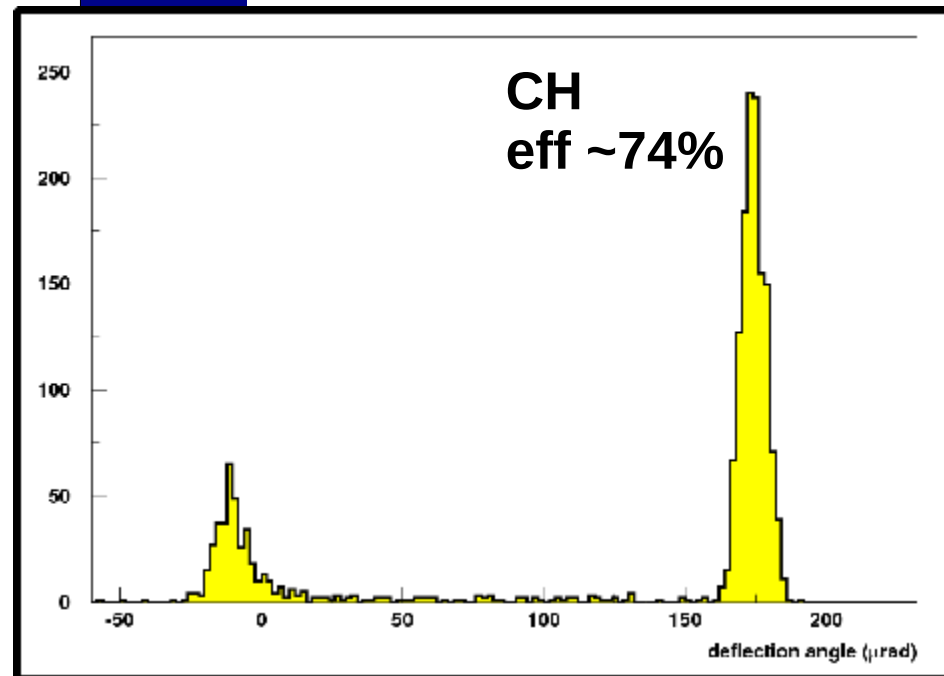
Efficienza di channeling e torsione



Top view



feedback laser



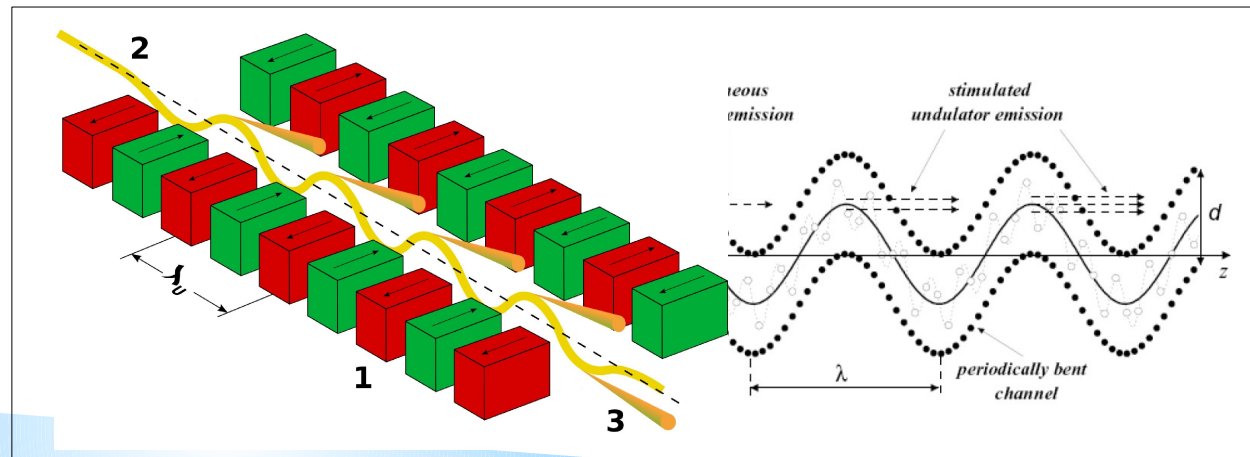
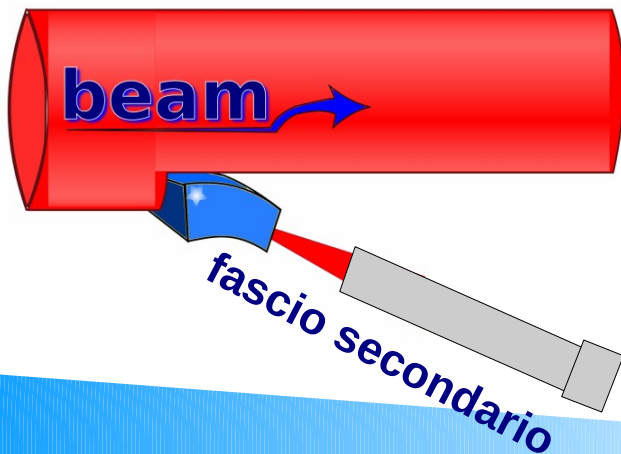
Le applicazioni:

DEFLESSIONE

- ▶ Estrazione per creare fasci secondari
- ▶ Beam splitting
- ▶ Micro beam
- ▶ Collimazione

EMISSIONE DI RADIAZIONE

- ▶ Identificazione di particelle (TRD)
- ▶ Collimazione di e^+/e^-
- ▶ Sorgente di e^+ (ILC e CLIC)
- ▶ Produzione di raggi X e γ
Channeling/ VR ecc...
Undulator crystal

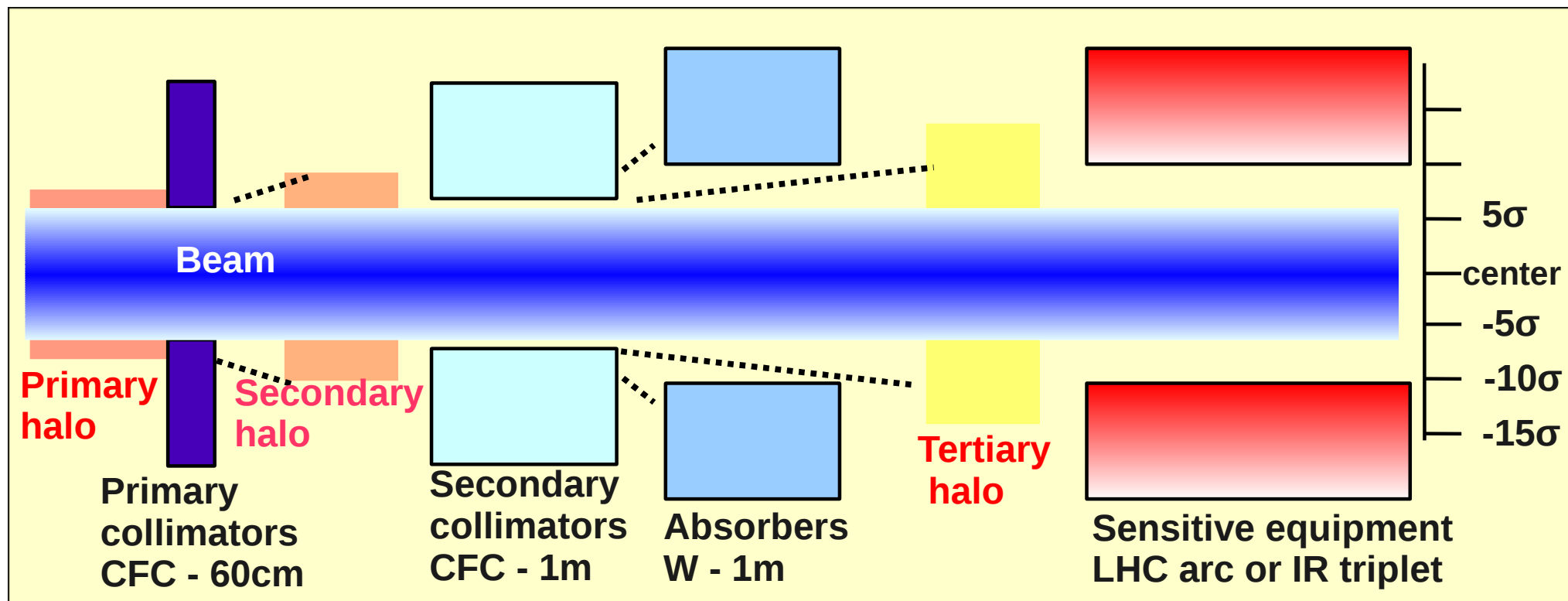




La collimazione

Attuale schema (multistadio) di collimazione di LHC

limita la luminosità della macchina al meglio al 40% del valore nominale





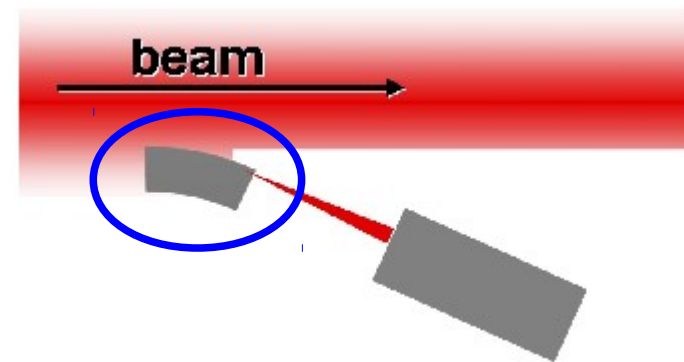
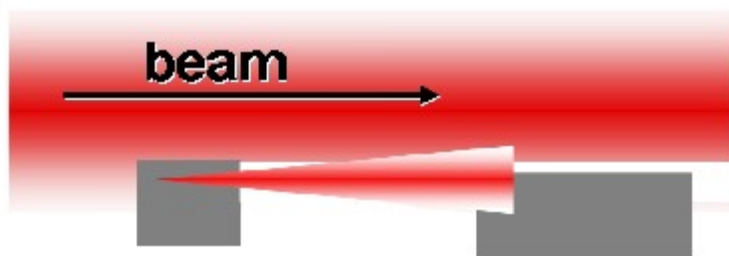
La collimazione

Attuale s
I limita la

IDEA:

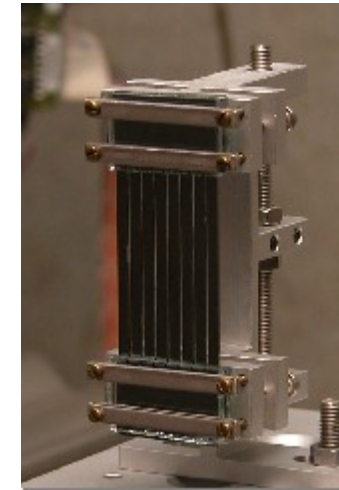
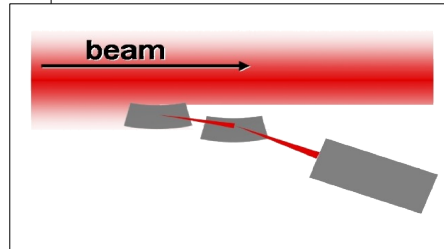
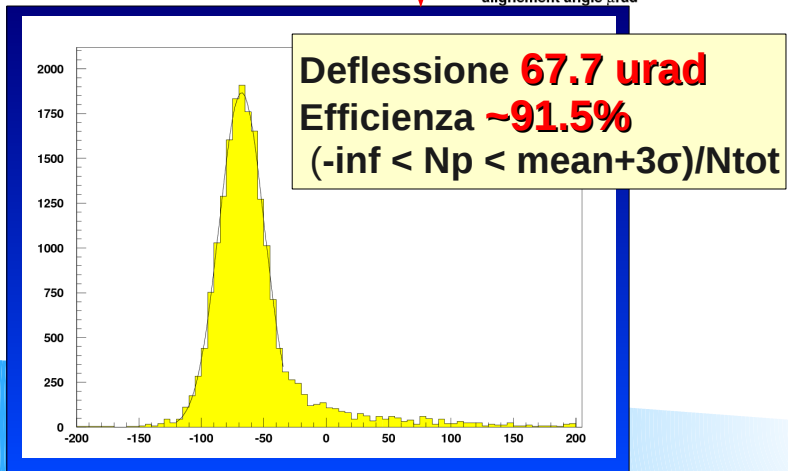
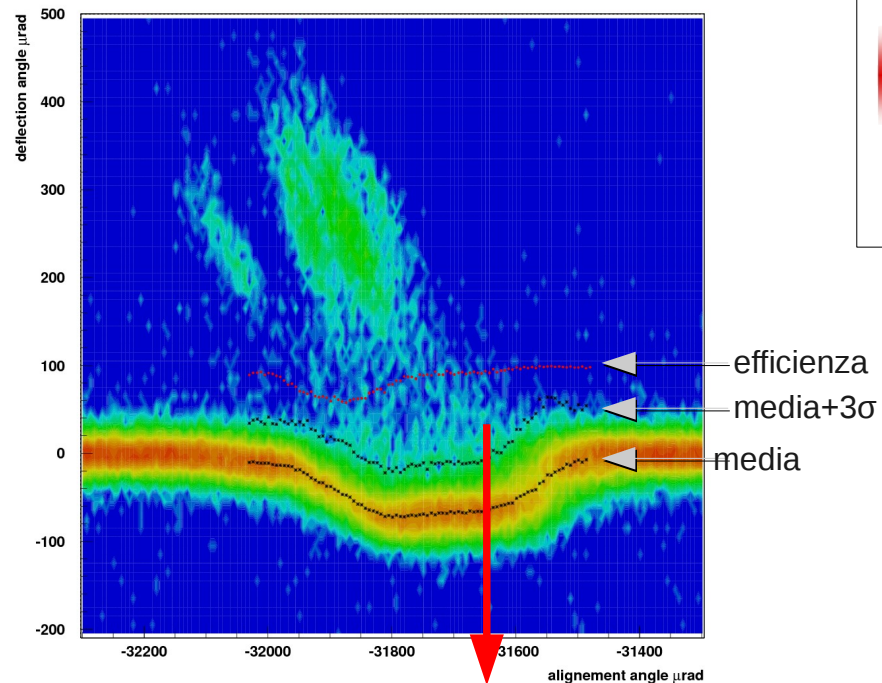
ominale

5 σ
10 σ
10 σ
ter

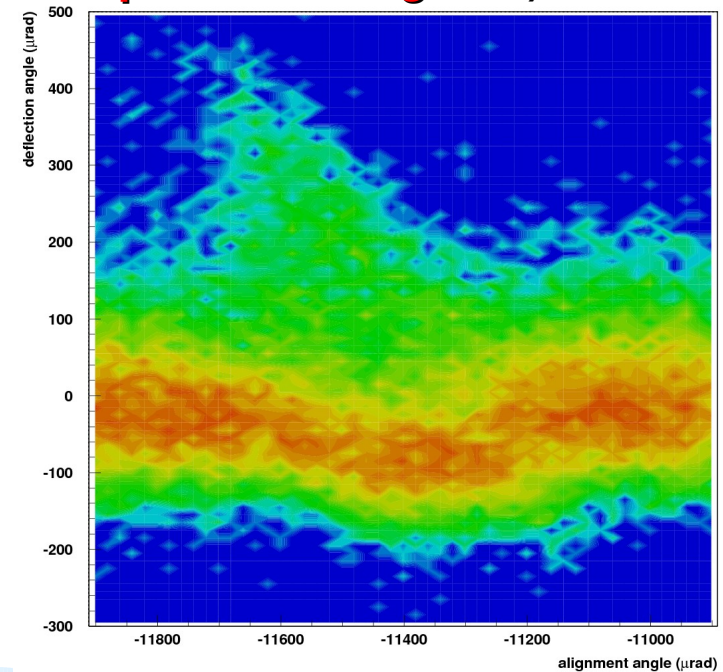


I multicristalli

Protoni di 400 GeV

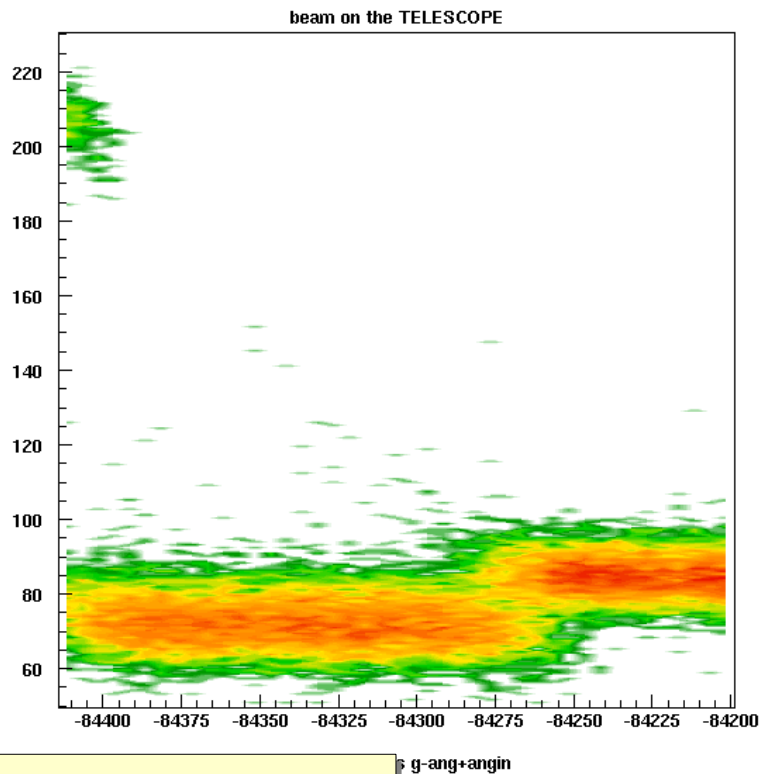


particelle negativi, 150 GeV



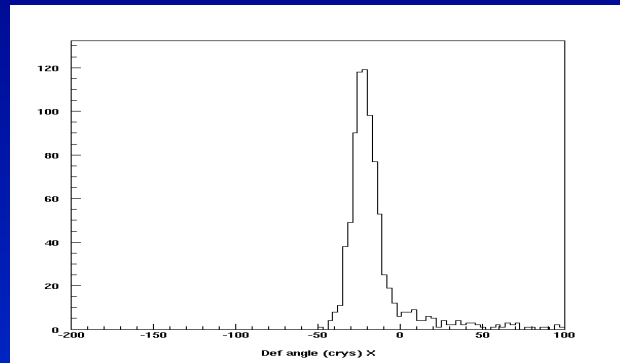
Oltre il silicio:

Cristallo quasi mosaico di Germanio (Protoni di 400 GeV)

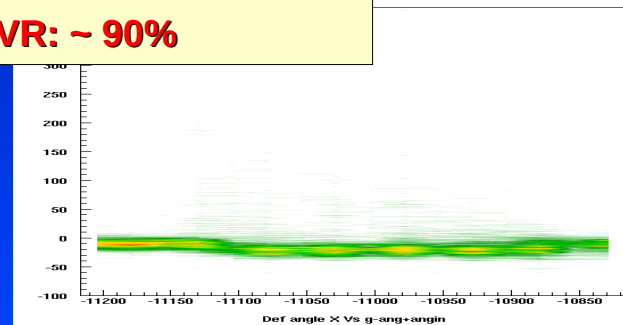


Alto Z
(rispetto al silicio)

Niobato di litio (Protoni di 400 GeV)



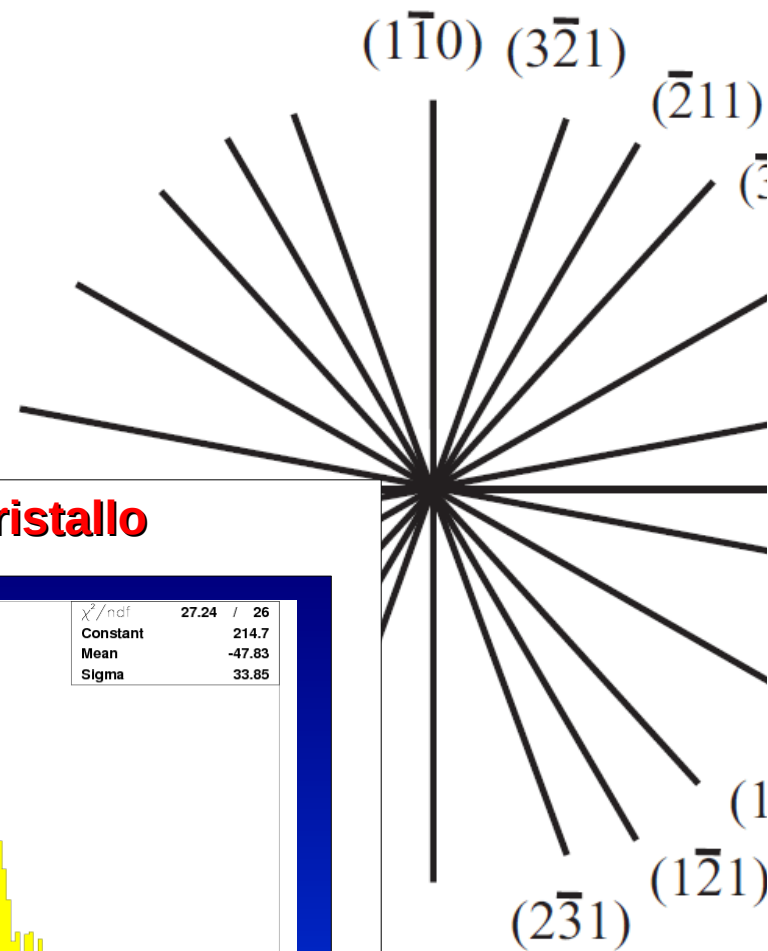
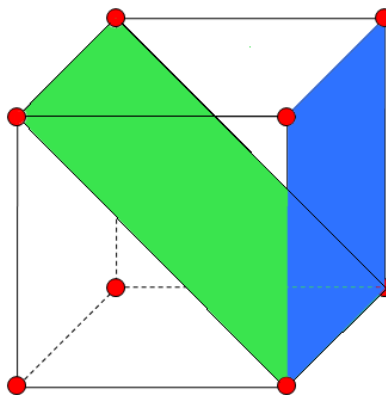
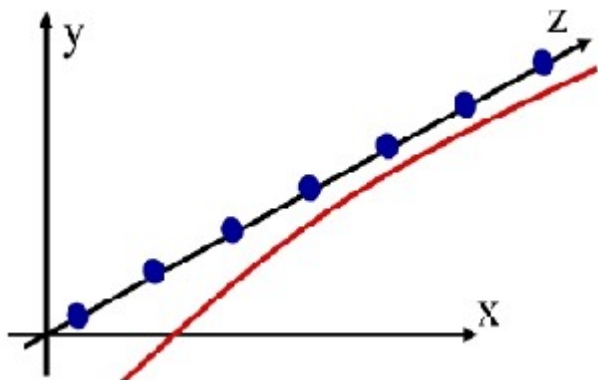
Eff. channeling: ~3%
 $\Theta_R = 13$ urad
Eff. VR: ~ 90%



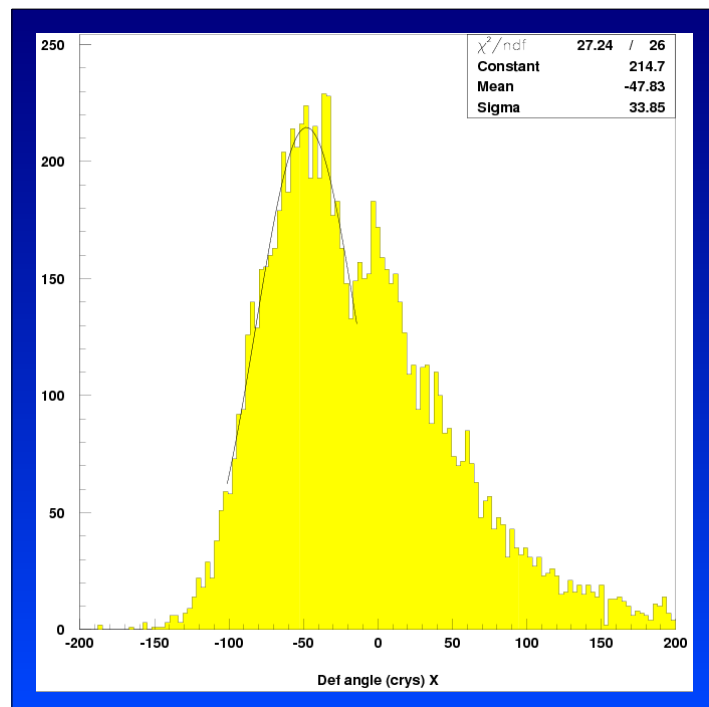
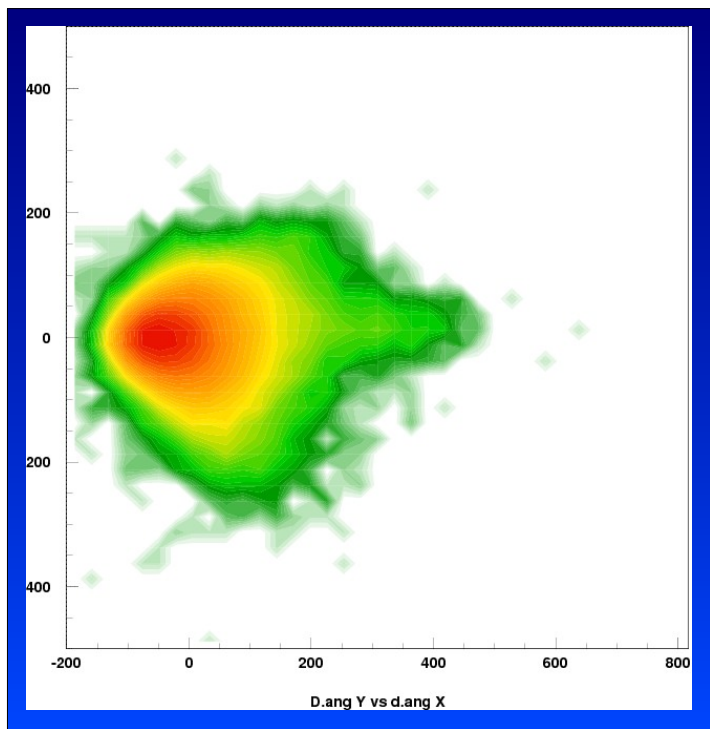
Materiale piezo elettrico

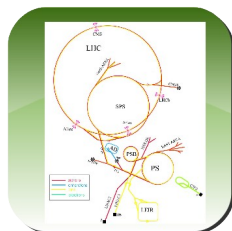


Oltre l'allineamento planare



Riflessione assiale: multiriflessione in un singolo cristallo



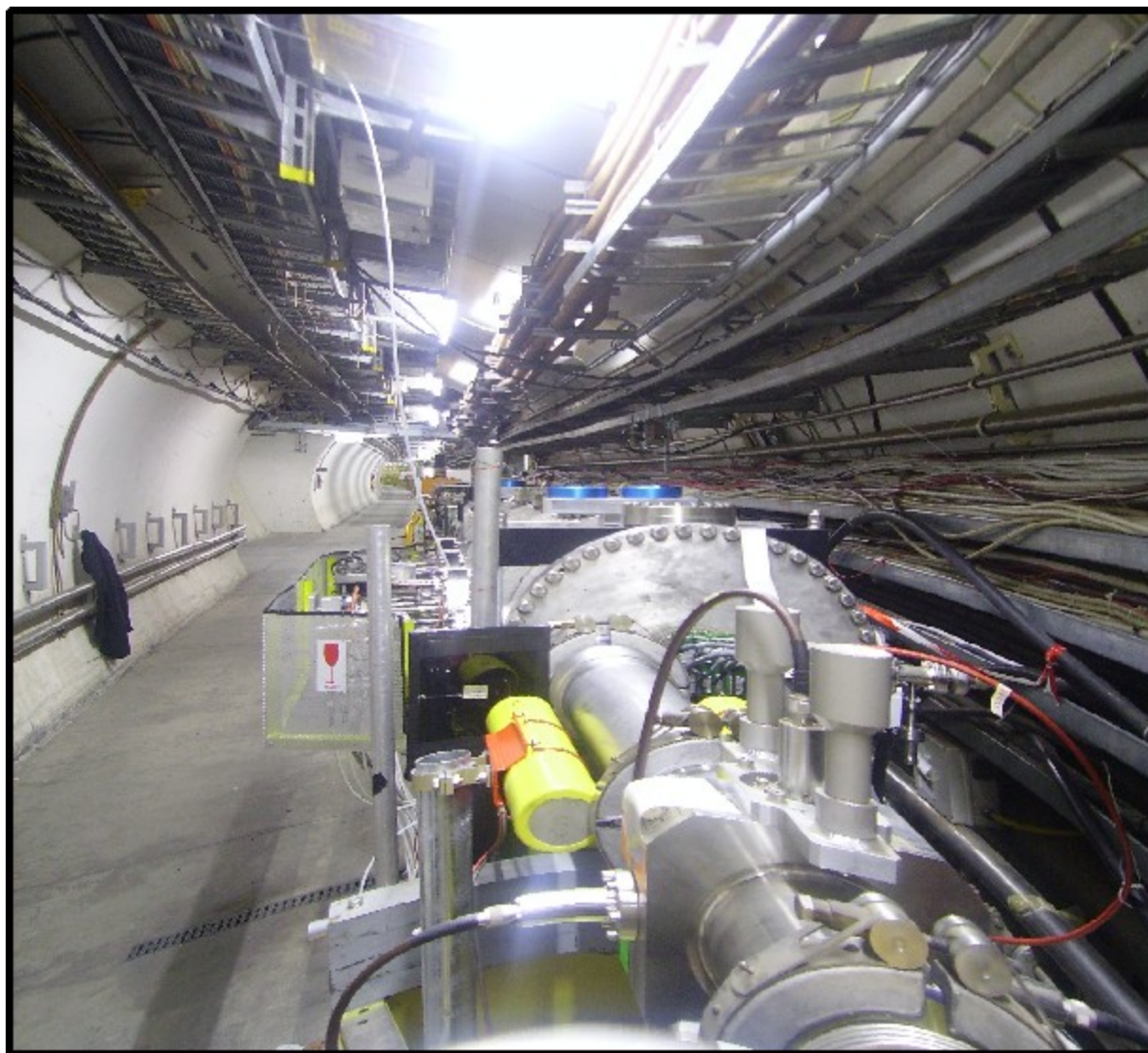
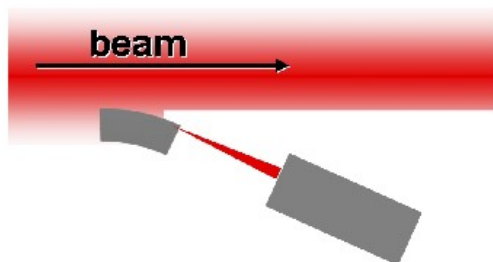


UA9 = cristalli curvi in un acceleratore circolare



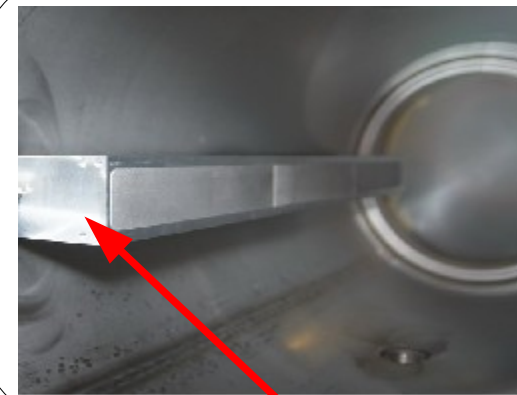
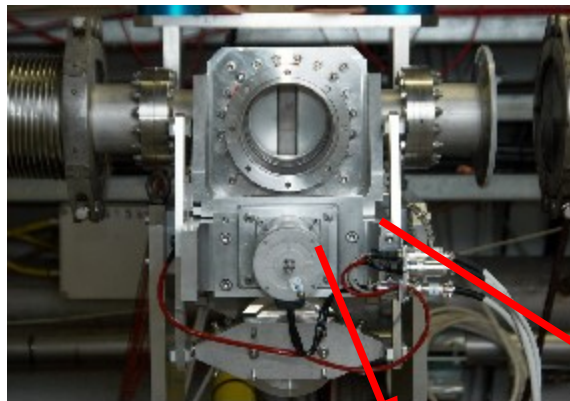
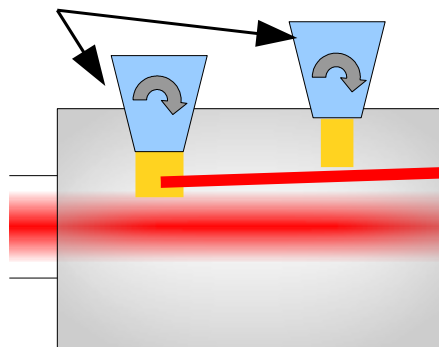
Le condizioni di un acceleratore circolare non sono riproducibili su una linea di test:

**effetti di bordo
multipassaggio**



UA9 in due parole: collimazione + tracking

Cristalli e
goniometri

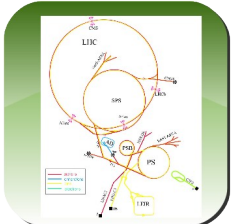


Assorbitore (W)

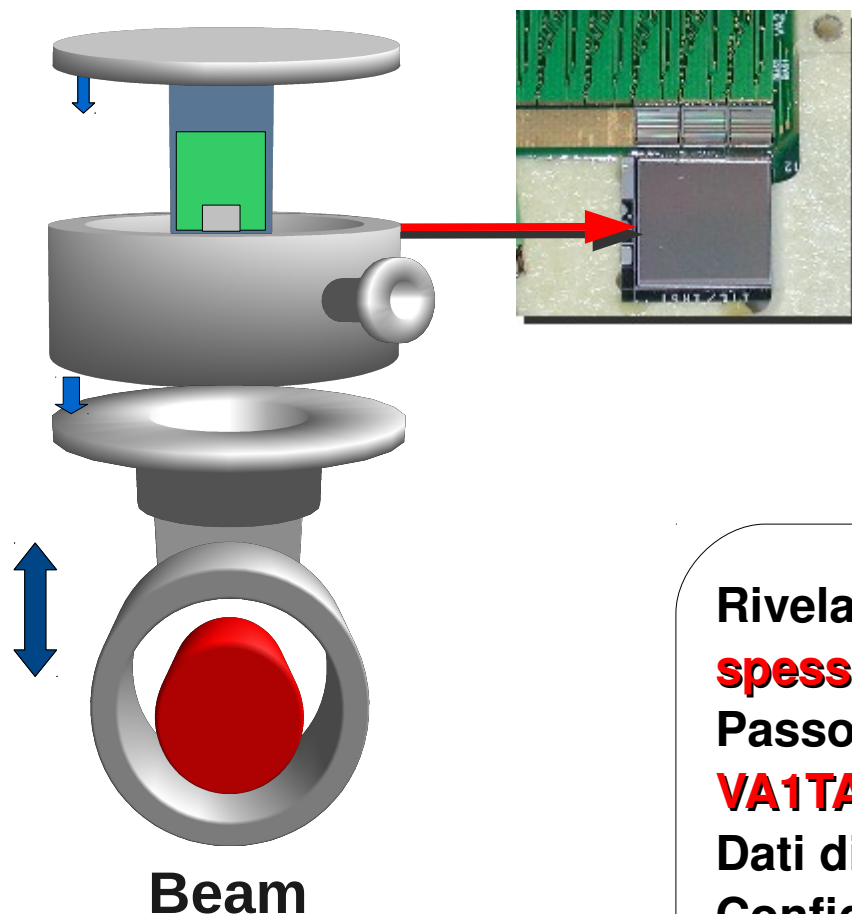
Roman pot



BLMs , GEMs e scintillatori

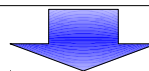


Il sistema di tracking:



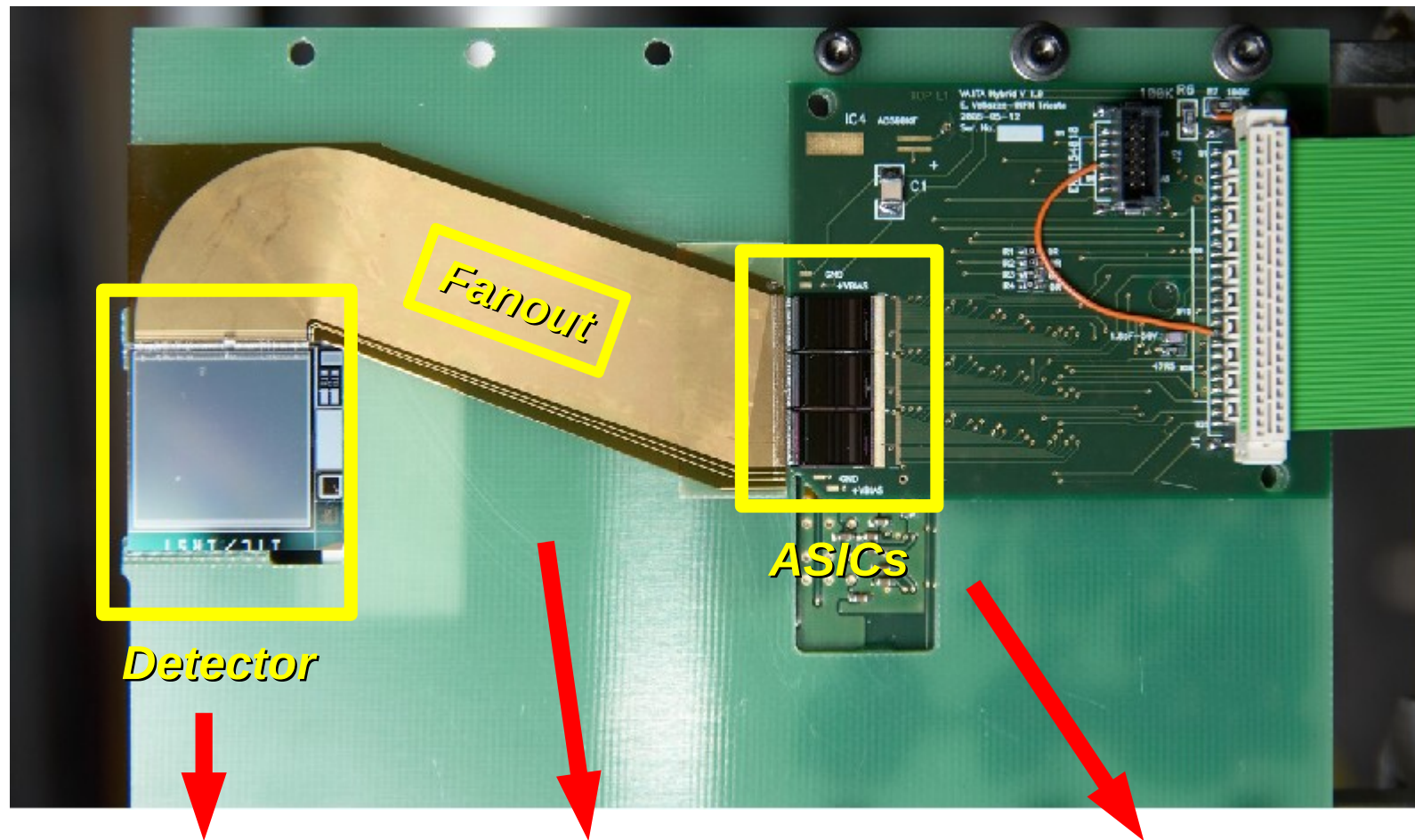
Le richieste

- **multiple scattering limitato**
- Alta **risoluzione spaziale**
- Sistema **'self triggering'**
- Ridotta **zona morta**
- I sistemi di configurazione e monitoraggio devono **essere remoti**



Rivelatore a microstrip di silicio doppia faccia:
spessore $300\mu\text{m}$;
Passo di lettura: **$50\mu\text{m}$** (strip floating sul lato J);
VA1TA self-triggering ASIC;
Dati digitalizzati trasmessi tramite **fibre ottiche**
Configurazione e controllo remoti
(utilizzando cavi standard)

Il Prototipo: **Lato giunzione**

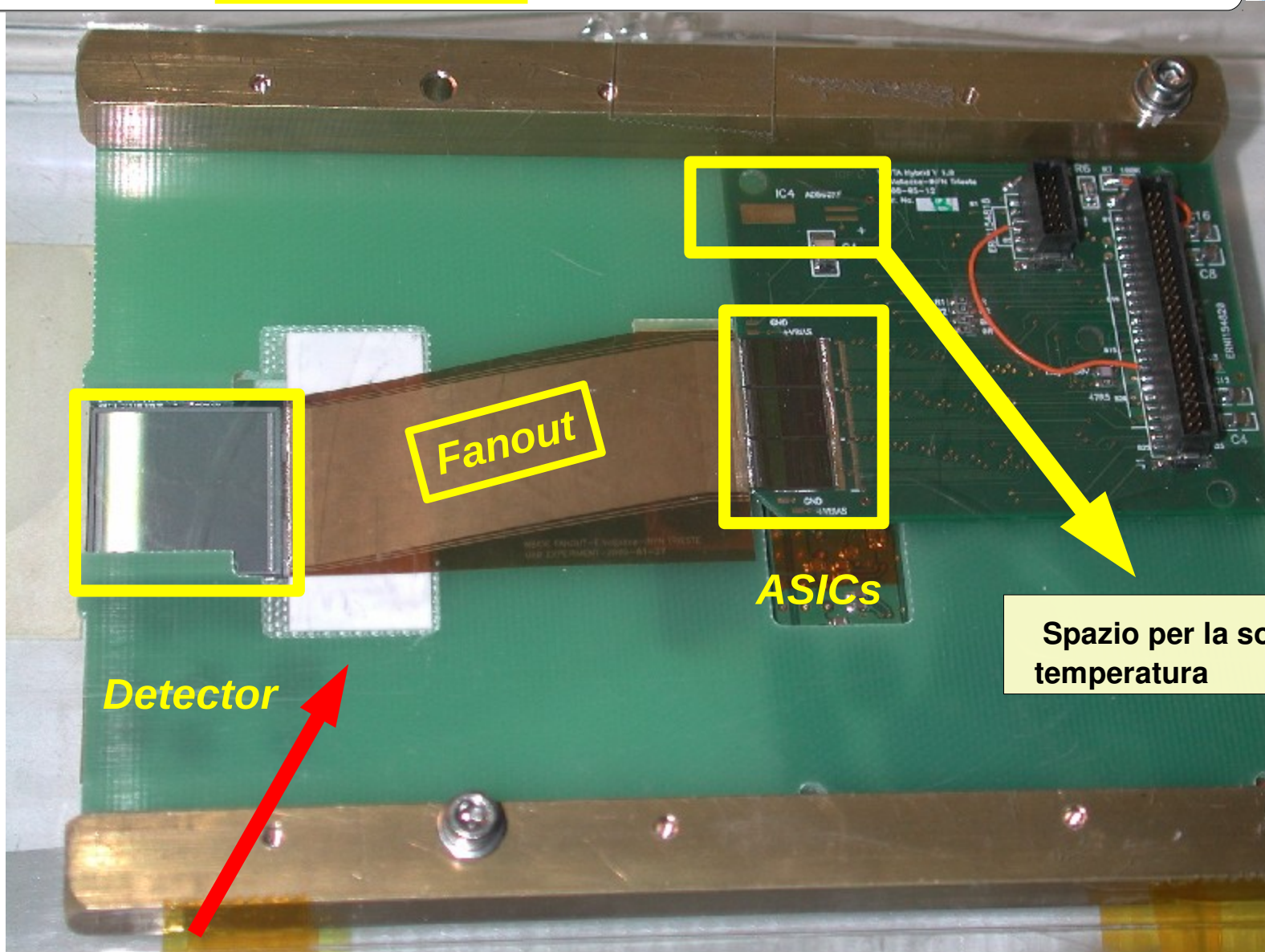


1.92x1.92 cm²
Passo fisico: 25μm;
Passo di lettura: 50μm →
strip floating
Prodotto da FBK

Upilex fanout
Tracce dorate, passo 50μm
Prodotto al CERN

VA1TA ASIC con preamplificatore,
shaper e sample&hold
auto-triggerante (200 ns)
Prodotto da Gamma Medica-Ideas

Il prototipo: **Il lato Omico**



Supporto ceramico per
il bonding

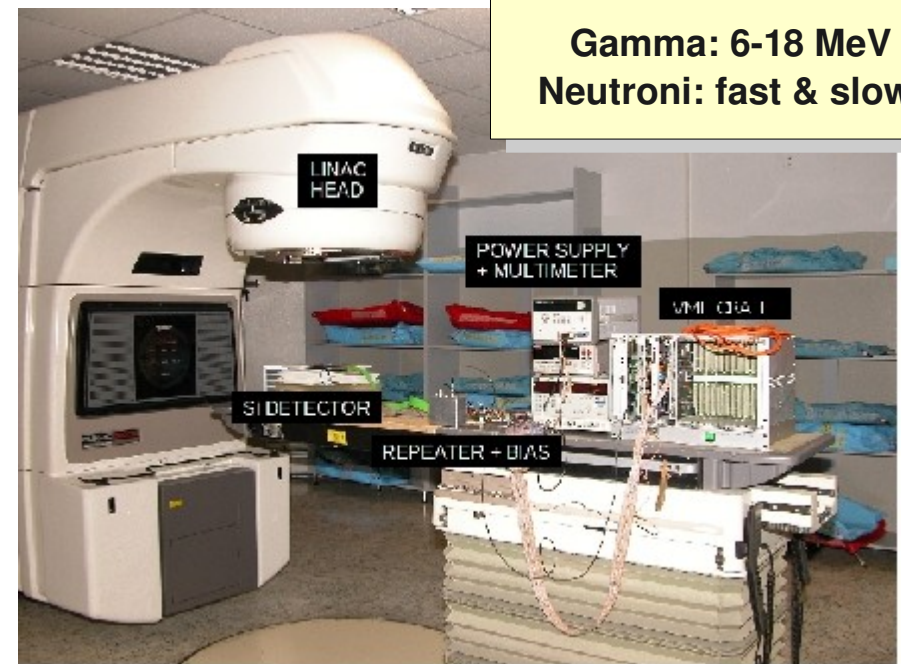
Test di resistenza alle radiazione

Test effettuati all'ospedale Sant'Anna con un **LINAC** per radioterapia

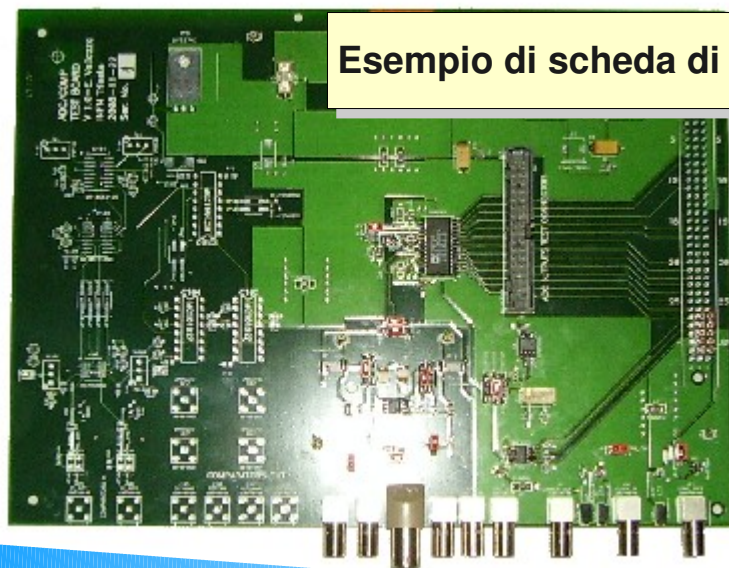
Ogni componente critico e' stato testato in modo indipendente su una scheda dedicata

Danno da radiazione testato con gamma (fino a un **1 kGy**, 300 Gy/year sono il valore atteso)

Test di SEU con neutroni



Gamma: 6-18 MeV
Neutroni: fast & slow

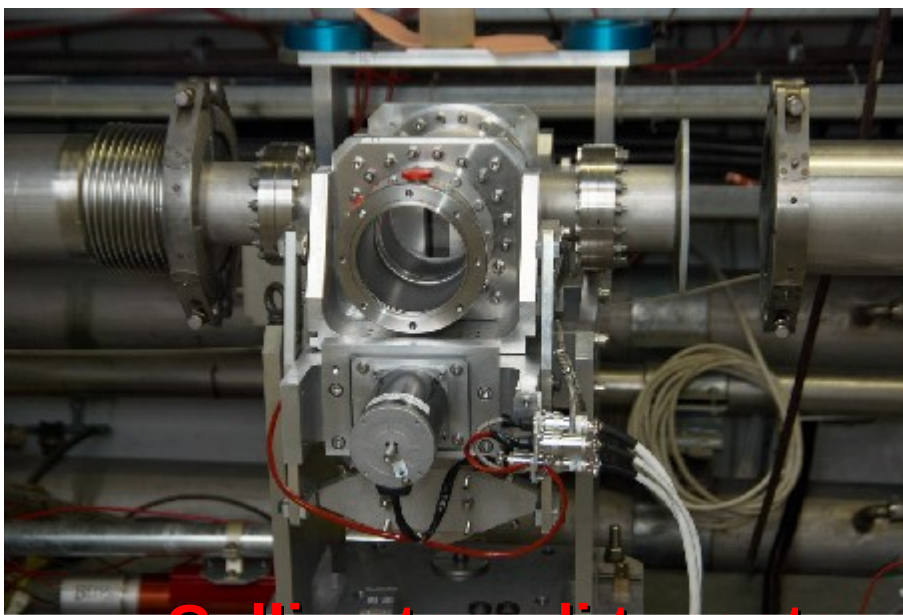


Esempio di scheda di test

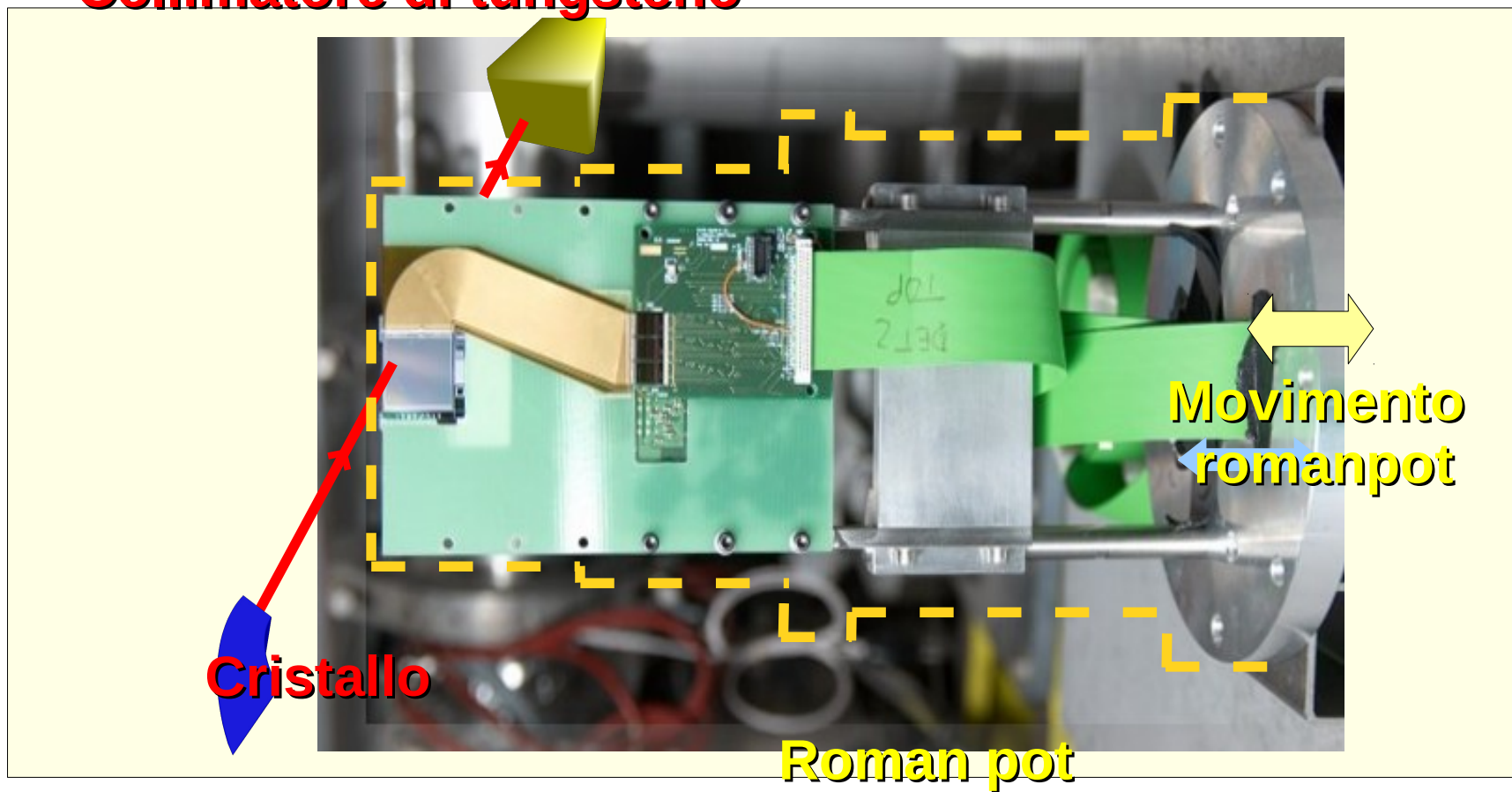
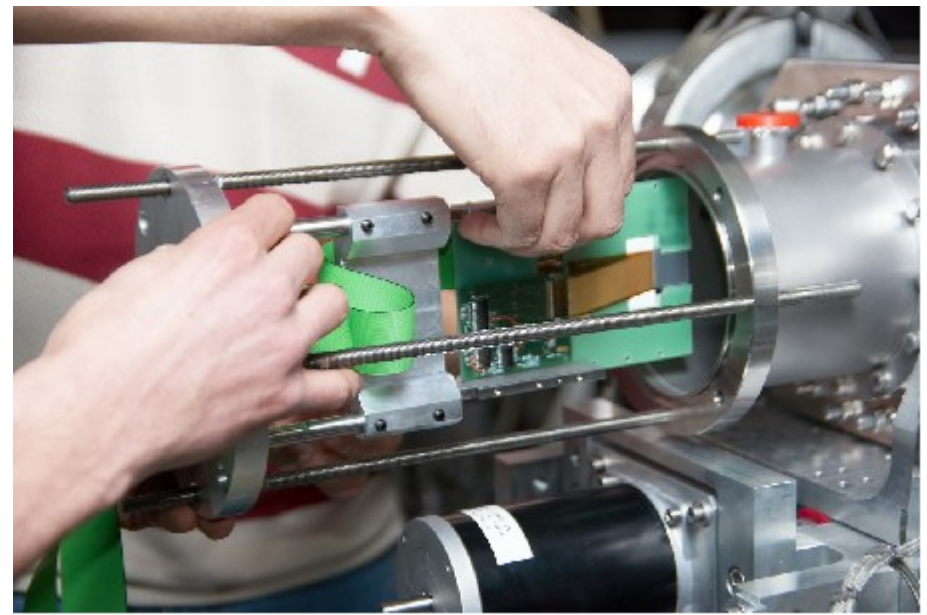
ASIC, ADC, DRIVER, RECEIVER e
REGOLATORI: **OK**

DAC: **KO**

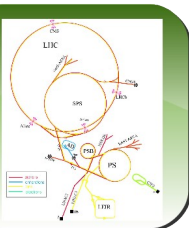
Sostituito con uno piu' resistente



Collimatore di tungsteno



Disposizione dei componenti:



ZONA
radiottiva
CON
Detector
Electronica di Frontend
FPGA programmable from the surface



ZONA
Niente radiazione e
accessibile

CON
PC
crate VME



Superficie

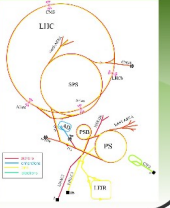
ZONA
Non radioattiva ma non
accessibile

CON
Repeater
Alimentatori

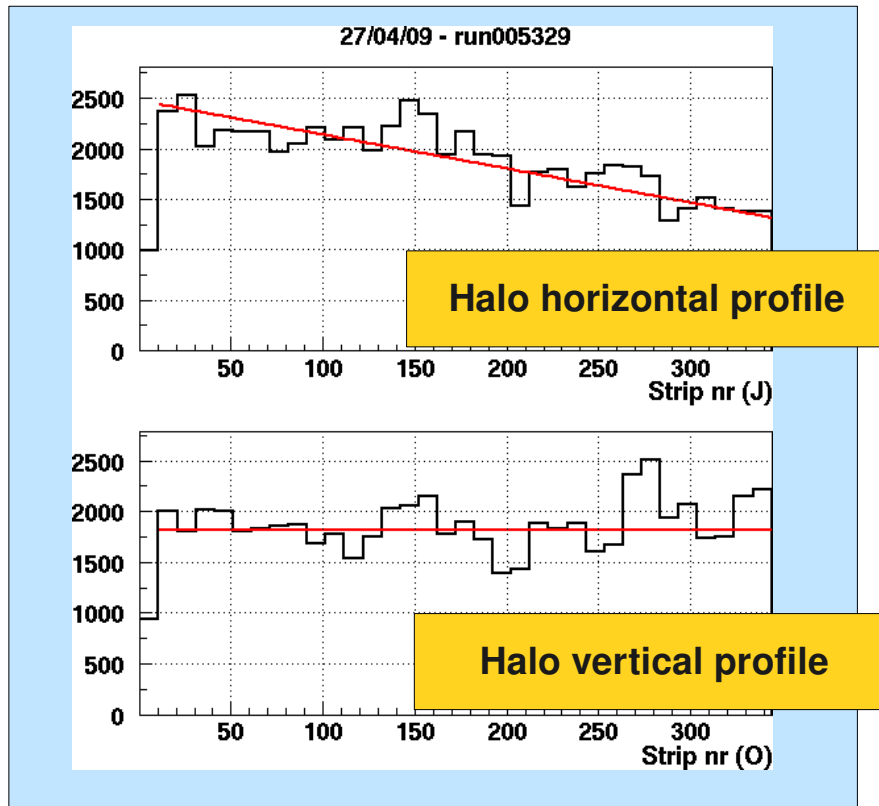


**SPS
tunnel**

**Pozzo di
servizio**



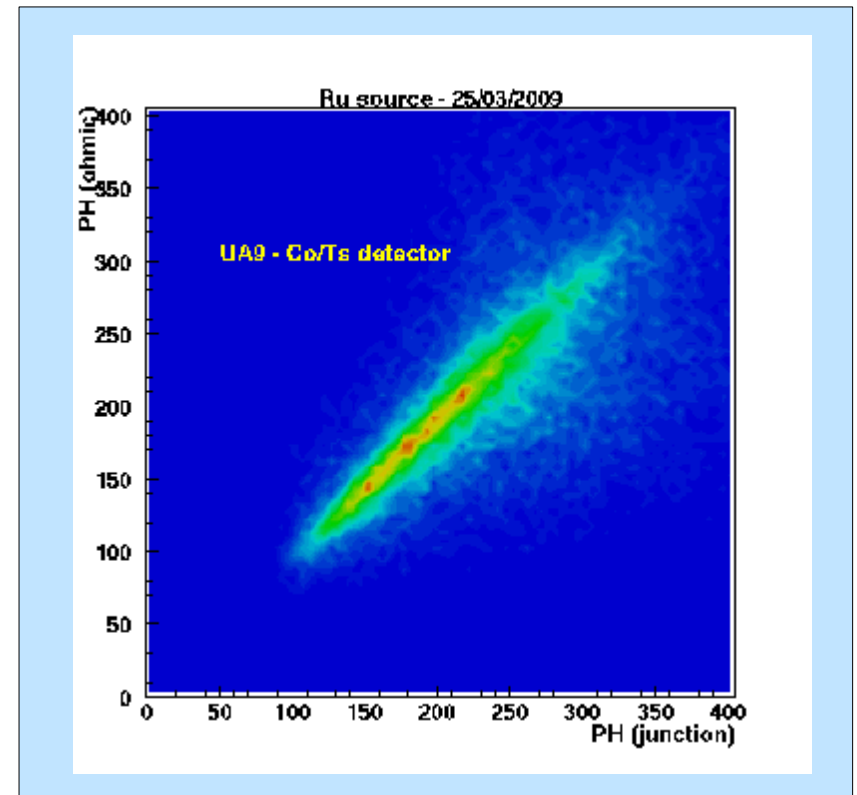
Risultati (1): Profilo dell'alone dell'SPS e correlazione di carica



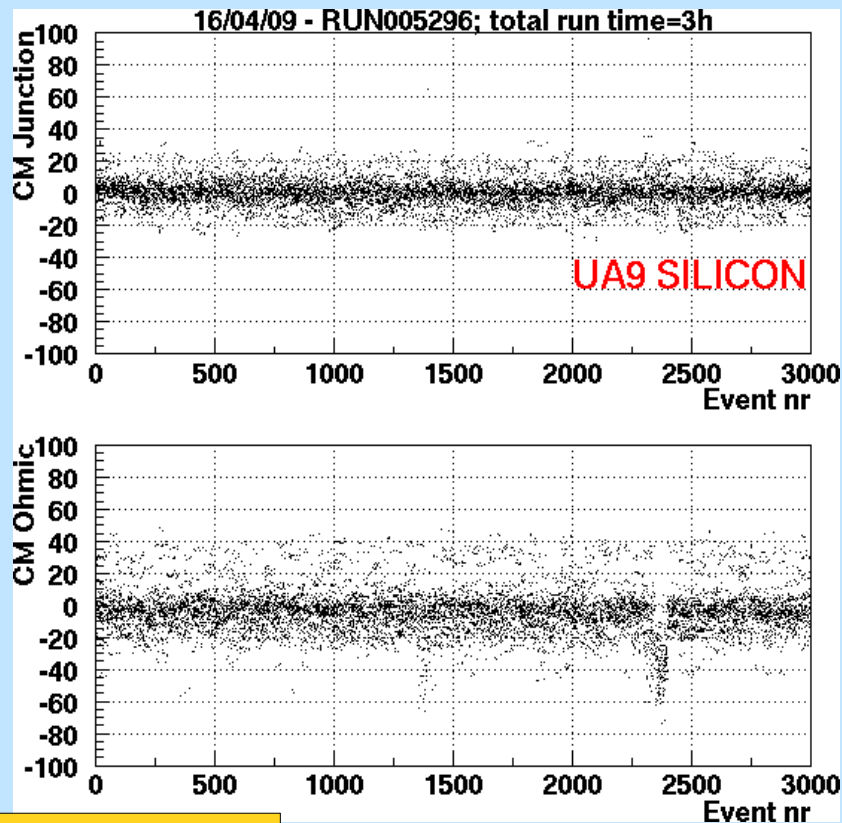
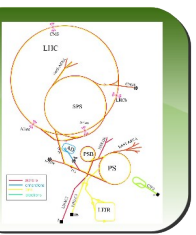
Profilo

Aprile / Maggio 2009

Correlazione segnale J - Ω

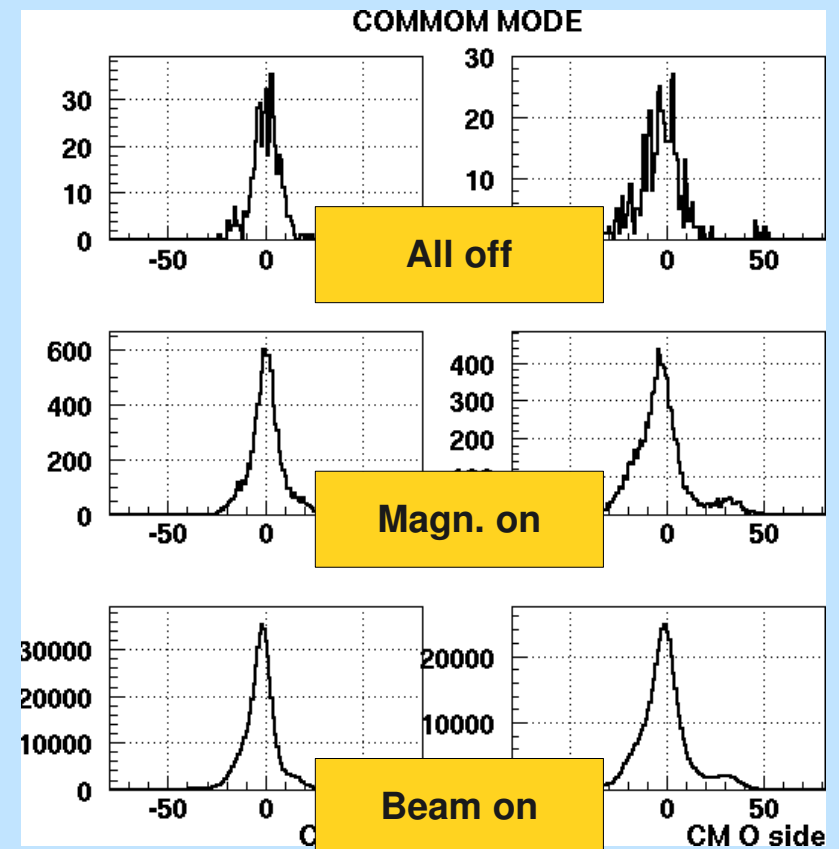


Risultati (2): Stabilita' del sistema



Trigger mask lost

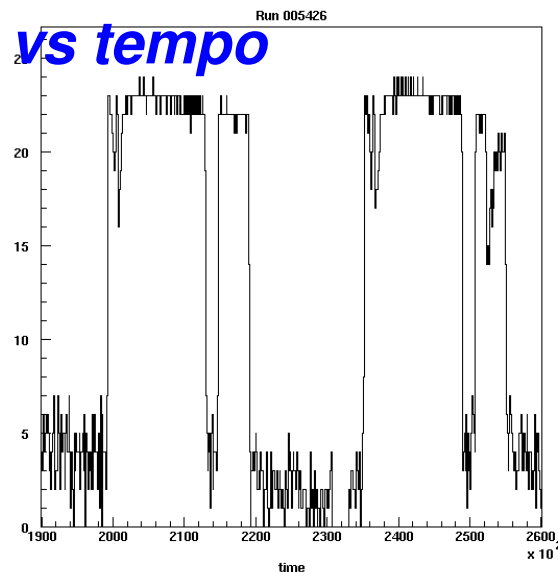
Common mode vs tempo



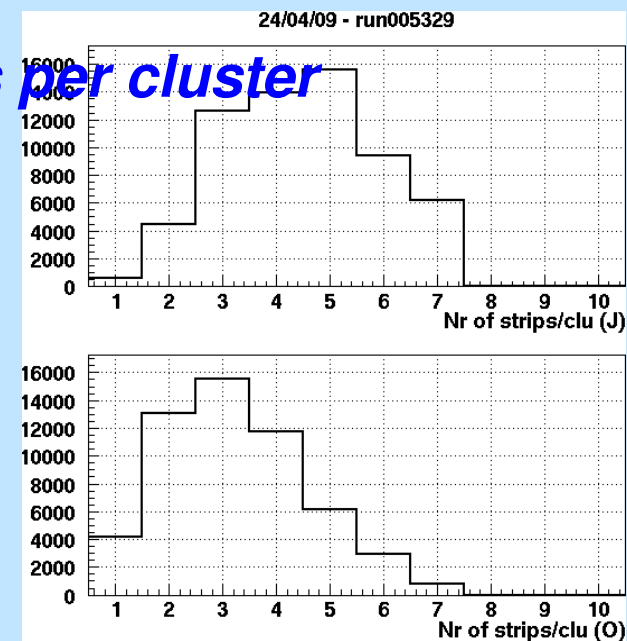
*Common mode
vs
condizioni del fascio*

Risultati (3): intensita' del fascio

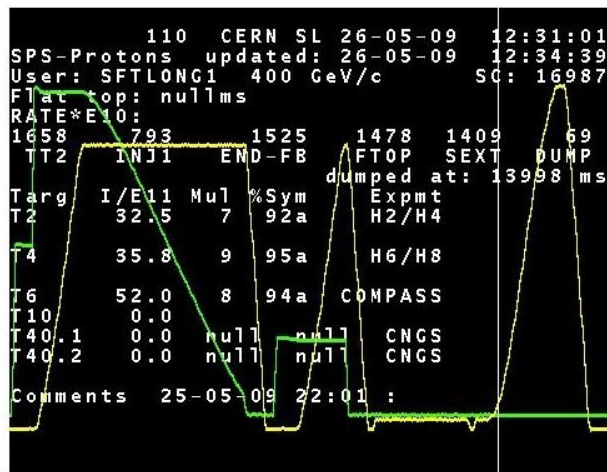
Triggers vs tempo



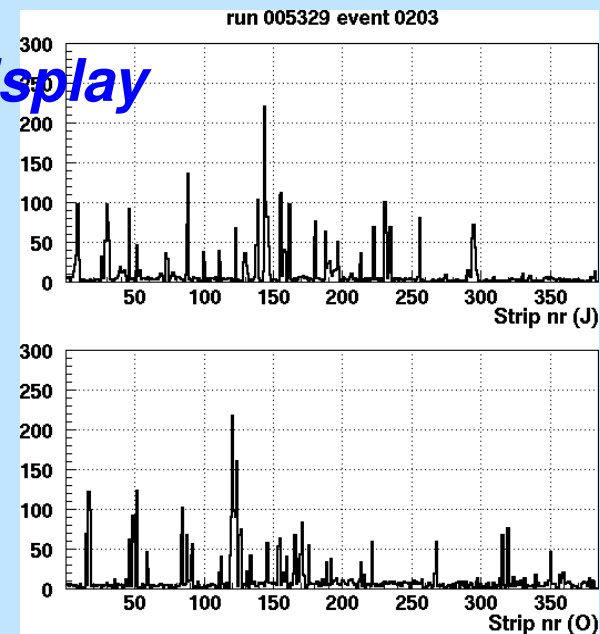
strips per cluster



Spill SPS

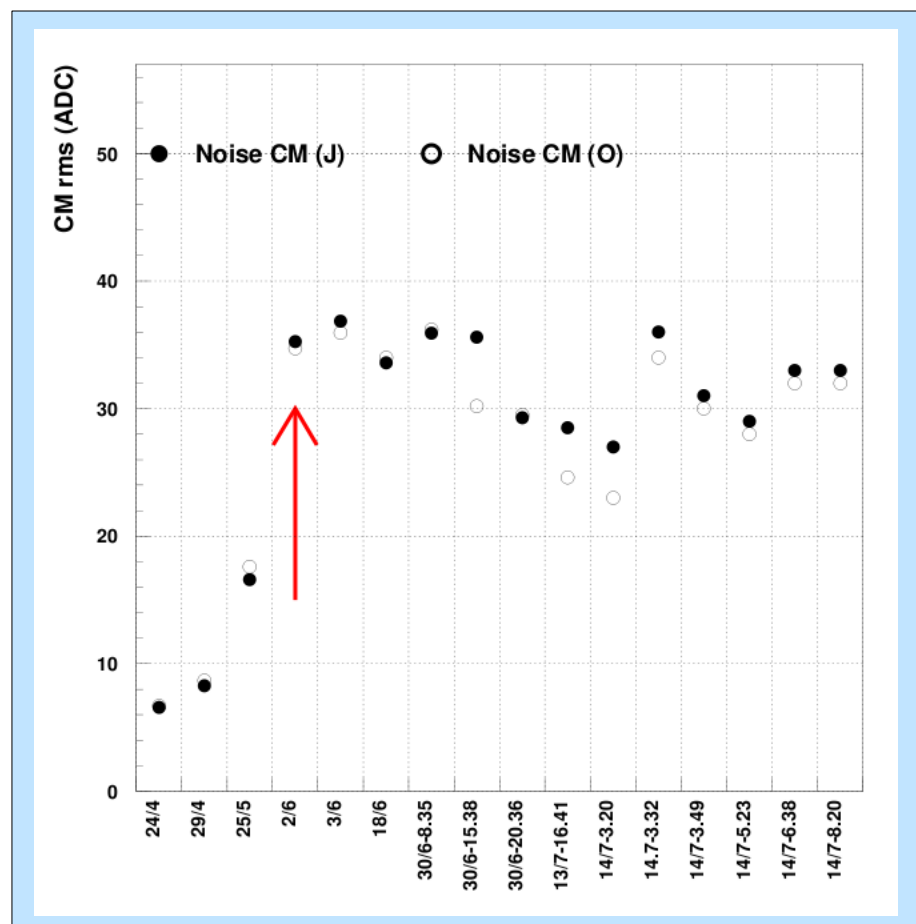
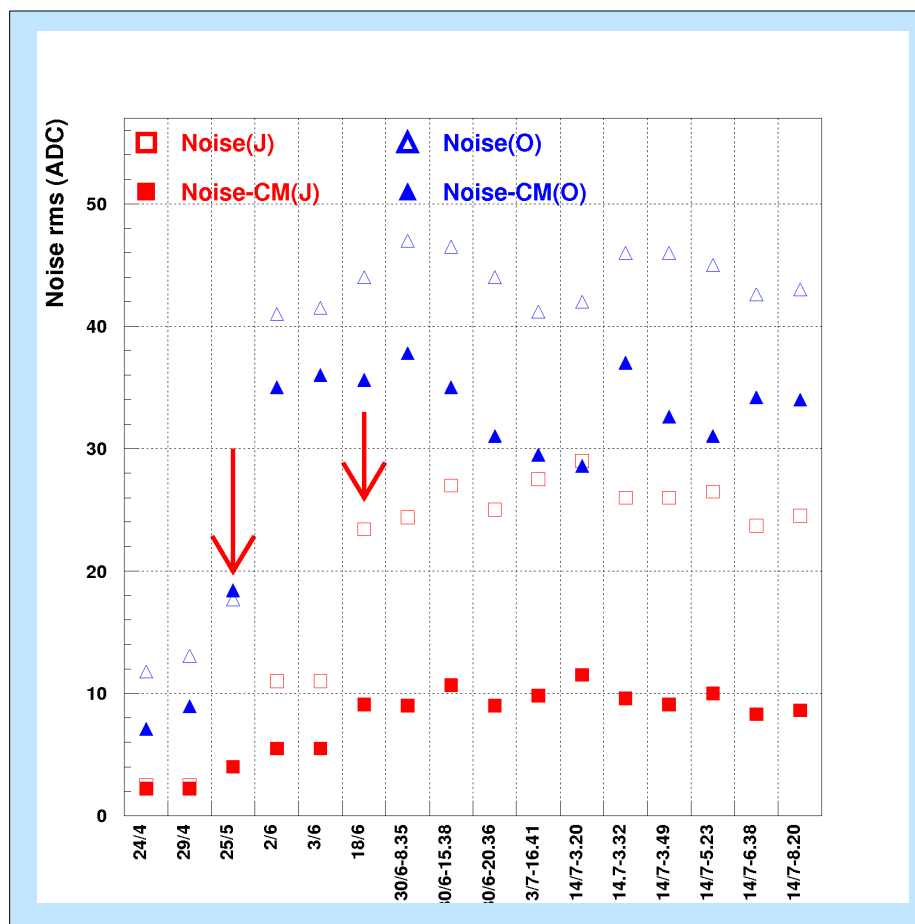


Event display



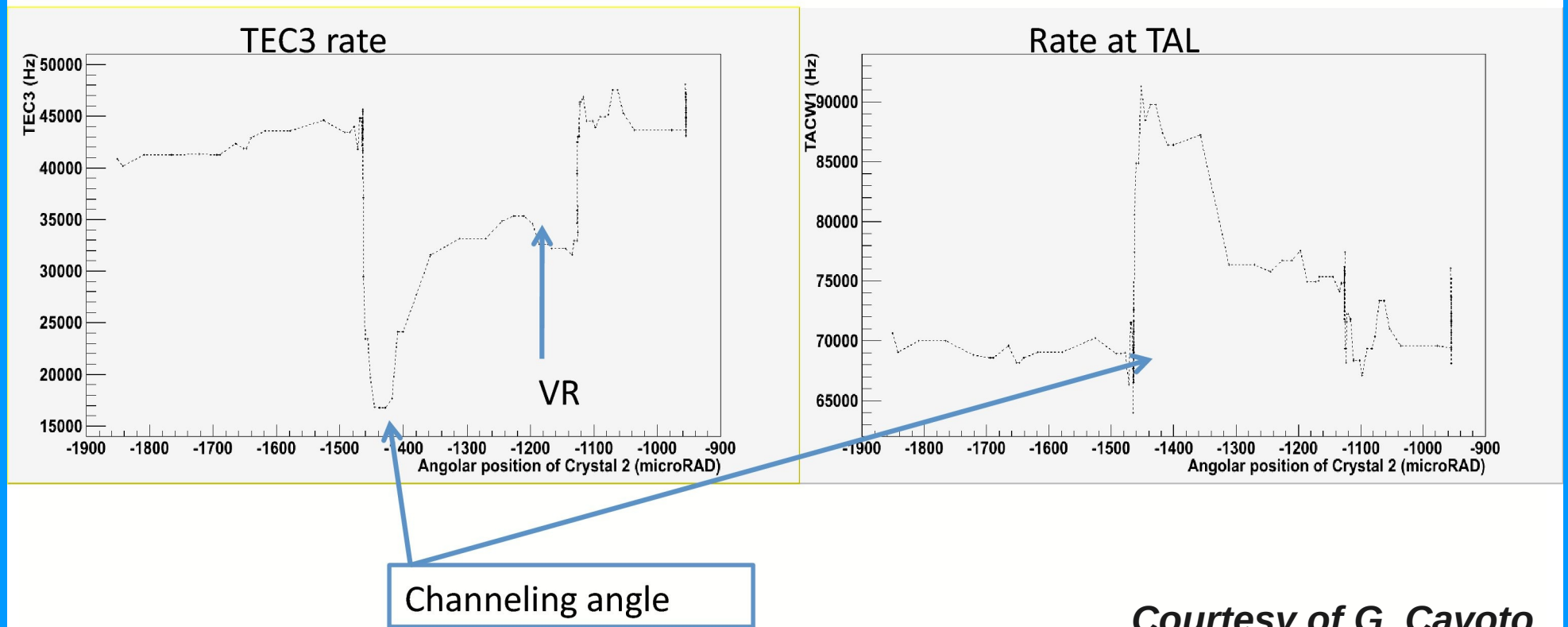
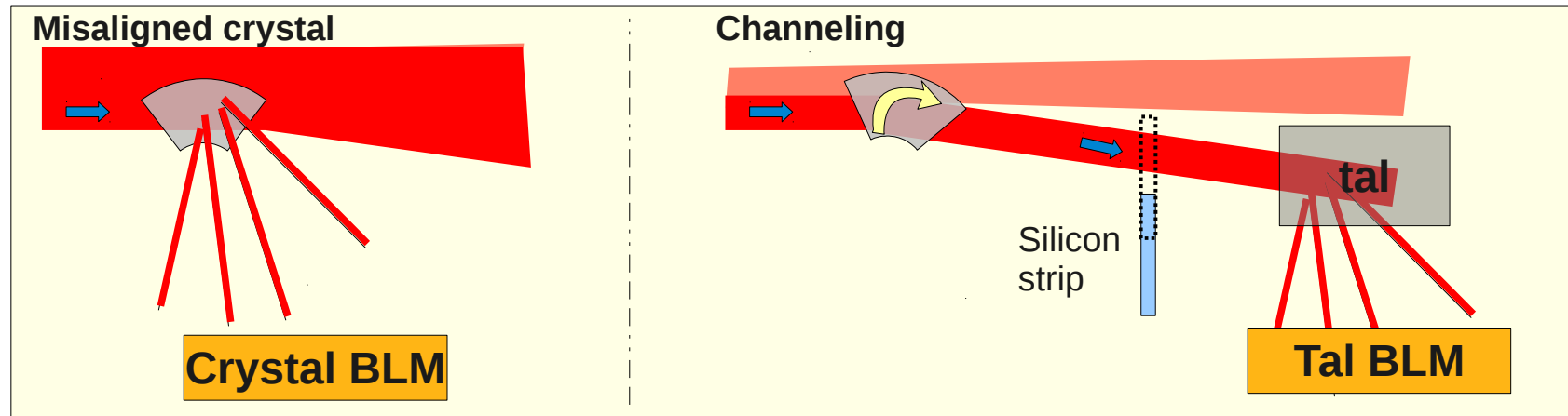
Risultati (4): Aumento del rumore nel tempo

➡ *Sia il common mode che il rumore intrinseco sono aumentati...*



➡ *Il numero di strip non funzionanti e' quasi raddoppiato dall'installazione alla prima presa dati!*

I primi passi di UA9, I cristalli funzionano!



Courtesy of G. Cavoto

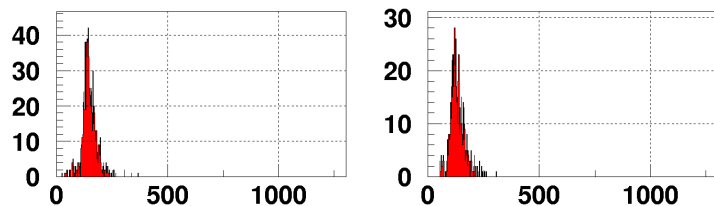
Il primo MD con il nostro prototipo

**Condizione del fascio:
singolo bunch di 5ns**

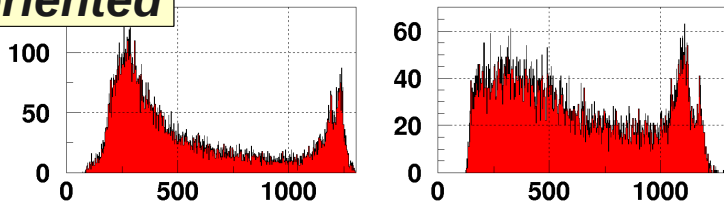


**Il sistema standard di identificazione della
posizione non puo' essere usato**

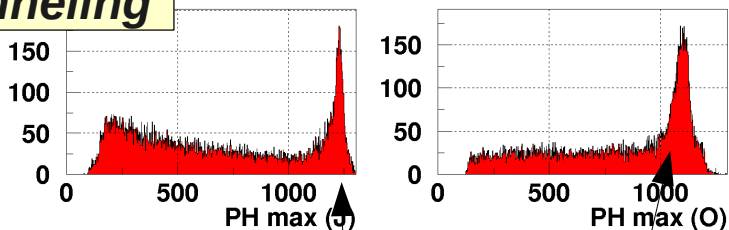
parking



Not oriented

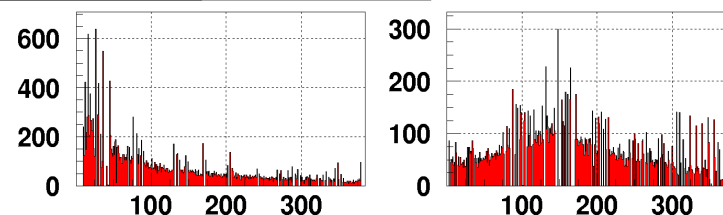


Channeling

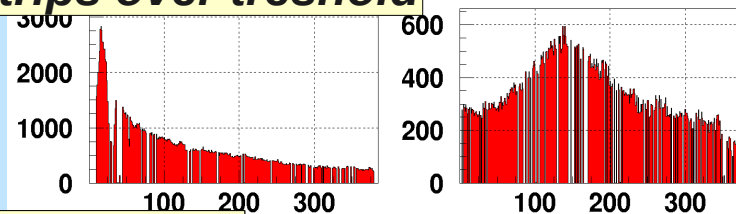


Saturazione del VA1TA (10mips)

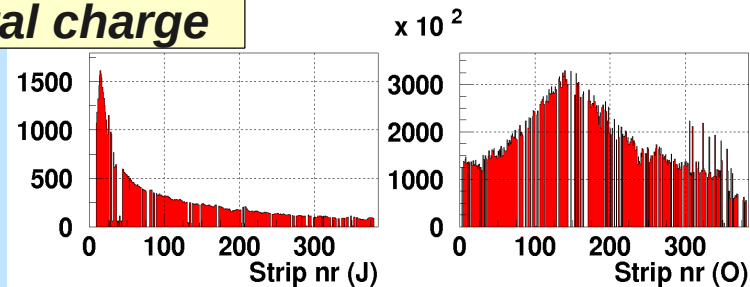
Strip with maximum



All strips over treshold

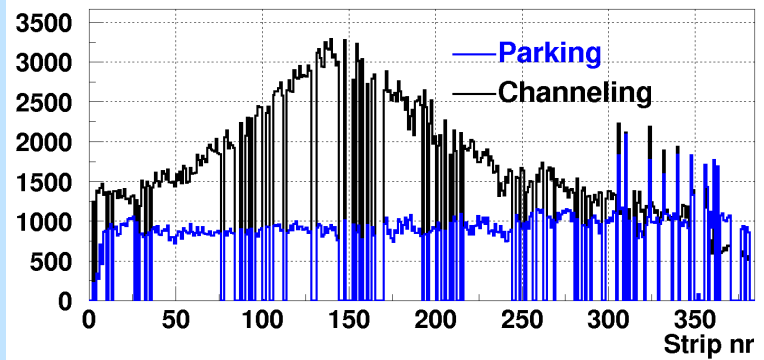
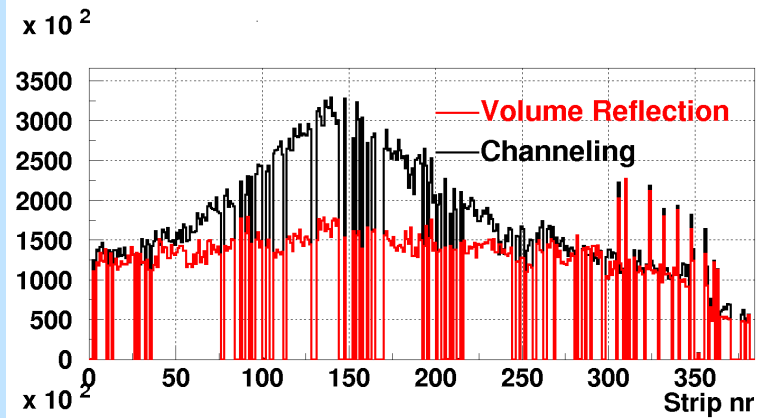
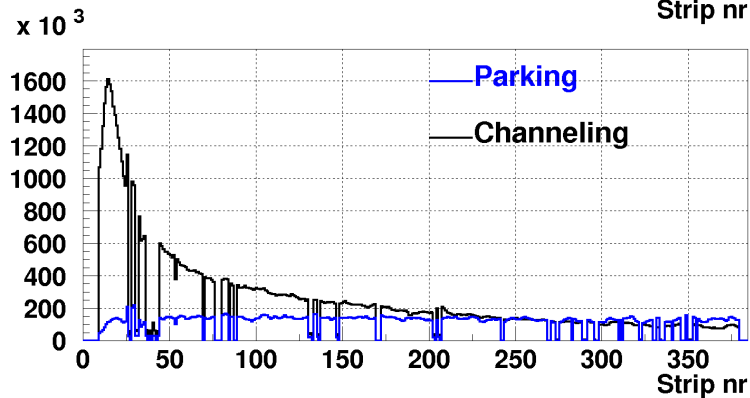
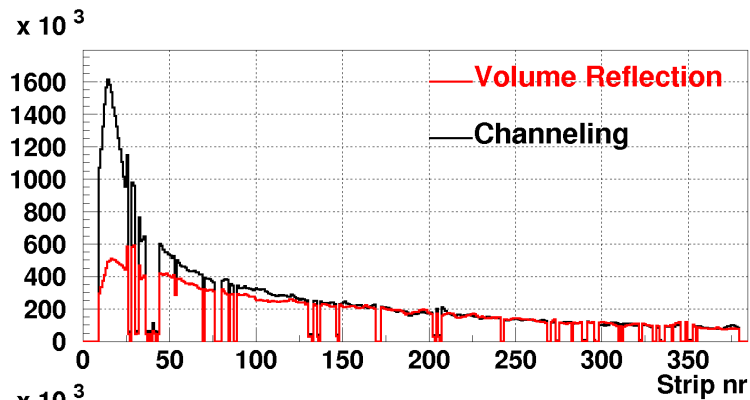
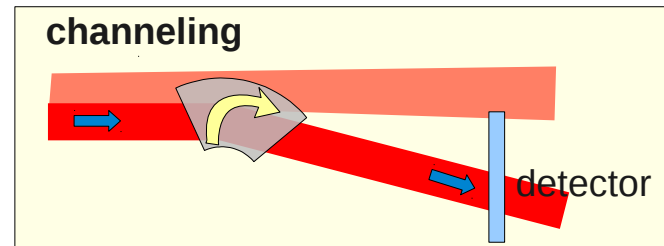
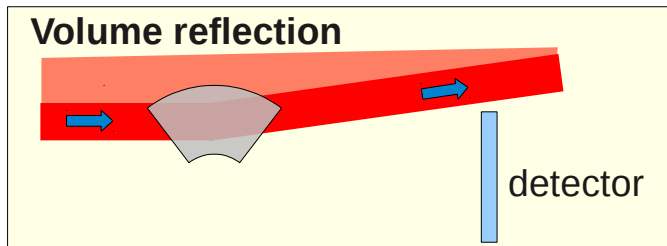


Total charge

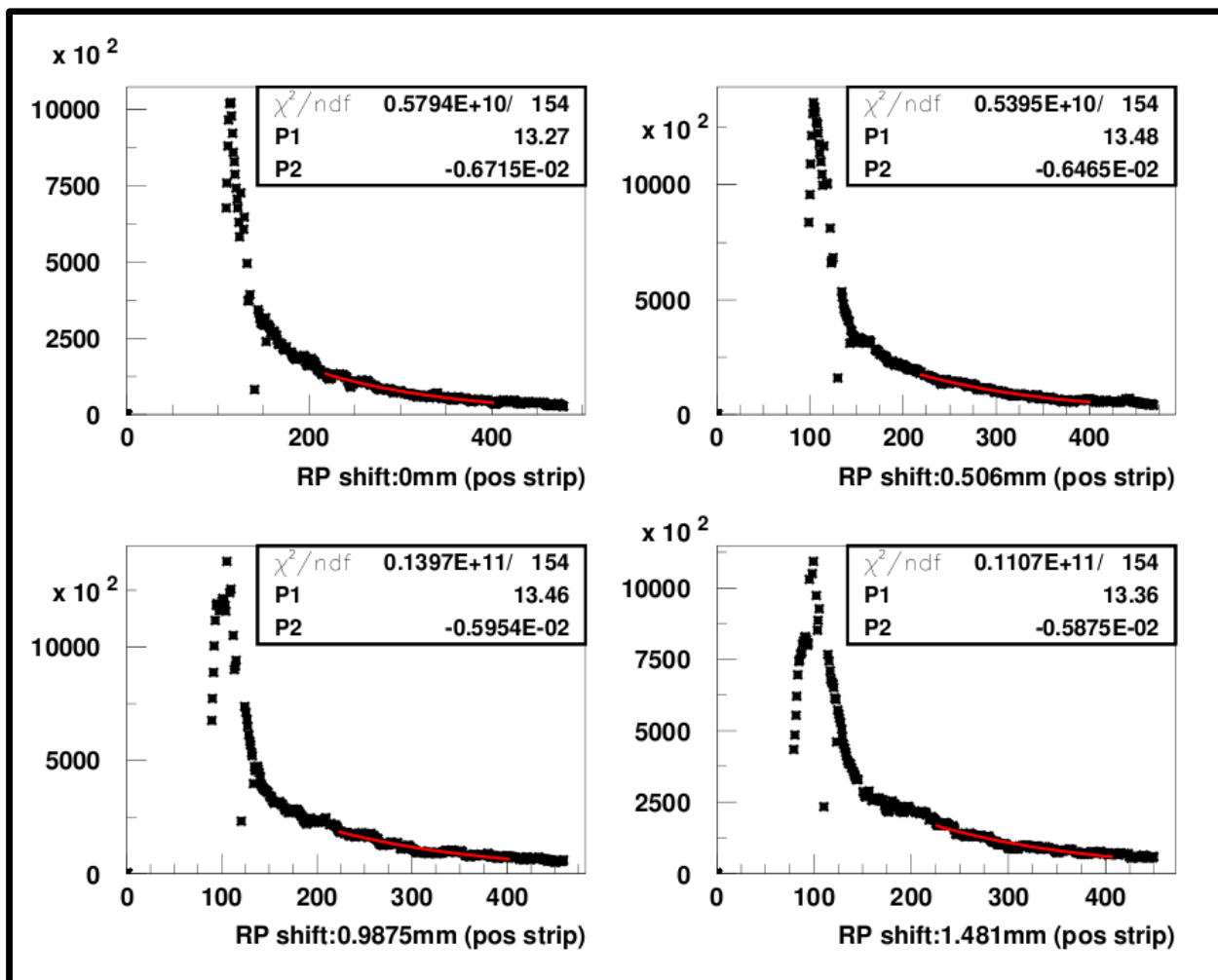
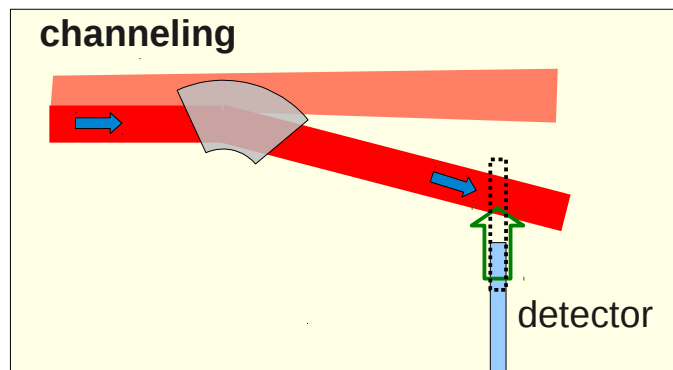


Il primo MD con il nostro prototipo → scan con il goniometro

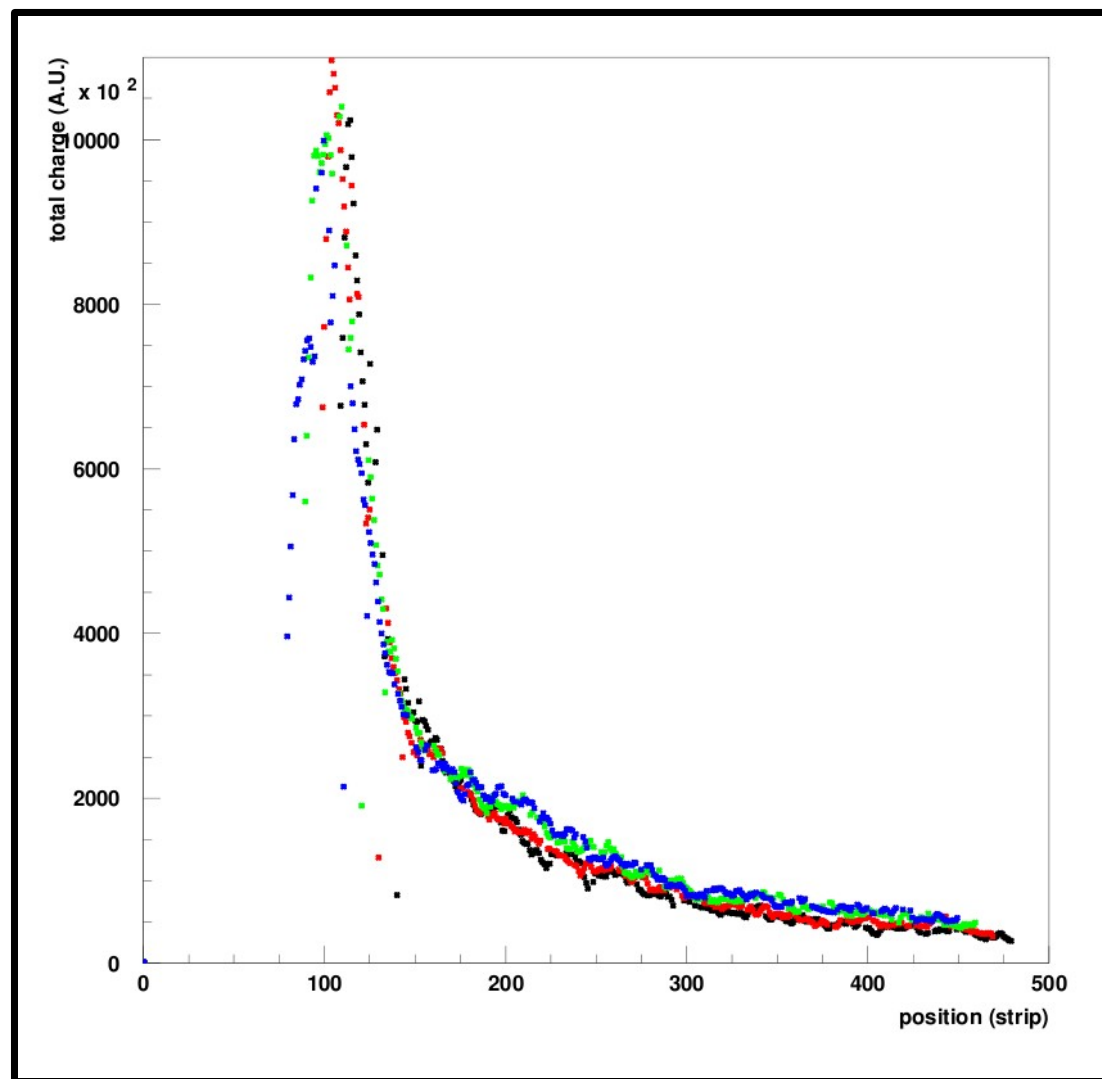
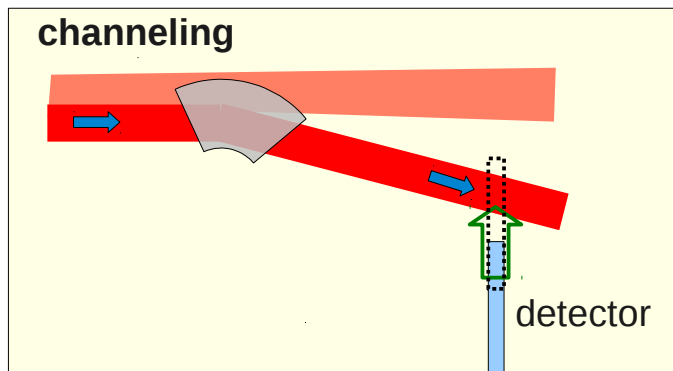
Beam intensity



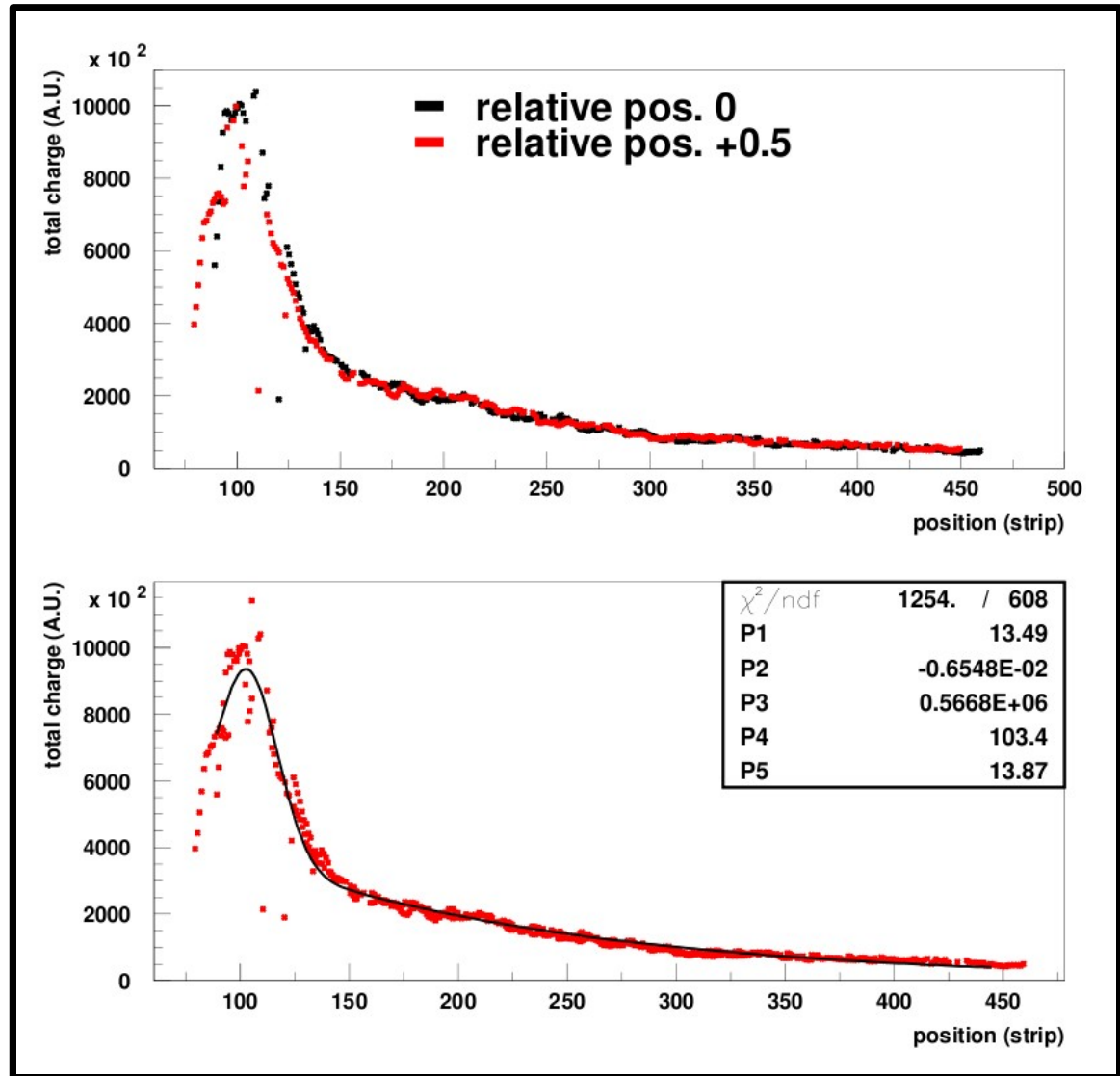
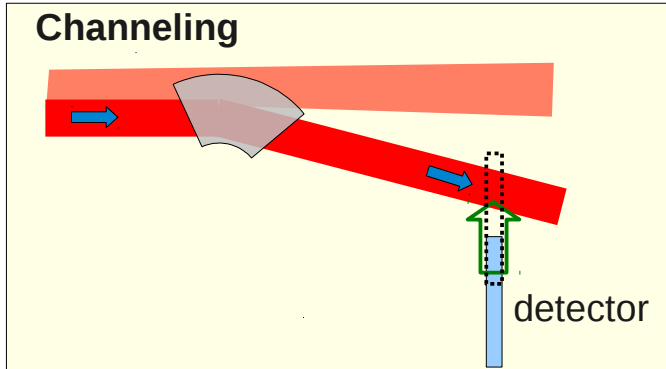
Il primo MD con il nostro prototipo → scan con il roman pot



Il primo MD con il nostro prototipo → scan con il roman pot



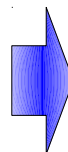
Il primo MD con il nostro prototipo → scan con il roman pot



Cosa abbiamo imparato dal prototipo:

Problemi

Alcune strip morte prima dell'installazione
Regione di bordo rumorosa
Deterioramento dovuto alla dose accumulata
Condizioni del fascio molto diverse da quelle previste!

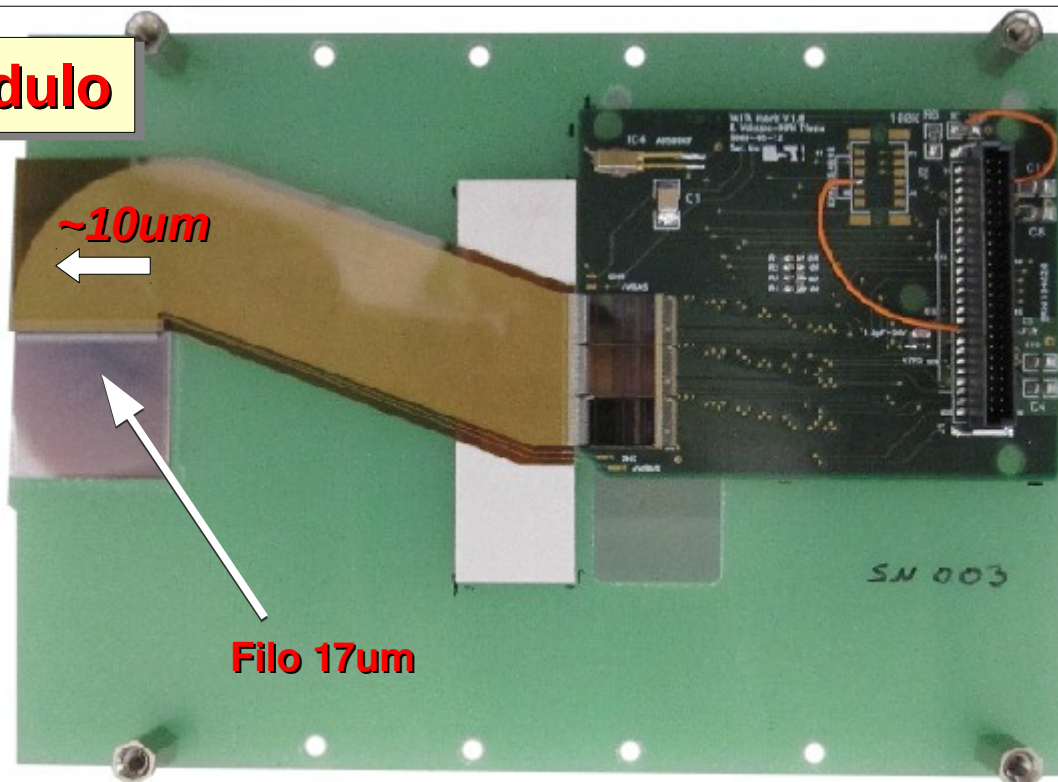


Soluzioni

Bonding con il filo da 17um
Riduzione della lunghezza del fanout
Uso di rivelatori singoli
Questo sfortunatamente dipende dalla collaborazione UA9

Nuovo modulo

Singolo layer →

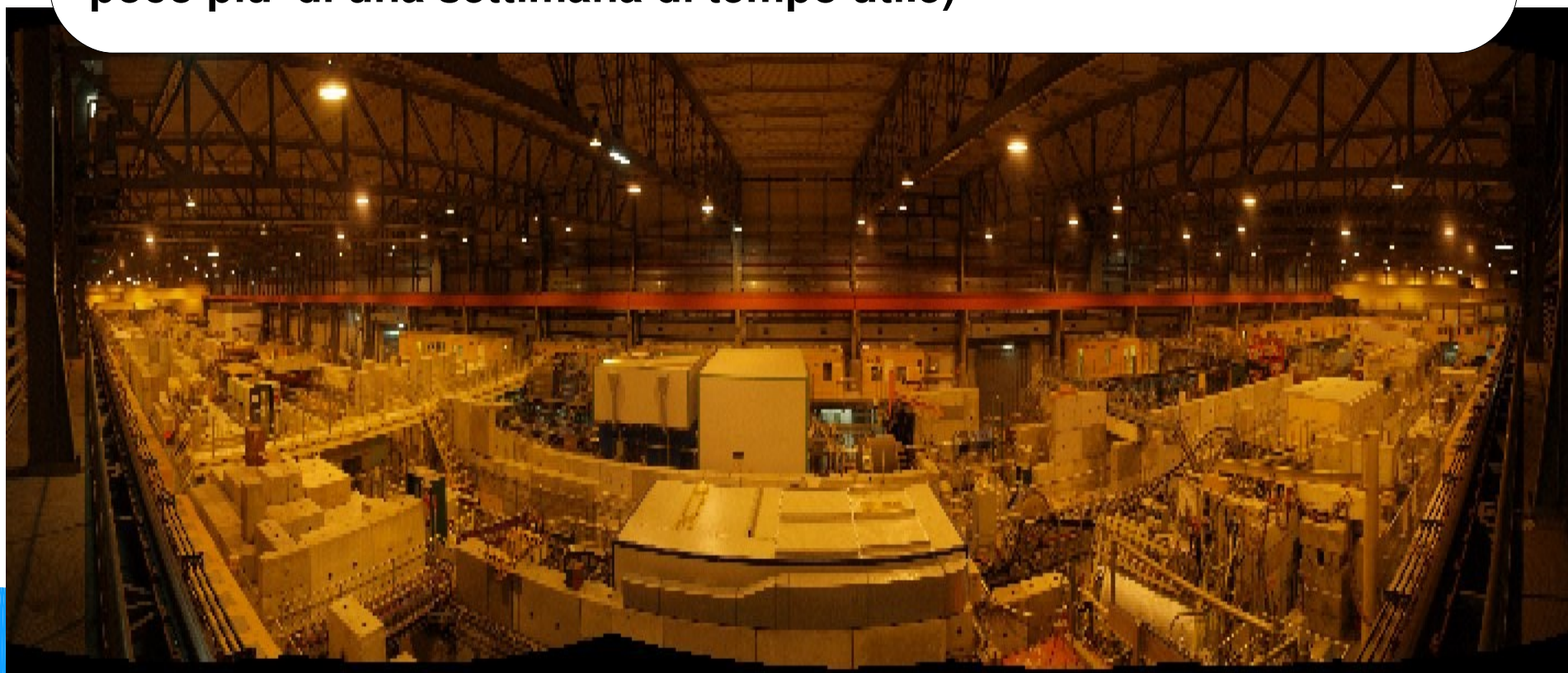




Insurad

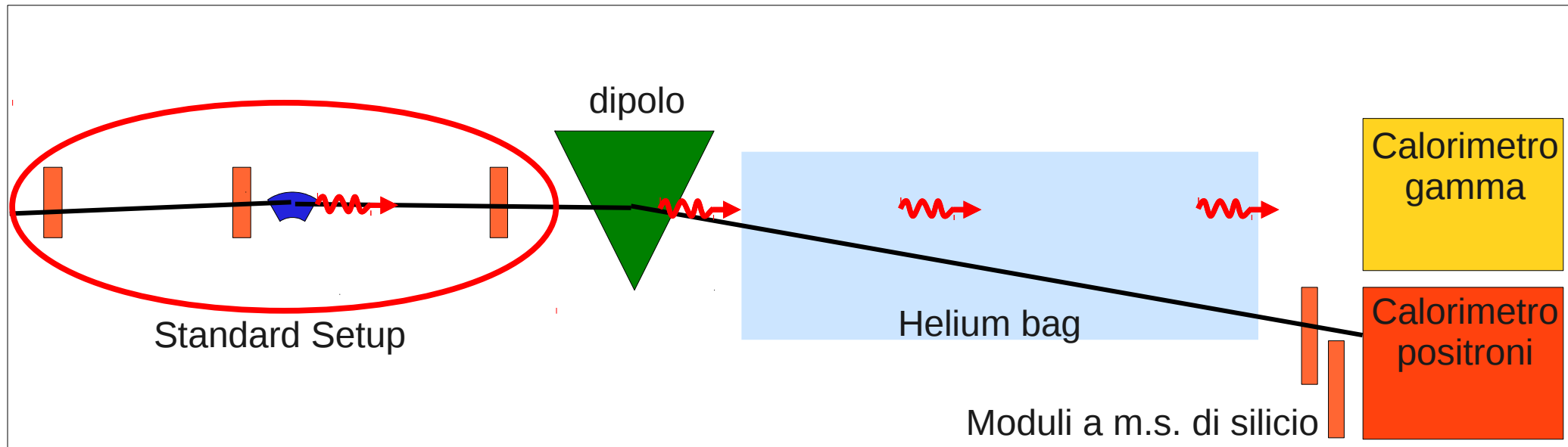
Misura degli **spettri di radiazione** emessi da diversi cristalli in diverse orientazioni

Fascio secondario di positroni di momento $120 \text{ GeV}/c$ (purtroppo poco piu' di una settimana di tempo utile)



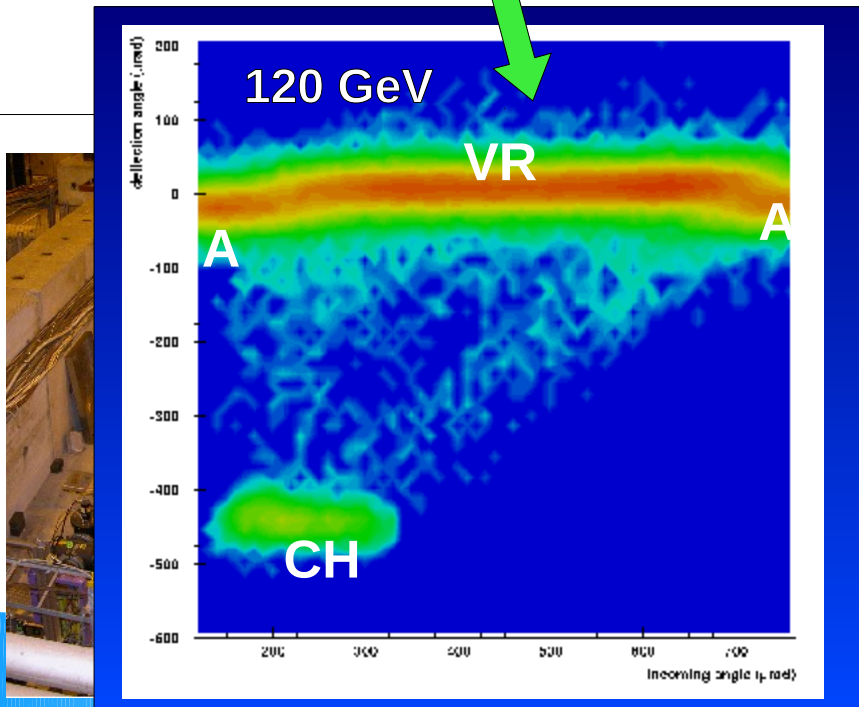
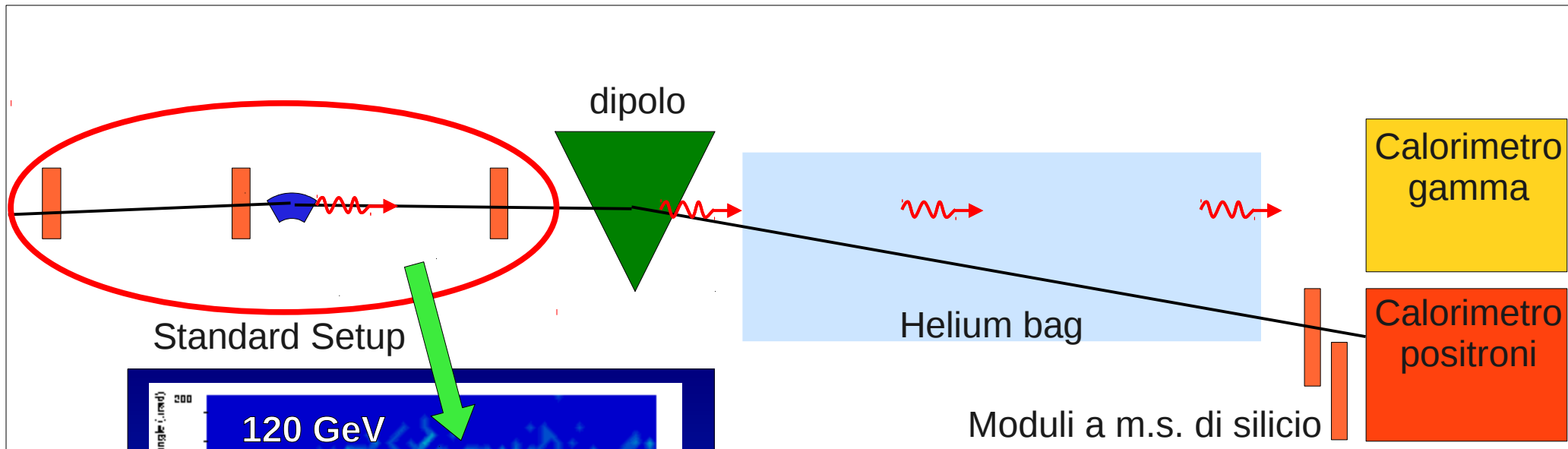


Emissione di radiazione: test con e^+ di 120 GeV



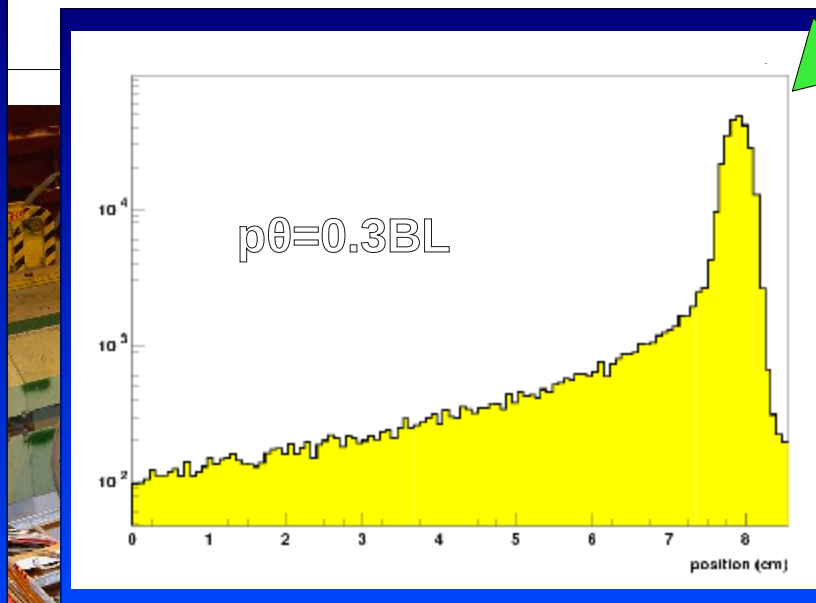
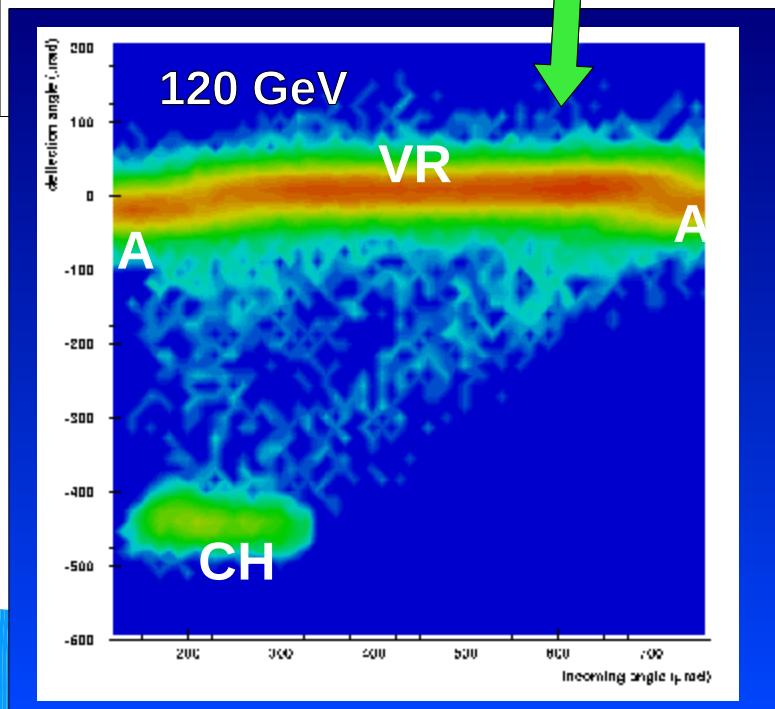
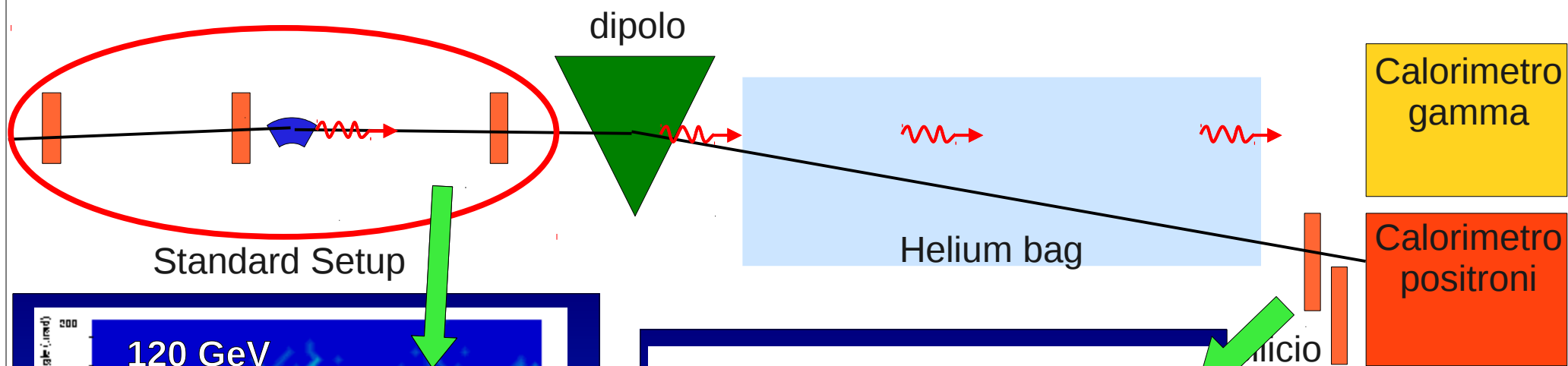


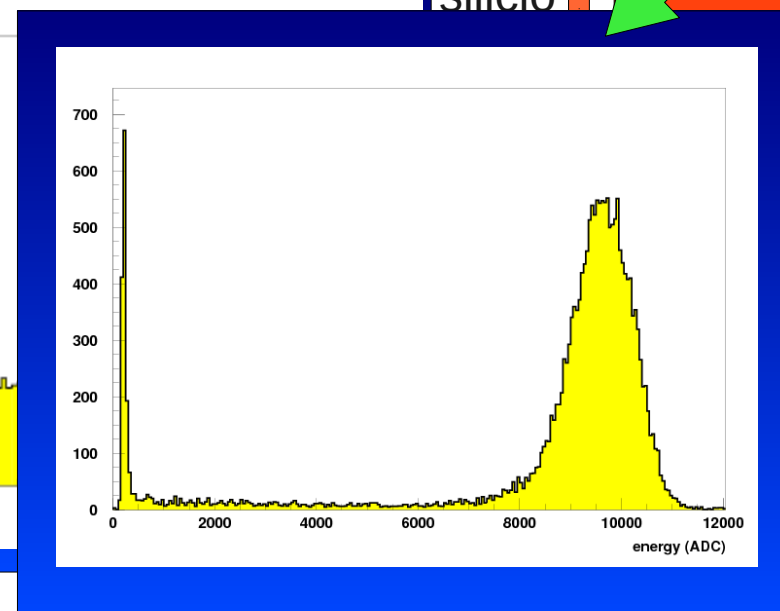
Emissione di radiazione: test con e^+ di 120 GeV





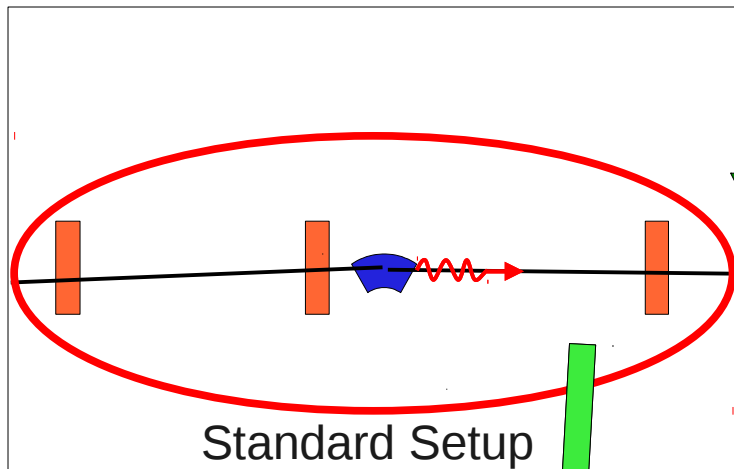
Emissione di radiazione: test con e⁺ di 120 GeV



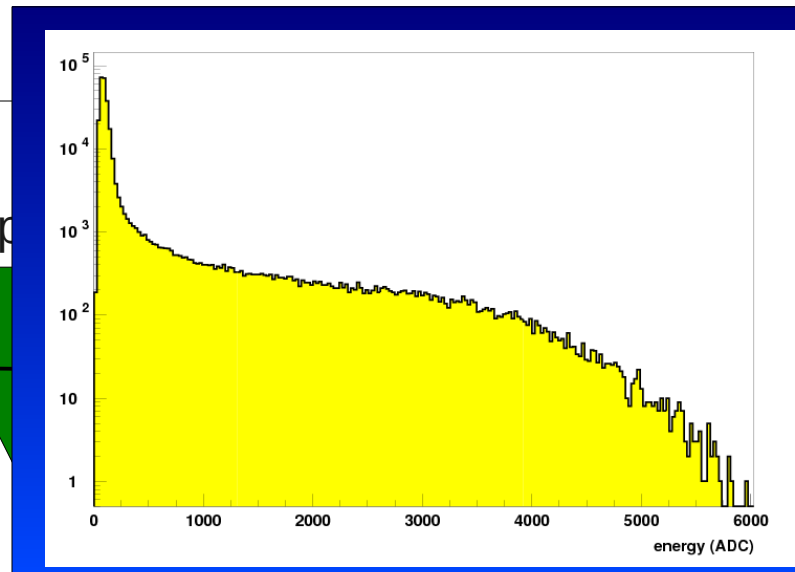
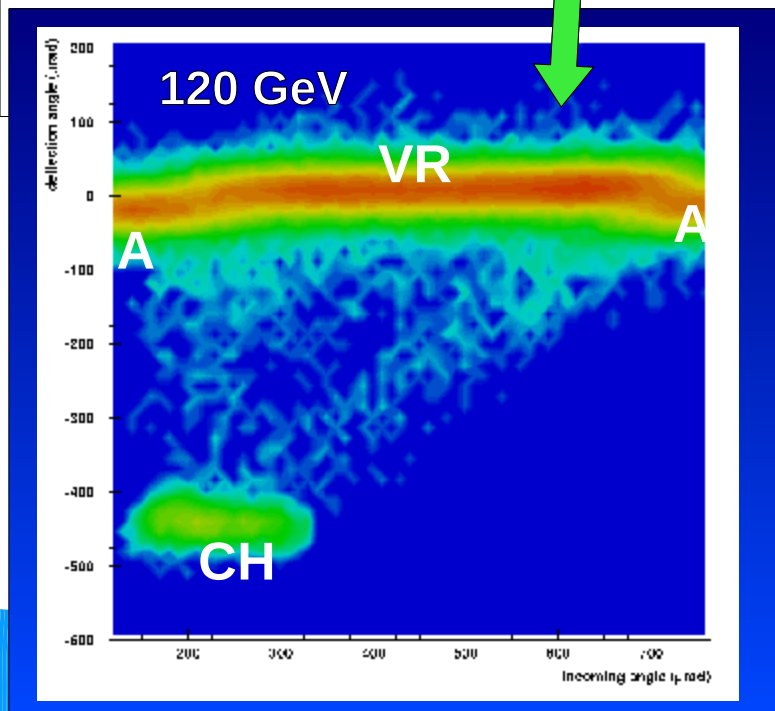




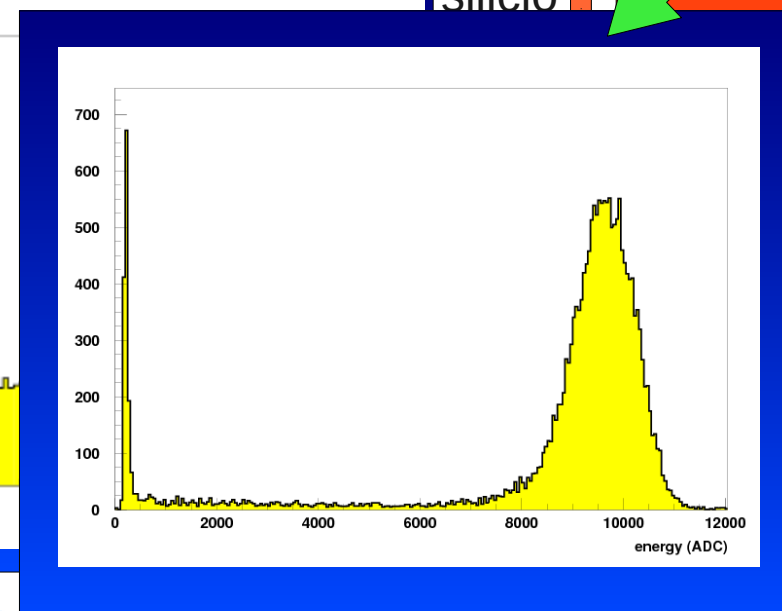
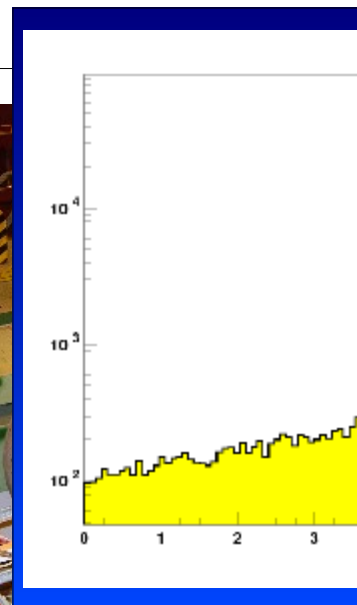
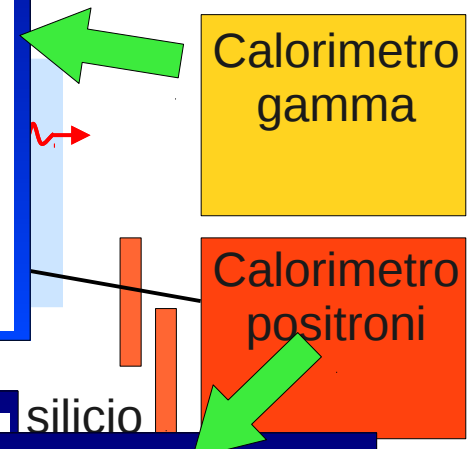
Emissione di radiazione: test con e^+ di 120 GeV



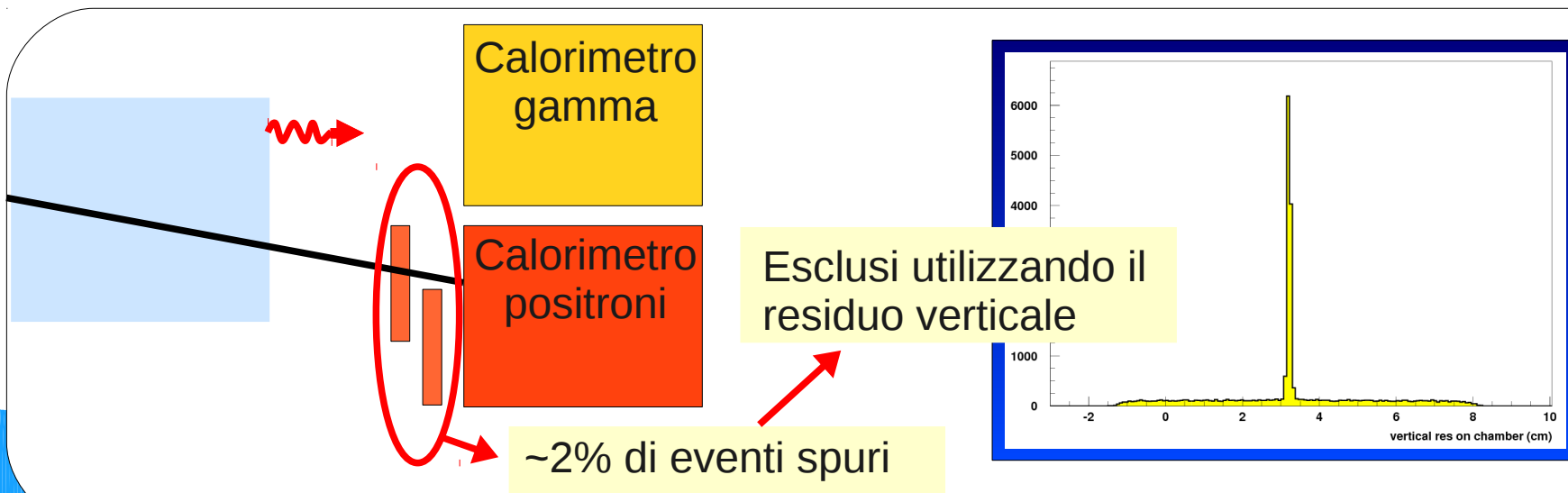
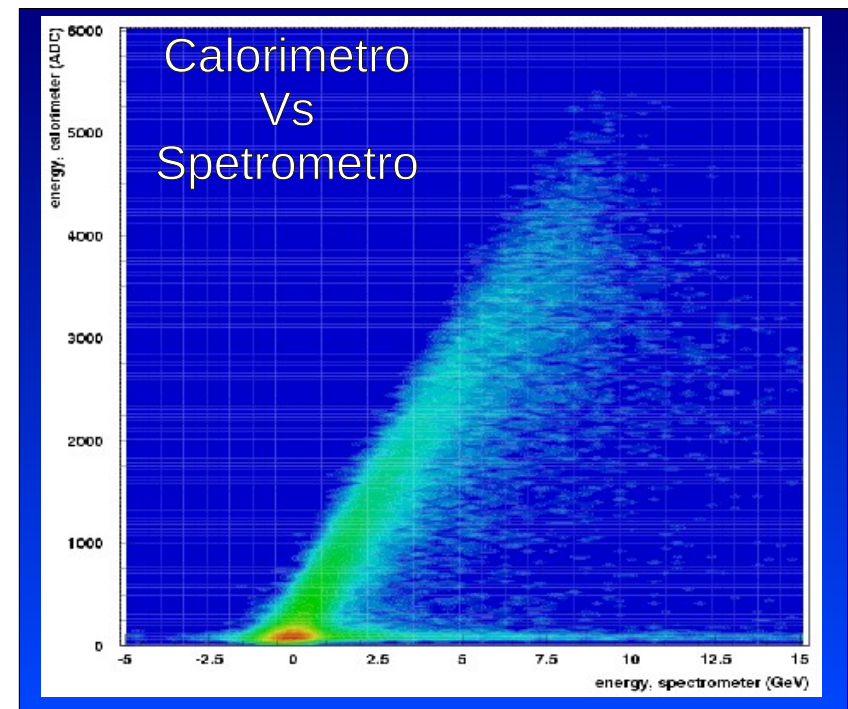
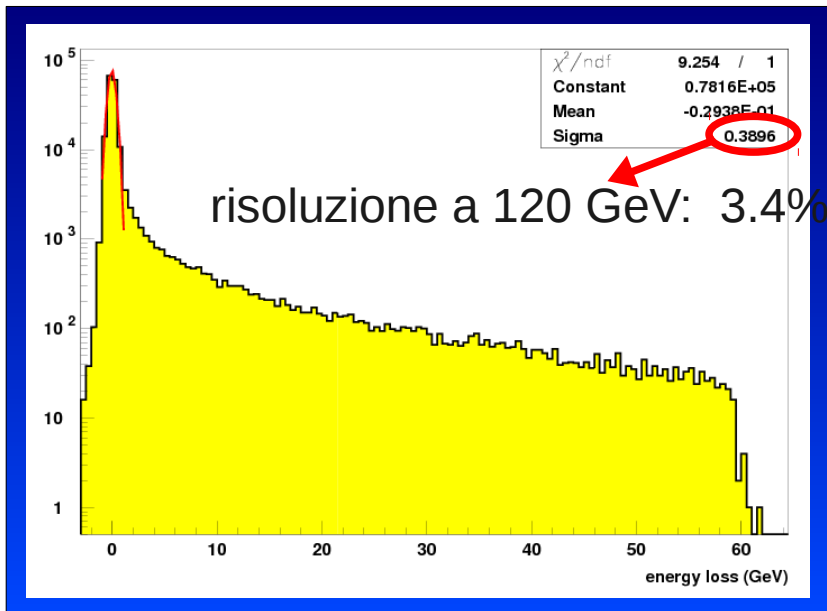
Standard Setup



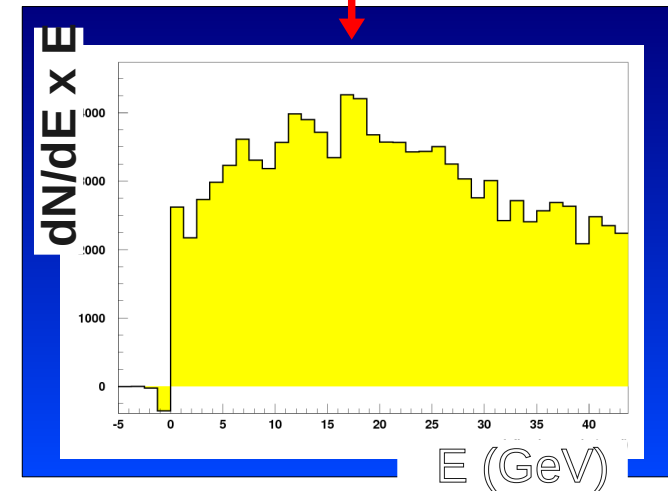
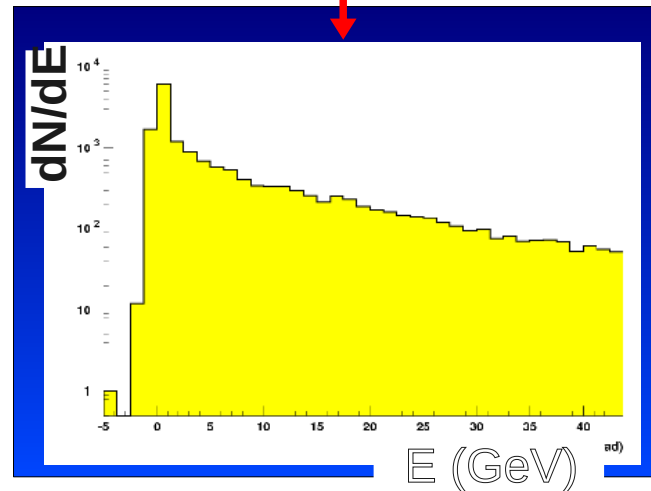
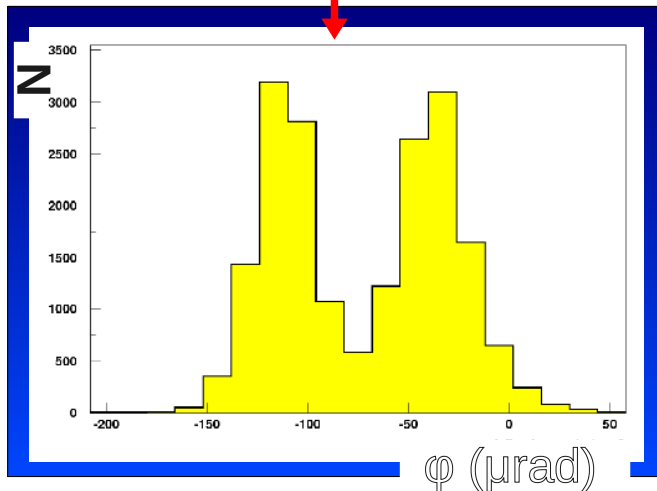
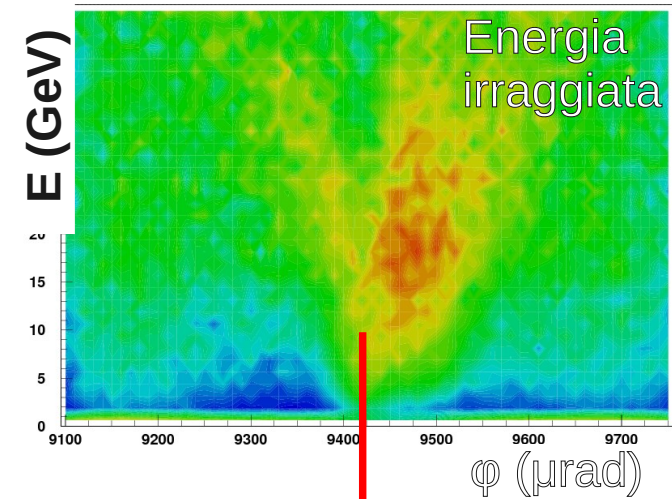
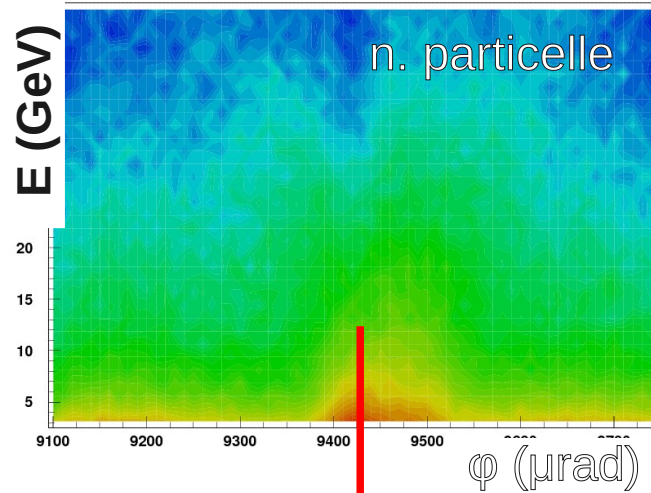
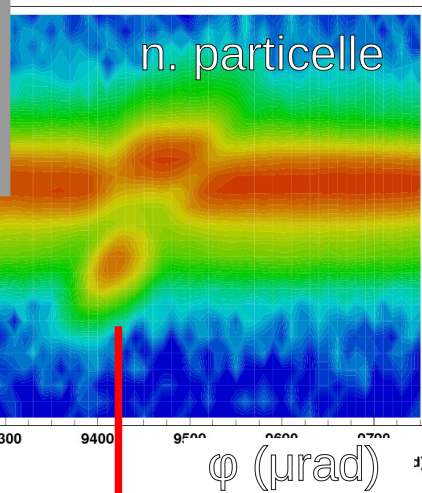
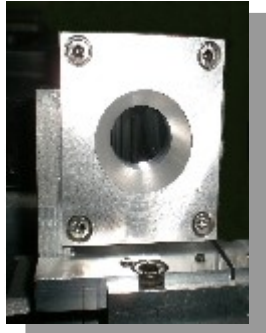
dip



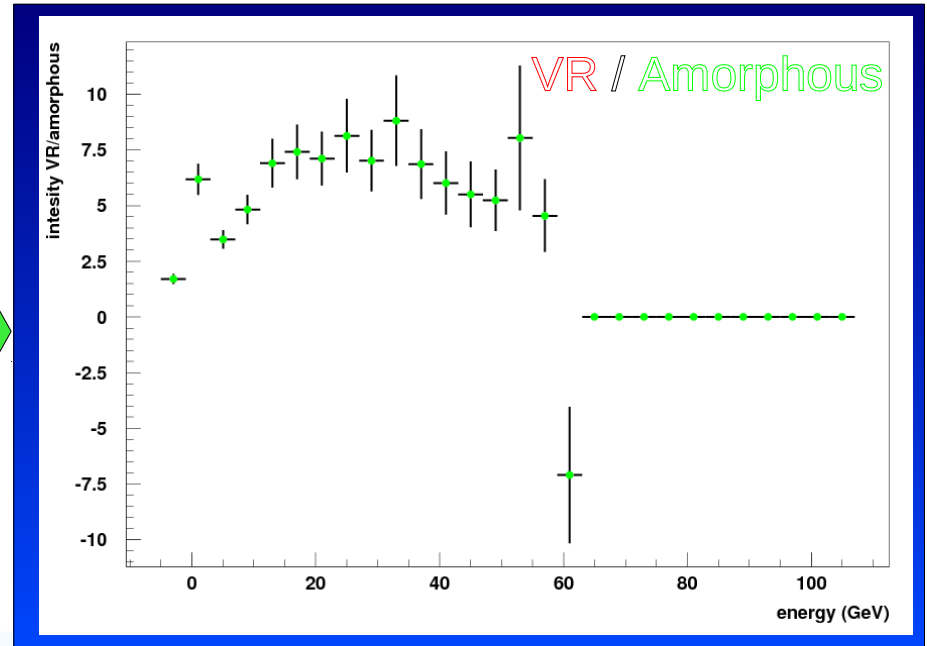
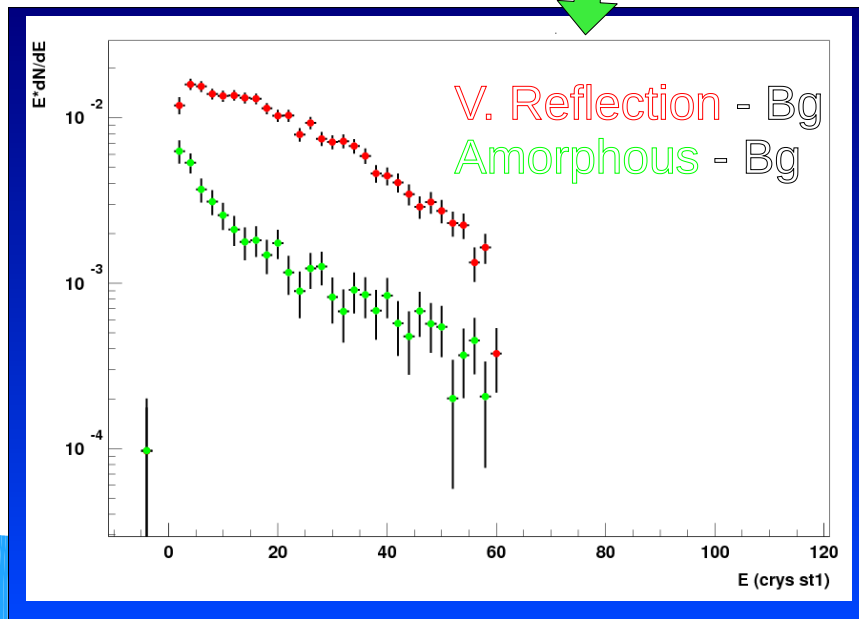
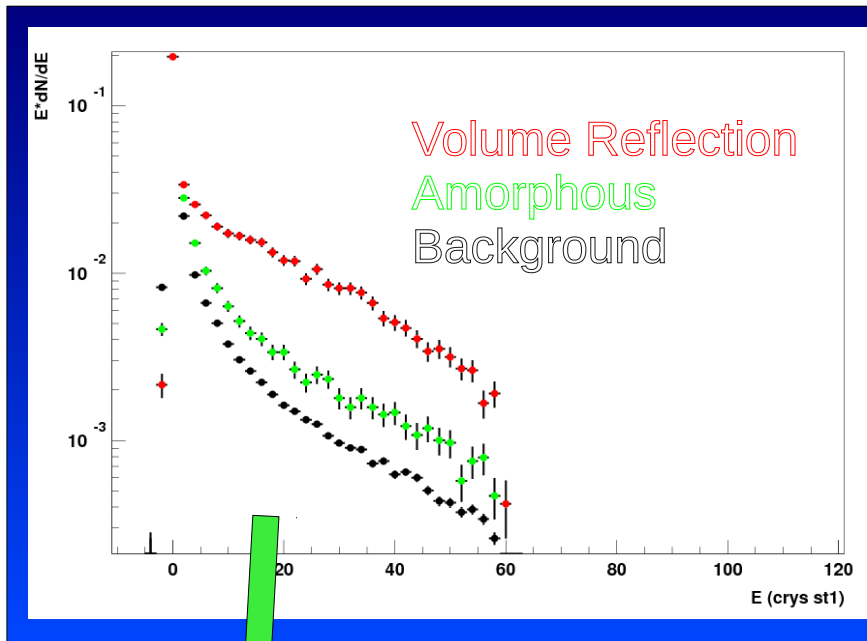
Performance



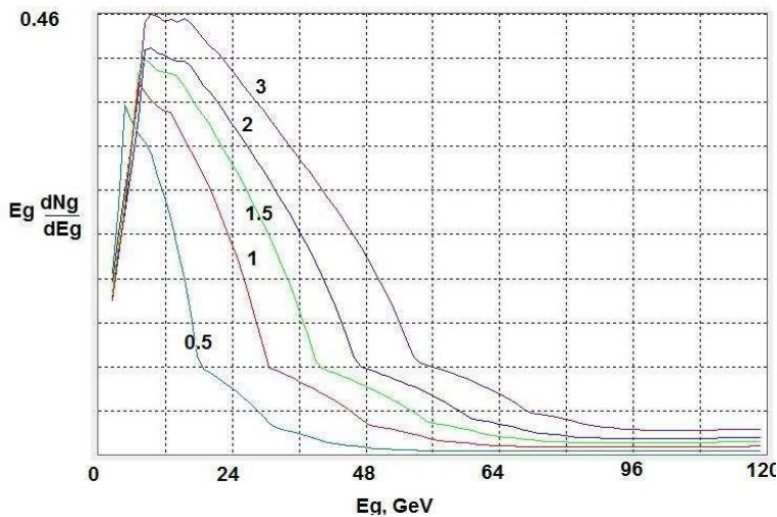
Risultati QM2 → piani (111)



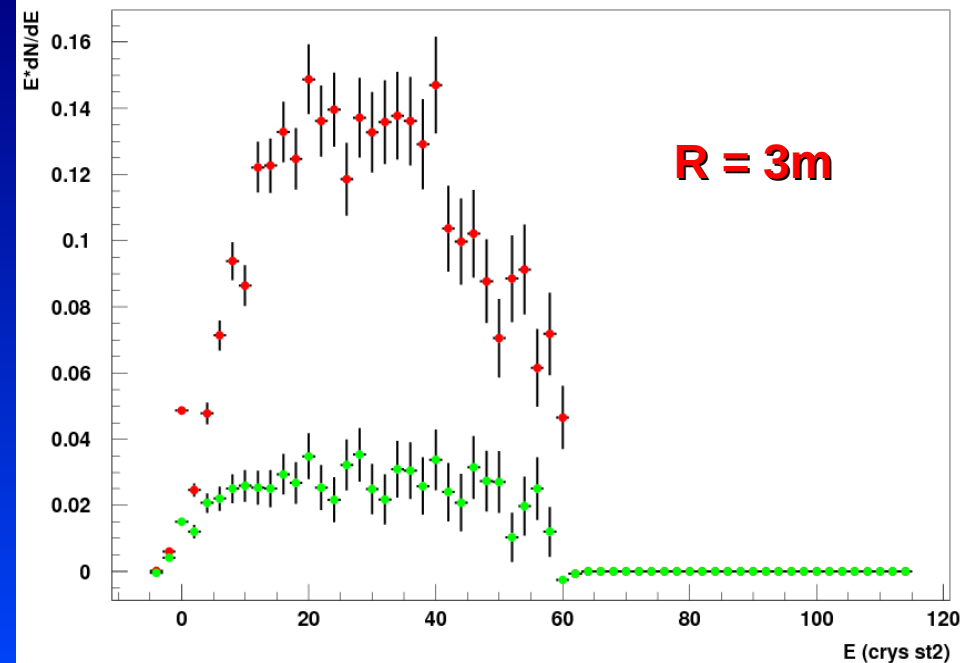
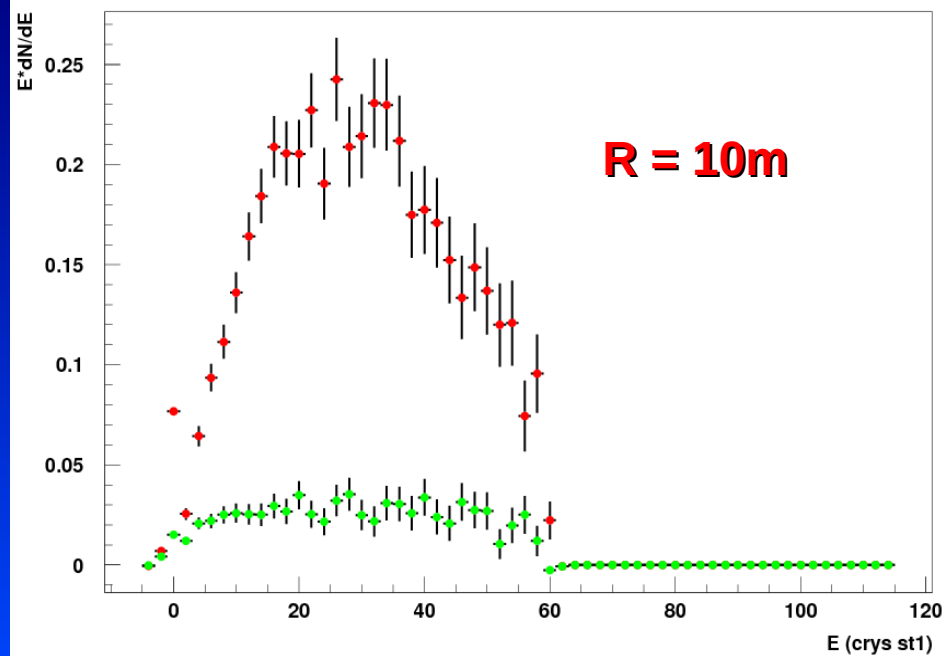
Risultati St14 → piani (110)



Risultati St14 → piani (110)



Calcolo teorico
(emissione di singolo fotone)



Modifiche al setup per il 2010:

trigger 'sottile'

Standard Setup

dipolo

Pair detector?

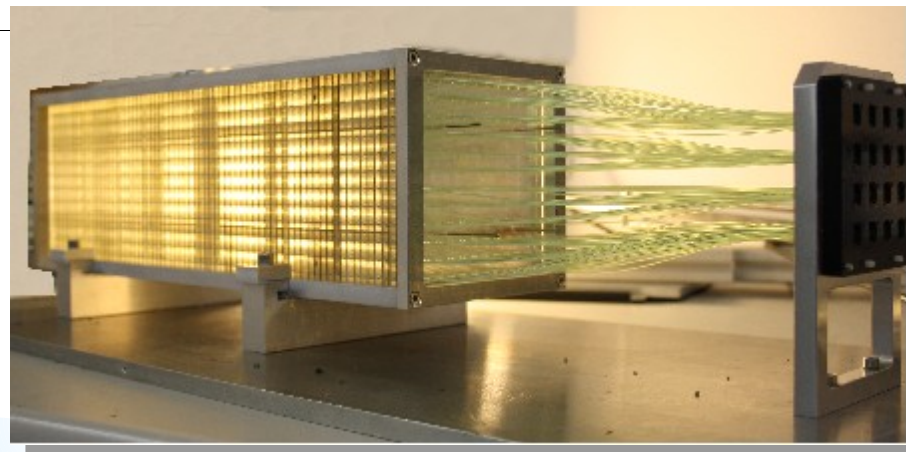
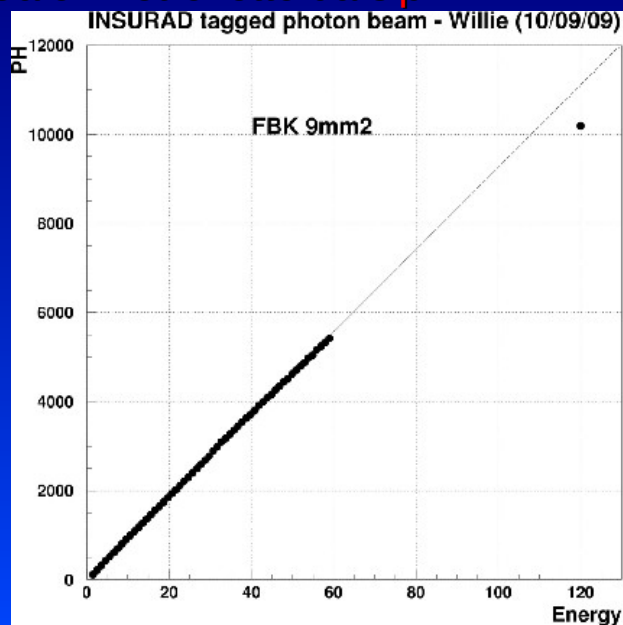
Helium bag

Calorimetro gamma

Calorimetro positroni

Moduli a m.s. di silicio

Calorimetro letto da sipm!



Concludendo:

Il problema della **collimazione di LHC** ha riaccessso l'interesse verso il channeling

L'applicazione di nuove energie e moderne tecnologie hanno provocato l'apertura di nuove porte

Nel futuro bisognerà:

- Continuare il lavoro di ricerca
- **Consolidare** le conoscenze fino qui acquisite
- Valutare criticamente le possibili **applicazioni**

Cristalli curvi, le ultime novità

Grazie dell'attenzione!

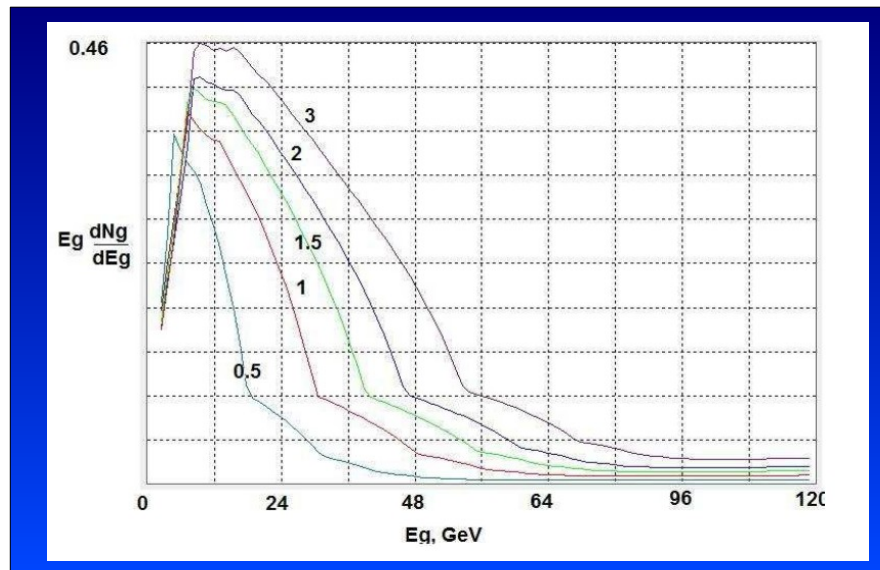
Said Hasan

Università degli studi dell'Insubria

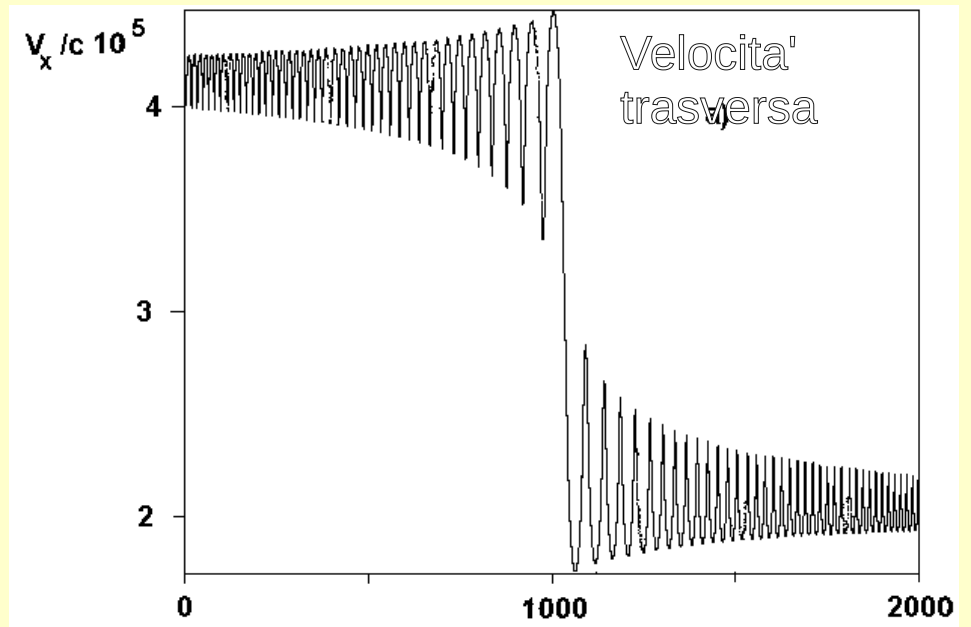
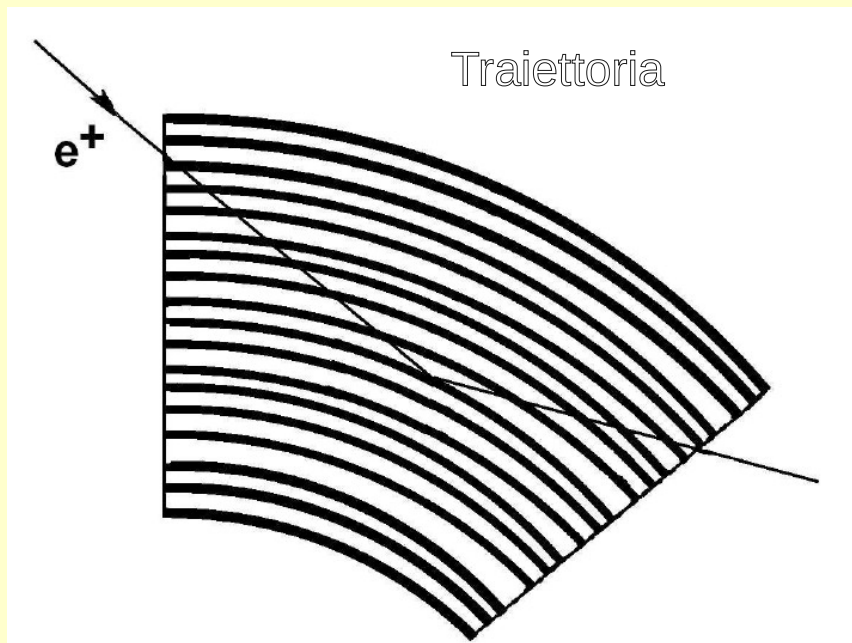
Seminario di dottorato (XXIII ciclo)



Risultati St14 → piani (110)

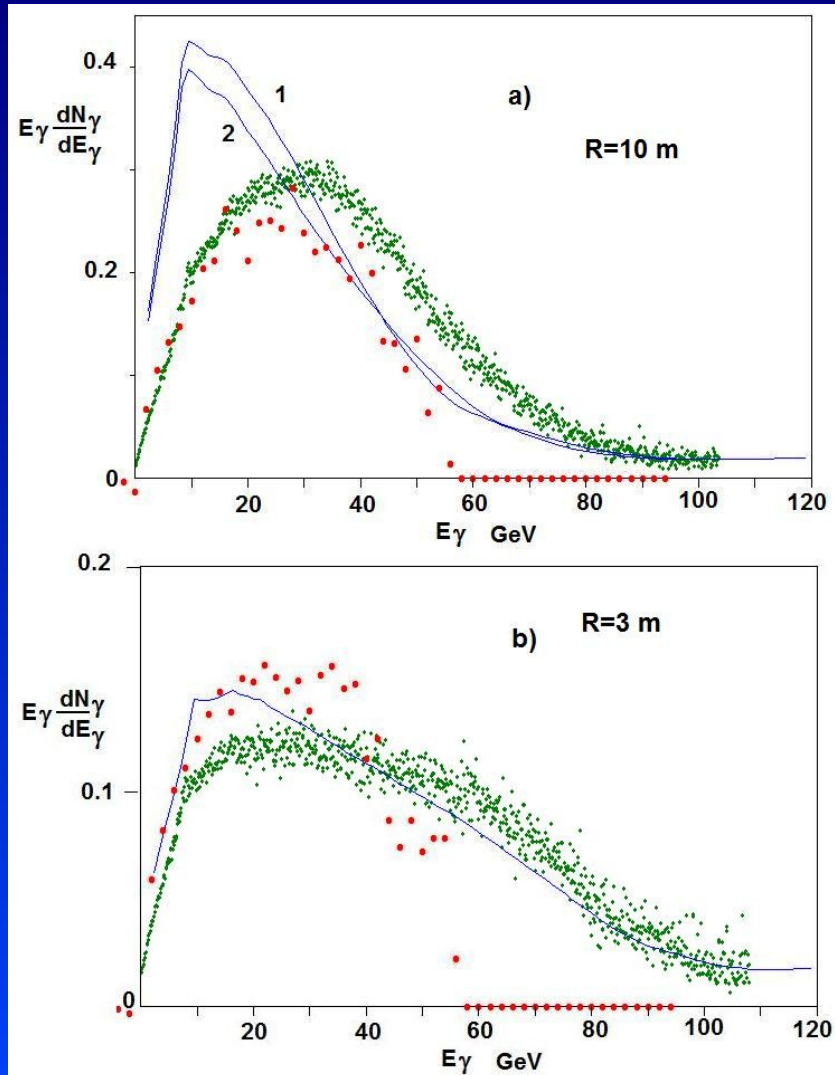


Calcolo teorico
(emissione di singolo fotone)





Backup





Backup

