UNIVERSITA' DEGLI STUDI DI CATANIA
FACOLTÀ DI SCIENZE MATEMATICHE, FISICHE E NATURALI
Corso di Laurea in Fisica

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Caratterizzazione del rivelatore TOF dello spettrometro HADES

Relatori:

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Dr. P. Finocchiaro

Sommario

- Motivazioni dell'esperimento
- Lo spettrometro HADES
- Il rivelatore a tempo di volo
- Prestazioni del rivelatore
- Identificazione di particelle
- Primi risultati

Problematica Fisica

Collisioni tra ioni pesanti ad energie relativistiche (1 ÷ 2 AGeV)

Proprietà degli adroni nella materia nucleare

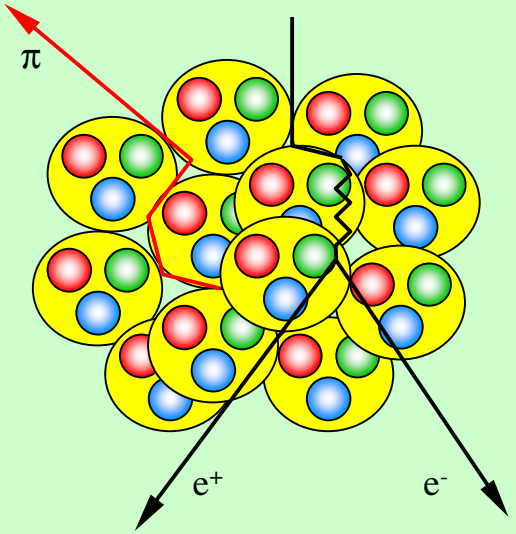
Mesoni vettori leggeri

Sonde per la materia nucleare

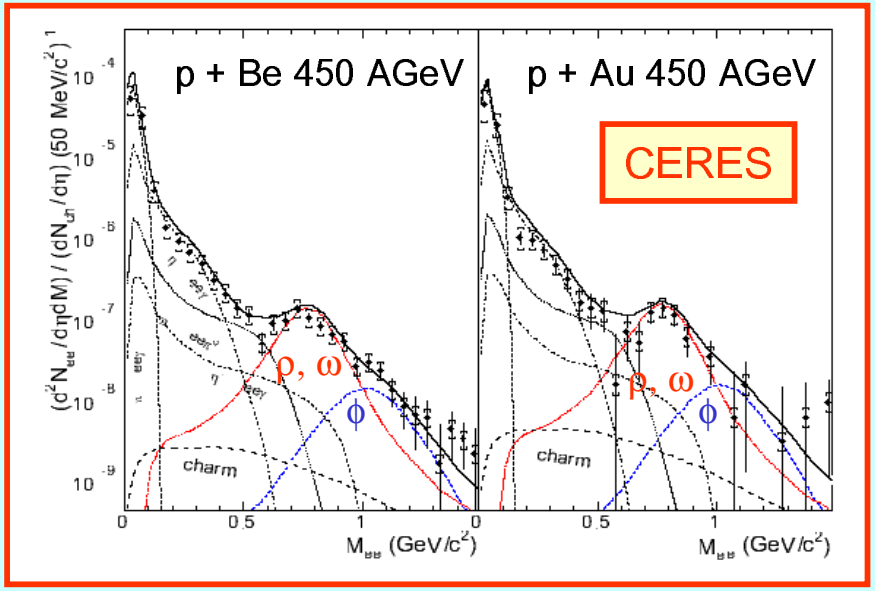
Mesoni	Massa [MeV/c^2]	Vita media [fm/c]	Decadimento principale	Branching ratio e^+e^-
ρ	769	1.3	$\pi\,\pi$	$4.5\cdot10^{-5}$
ω	783	23	$\pi\,^+\pi^-\,\pi^0$	$7.1\cdot10^{-5}$
ϕ	1019	44	K^+K^-	$2.9\cdot10^{-4}$

LEPTONI

Non risentono della forza forte



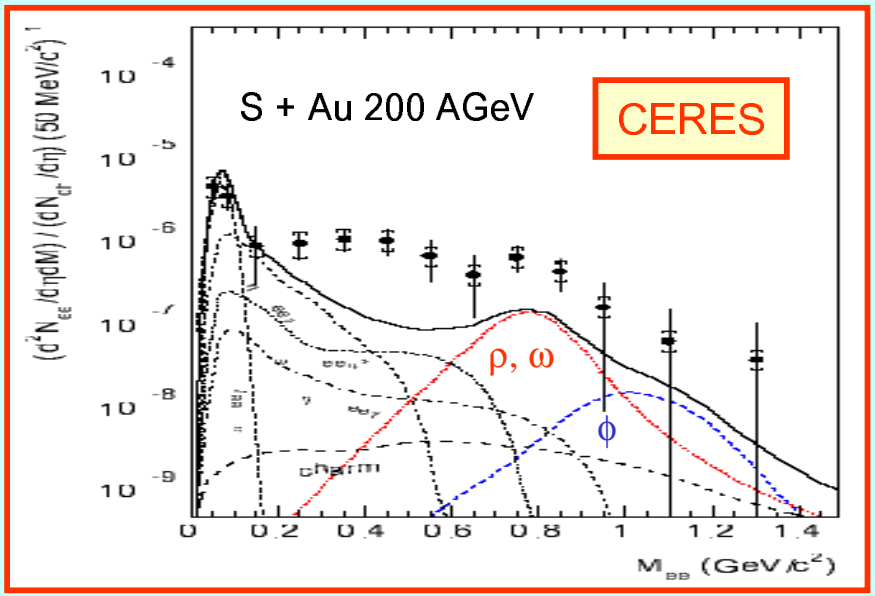
Probabilità molto bassa

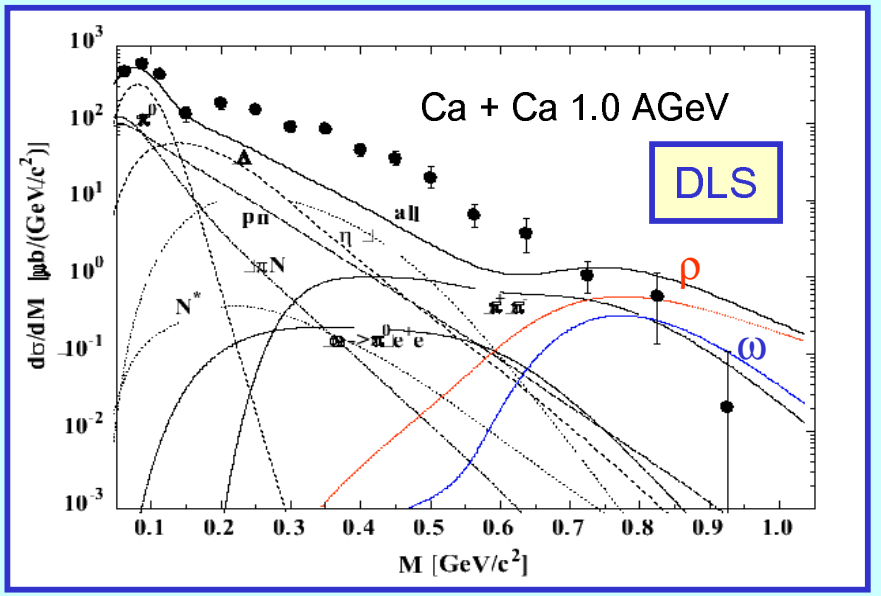


Risultati di altri esperimenti

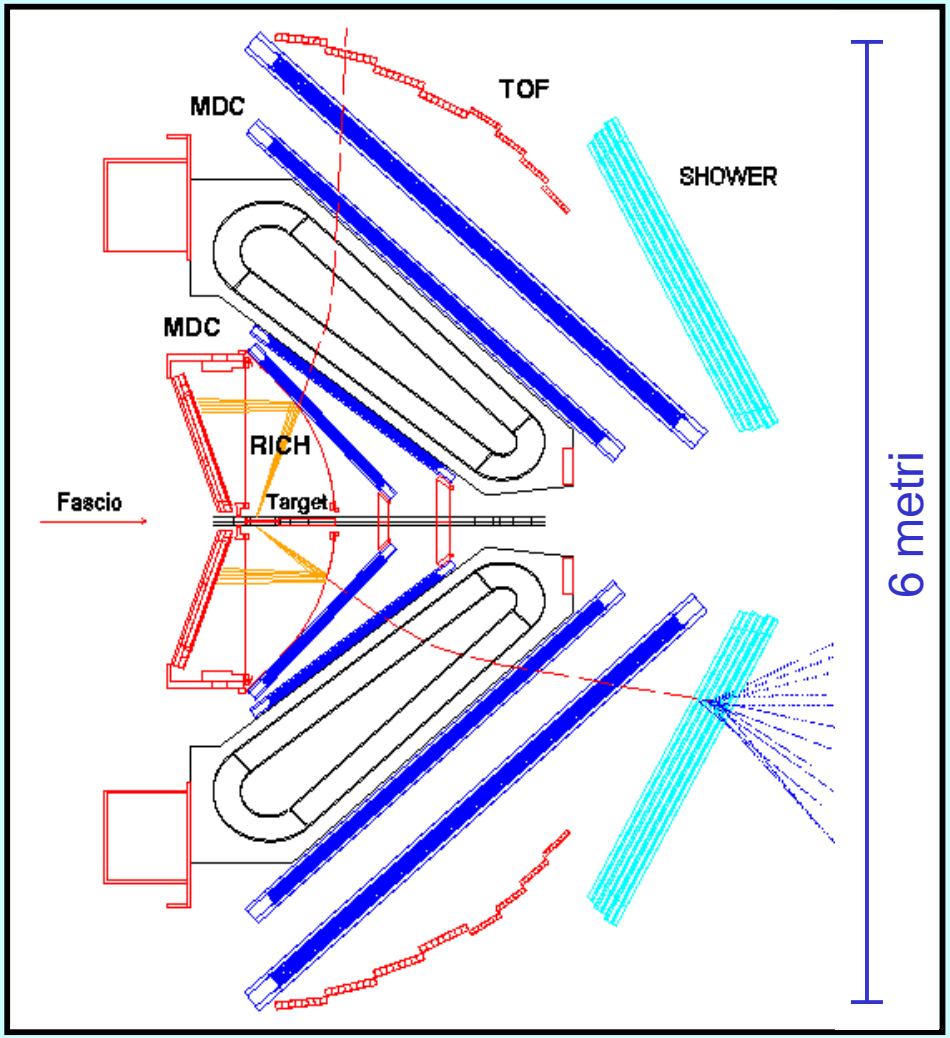
Sovraproduzione di dileptoni

?





HADES
High Acceptance Di-Electron Spectrometer

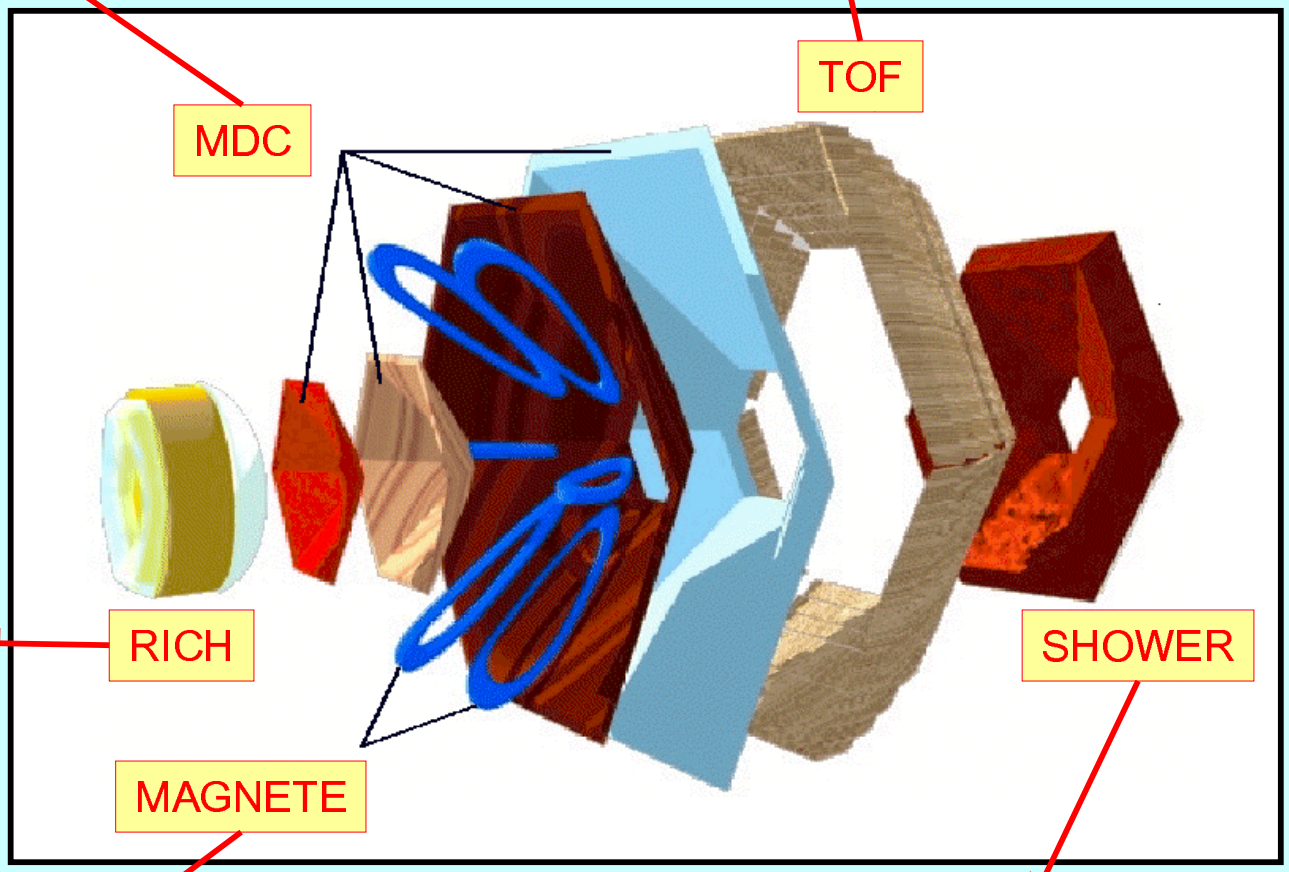


Spettrometro per coppie e^+ e^-

- E incidenti 1 ÷ 2 AGeV
- Accettanza geometrica ~ 40%
- Risoluzione in massa invariante $\Delta M/M \sim 1\%$
- Discriminazione elettrone/adrone
- Misura di molteplicità

Risoluzione spaziale σ_x ~ 100 μm

Rivelatore di tempo di volo σ_t ~ 150 ps



Rivelatore Cherenkov

Risoluzione in momento Δp/p ~ 1%

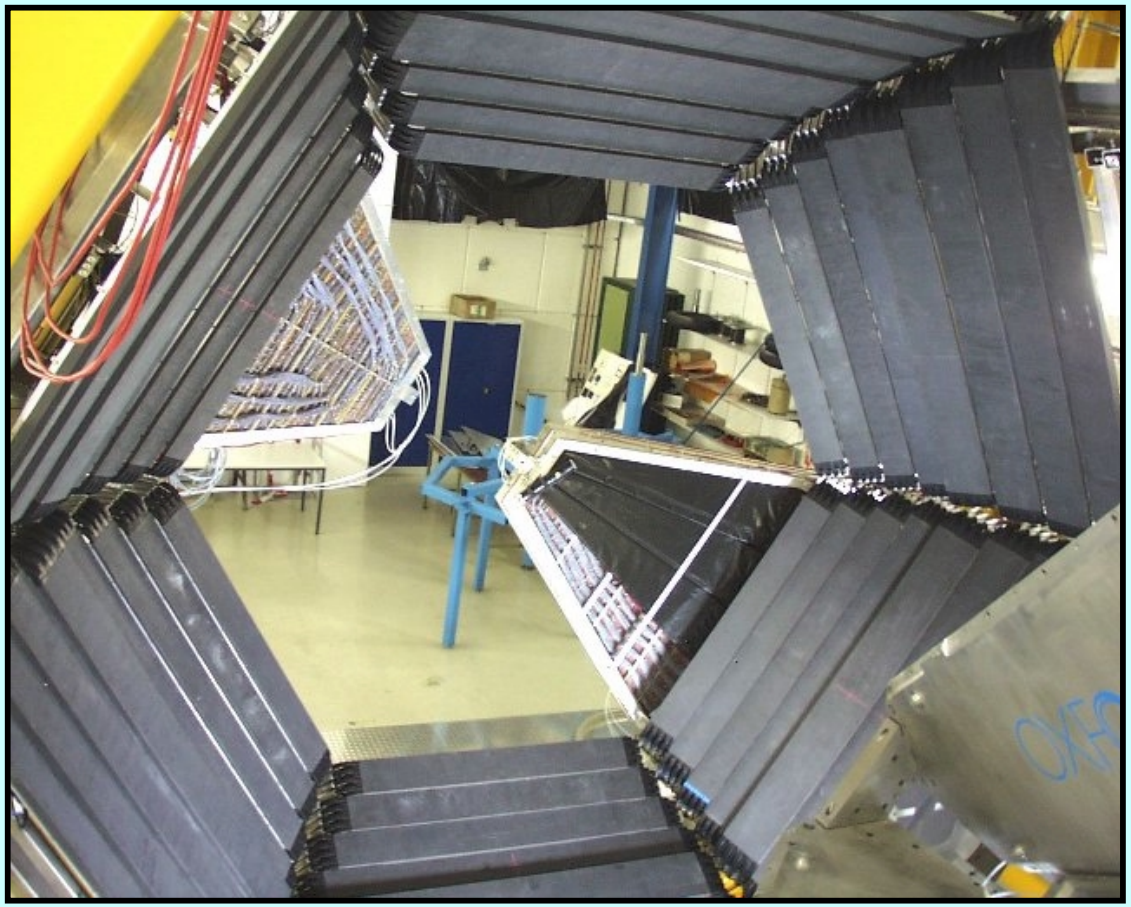
Rivelatore di sciame

Il rivelatore TOF

- Molteplicità di particelle cariche prodotte
- Posizione
- Tempo di volo
- Energia depositata

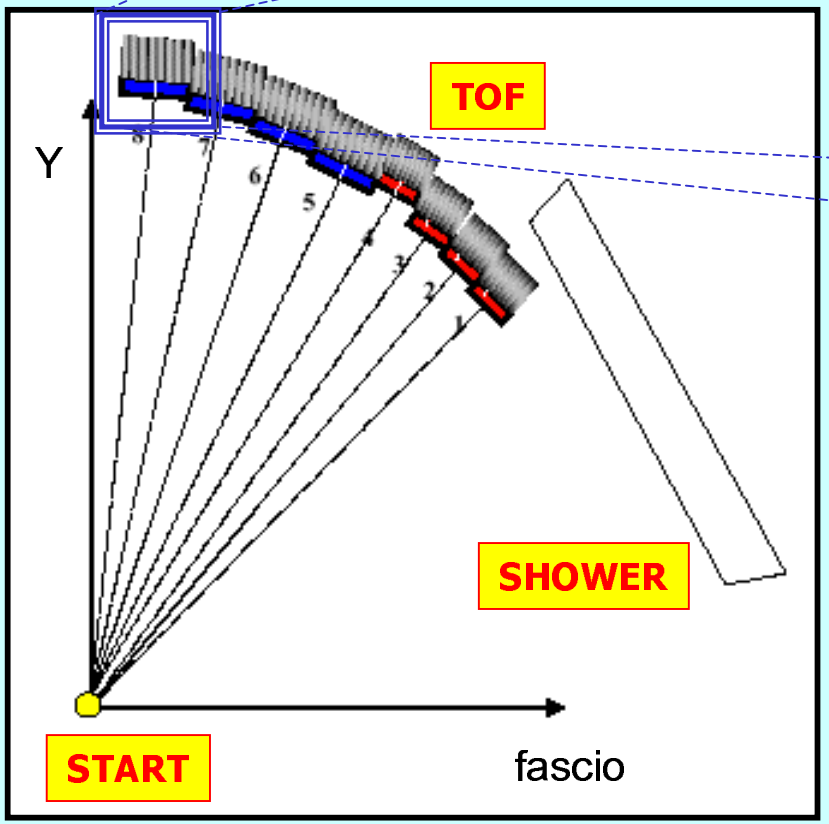
Copertura angolare:

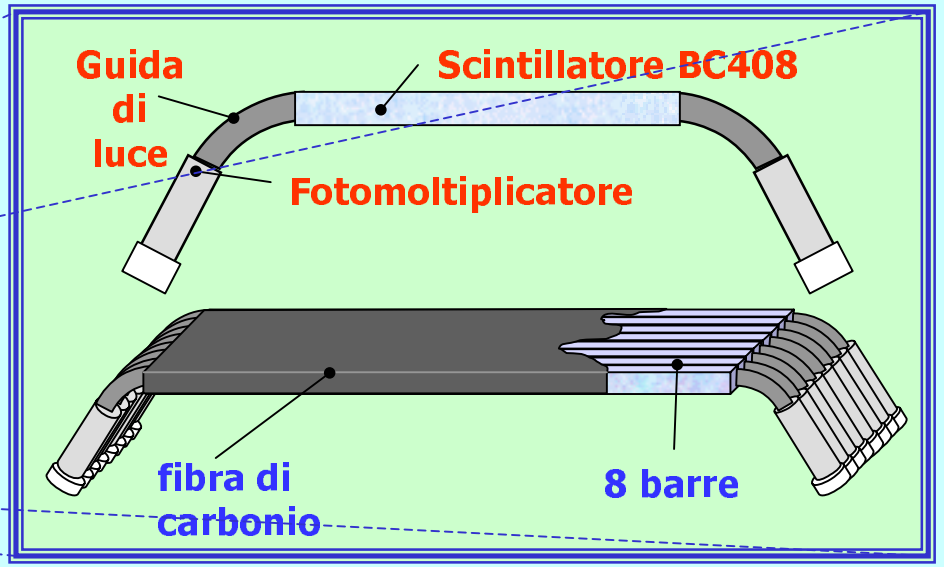
$\phi = 0° \div 360°$
$\theta = 44° \div 88°$



Barre spesse ➡ Sezione: 3 x 3 cm²

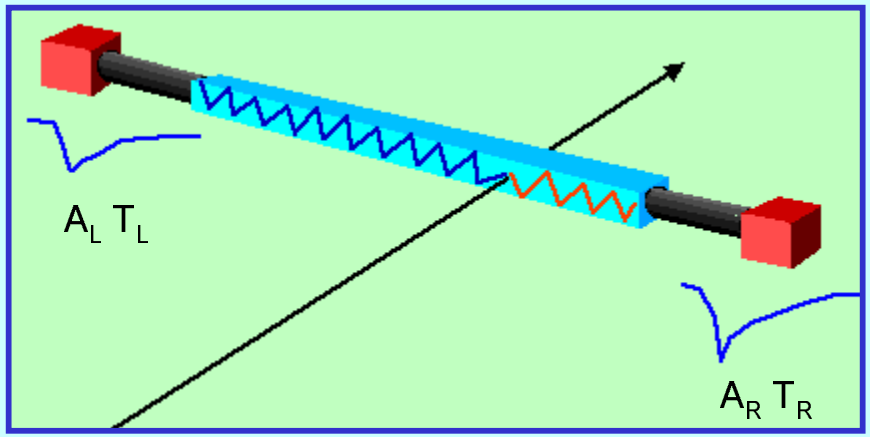
Barre sottili ➡ Sezione: 2 x 2 cm²





- Settori 6 x
- Moduli 8 x
- Barre 8 =

Totale barre: 384



Informazioni dai TDC:

- Posizione (TDC):

$$x_{TDC} = \frac{1}{2}(t_R - t_L)\cdot V_{gr} + x_{offset}$$

- Tempo di volo:

$$tof = \frac{1}{2}(t_R + t_L) + t_{offset}$$

Informazioni dagli ADC:

- Posizione (ADC):

$$x_{ADC} = \frac{1}{2} L_{at}\left(\ln\frac{A_L}{A_R} + g\right)$$

- Energia depositata:

$$E = k\sqrt{A_R A_L}$$

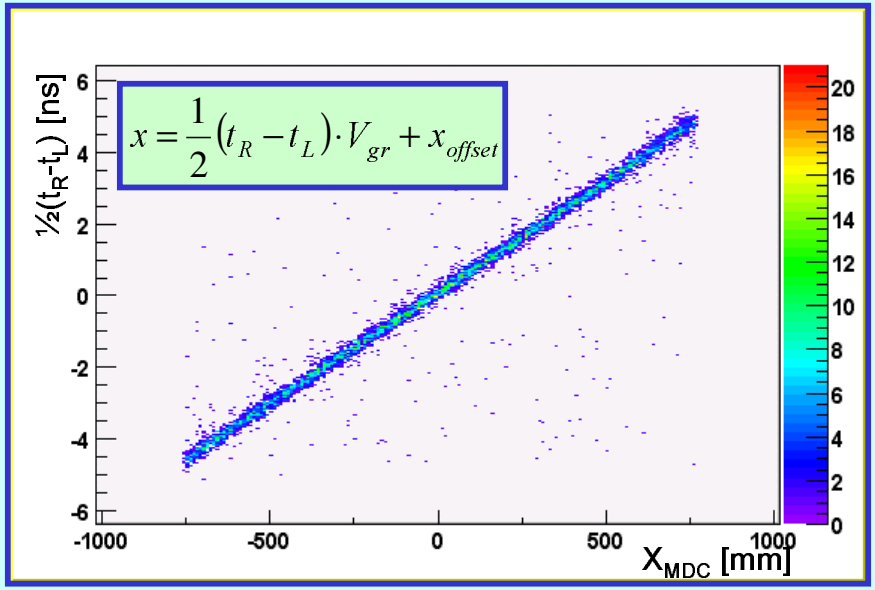
MDC & TOF

↓

X_{reale} vs $X_{misurato}$

↓

Calibrazione in posizione



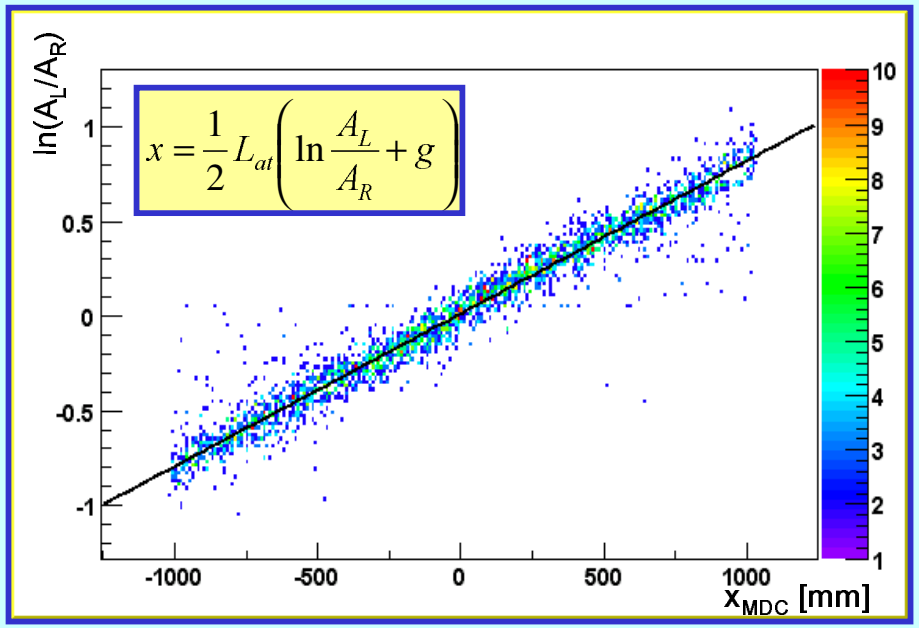
X_{MDC} - X_{TOF}

↓

Risoluzione spaziale

$$\sigma_{temp} = \frac{\sigma_{pos}}{V_g}$$

BARRE SPESSE	BARRE SOTTILI
V_{gr} ~ 165 mm/ns	V_{gr} ~ 163 mm/ns
σ_{pos} ~ 26 mm	σ_{pos} ~ 22 mm
σ_{temp} ~ 158 ps	σ_{temp} ~ 140 ps

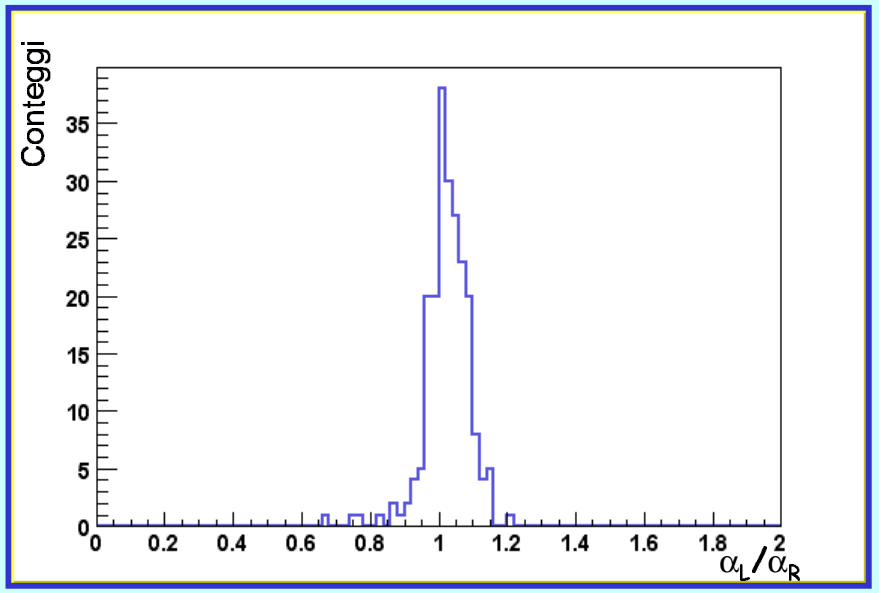


Lunghezze di attenuazione (valori tipici)

- Barre spesse: L_{at} ~ 2010 mm
- Barre sottili: L_{at} ~ 1750 mm

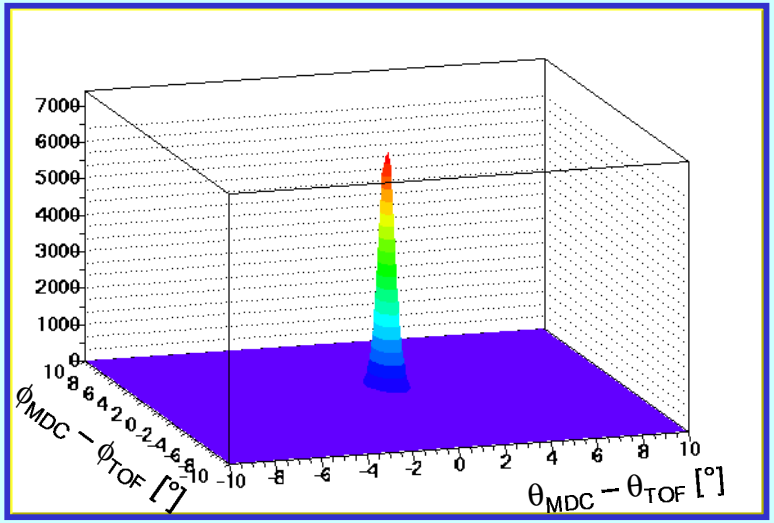
Asimmetria di guadagno

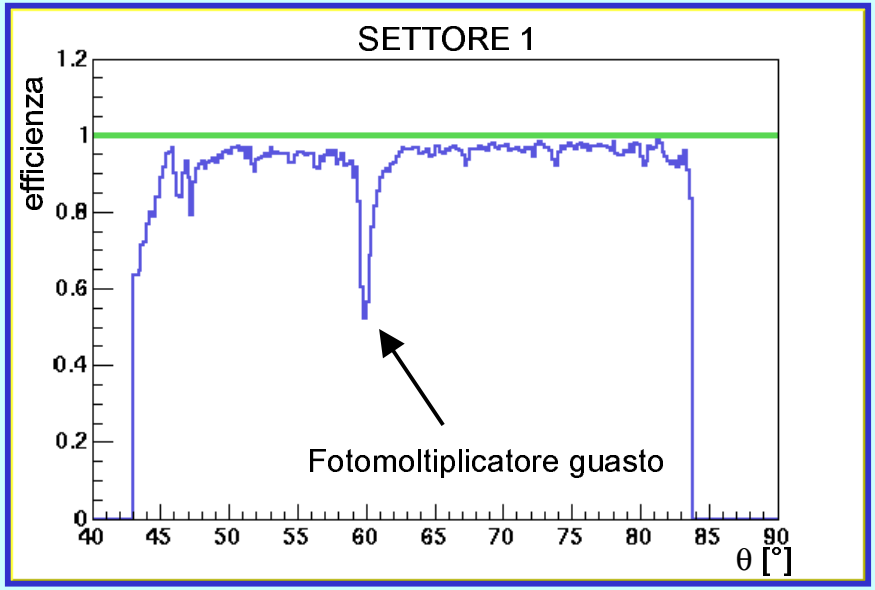
$$g = \ln \frac{\alpha_L}{\alpha_R}$$

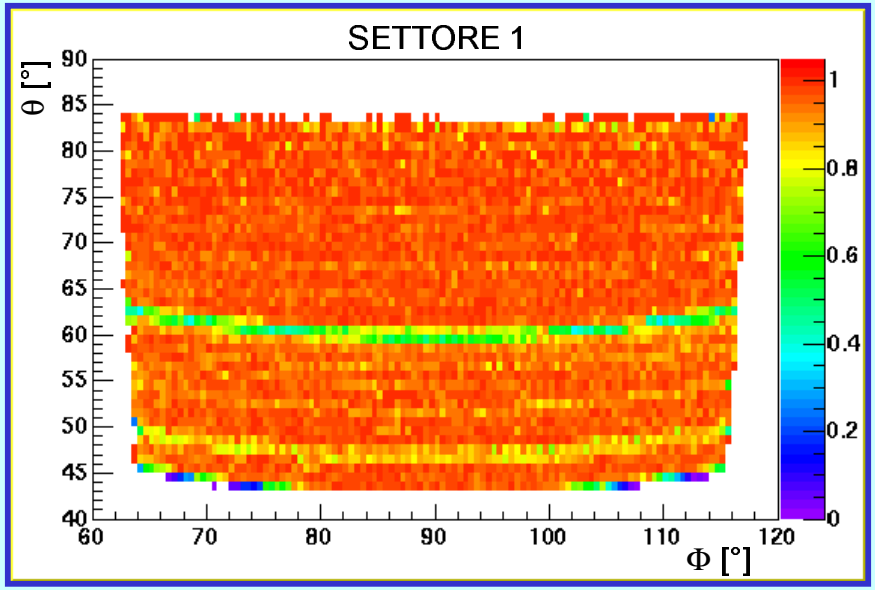


MDC & TOF

Efficienza di rivelazione







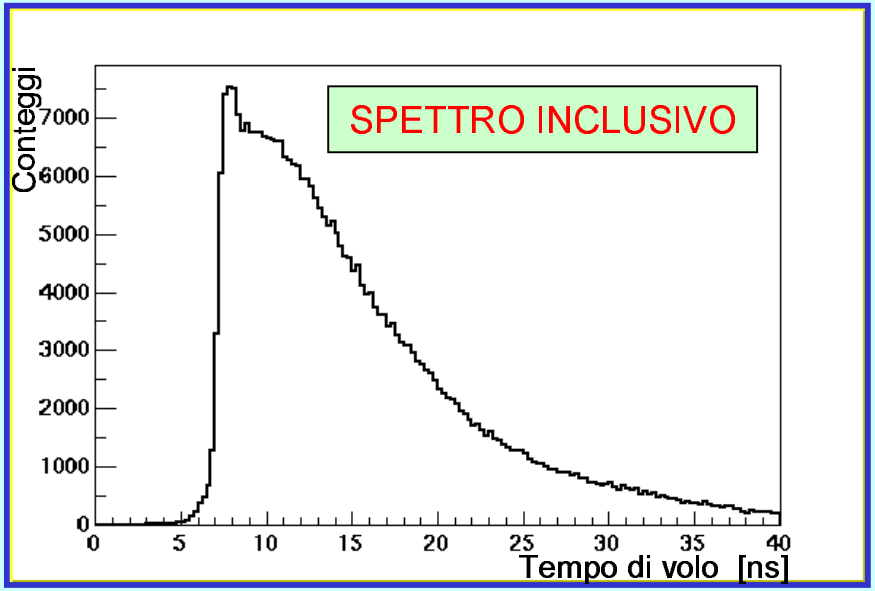
Valori di efficienza medi

Barre spesse: ε = 96.3%
Barre sottili: ε = 94.3%

RICH & TOF

↓

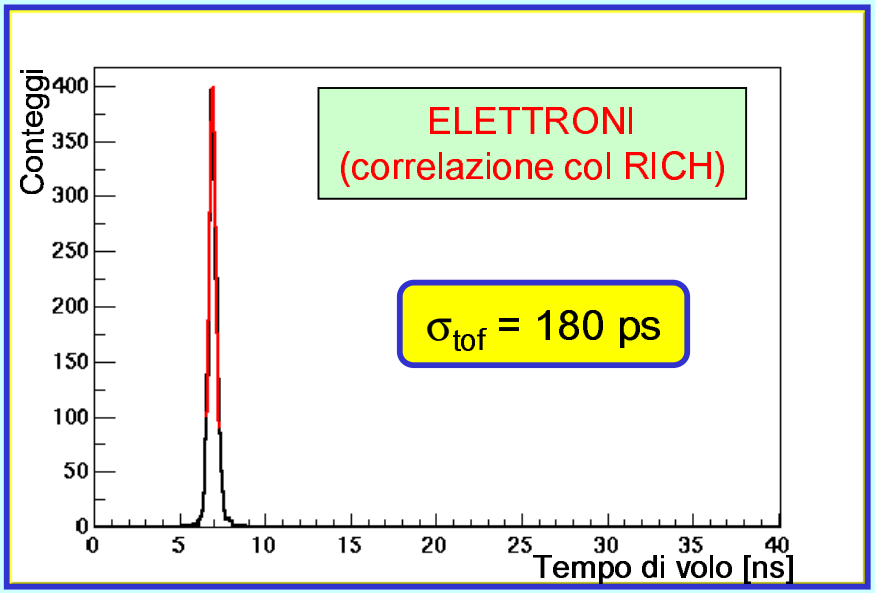
Risoluzione temporale



Tragitto di volo rinormalizzato

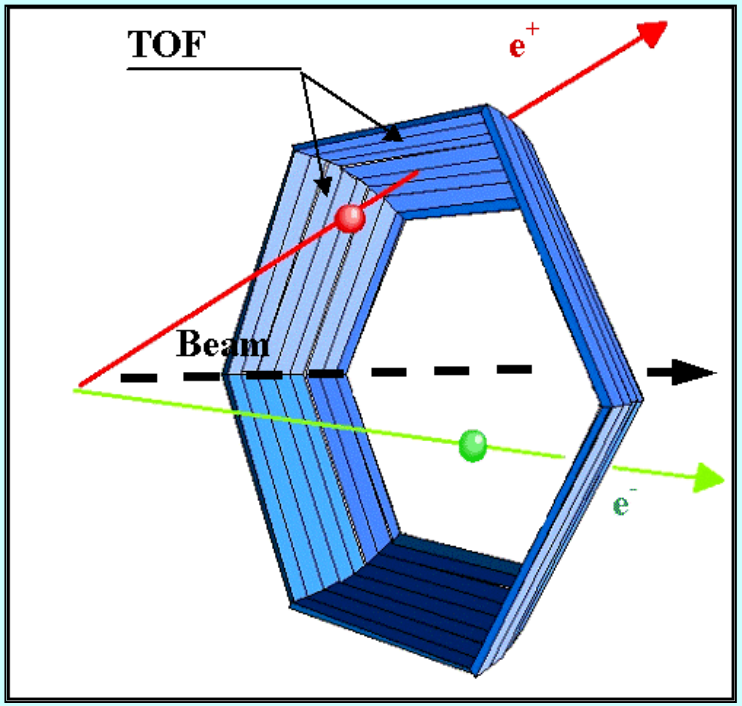
↓

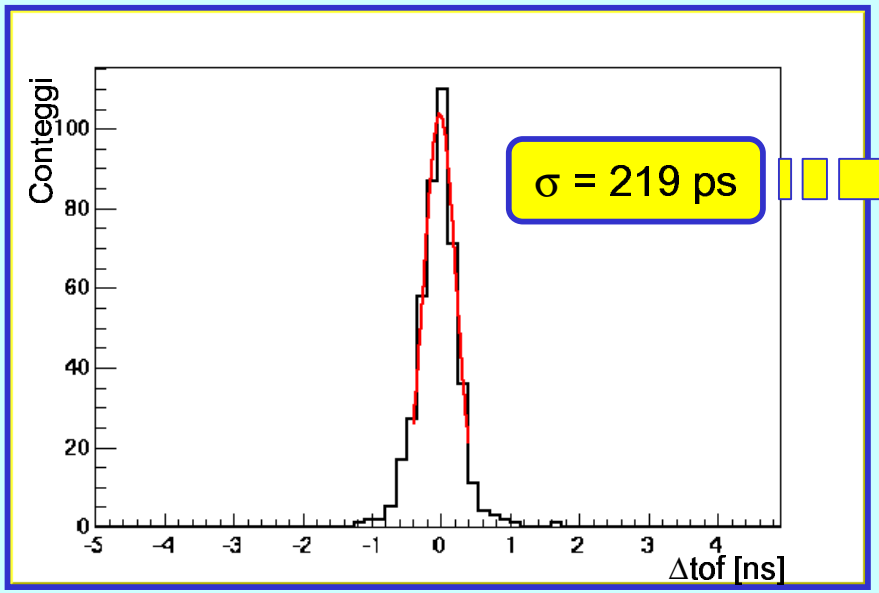
2100 mm



Dileptoni

$$\Delta tof = t_1 - t_2$$





σ = 219 ps

$$\sigma_{temp} = \frac{\sigma}{\sqrt{2}} = 155\,ps$$

$$\sigma_{tof} = \sqrt{\sigma^2_{temp} + \sigma^2_{START}}$$

σ_{START} ~ 92 ps

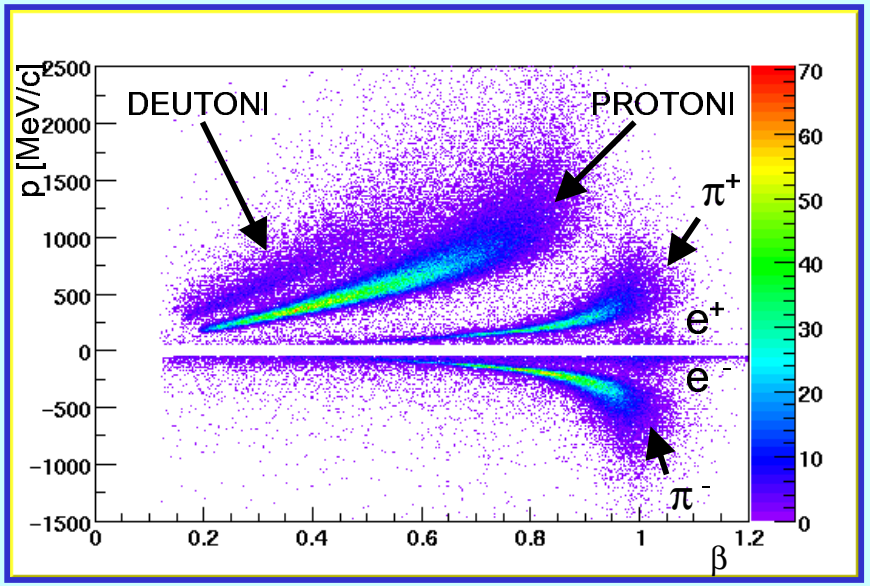
Identificazione di particelle

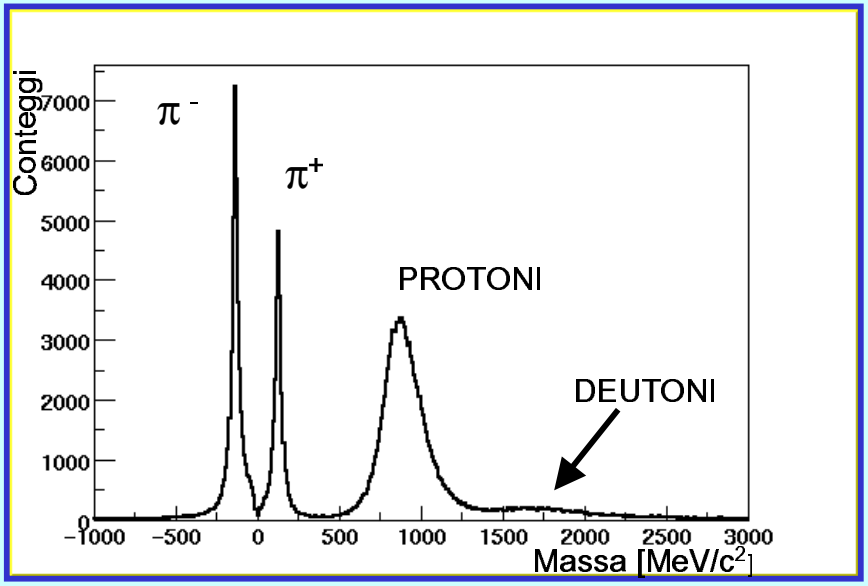
Calcolo di:

- Momento
- Velocità β

Massa ricostruita

$$m_0 = \frac{p}{\beta}\sqrt{1-\beta^2}$$

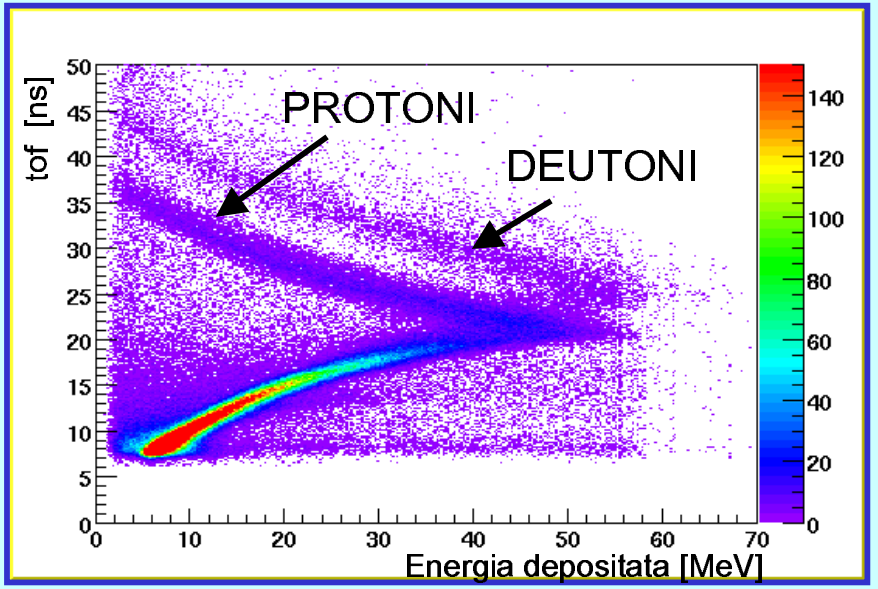




Tempo di volo
vs
Energia depositata

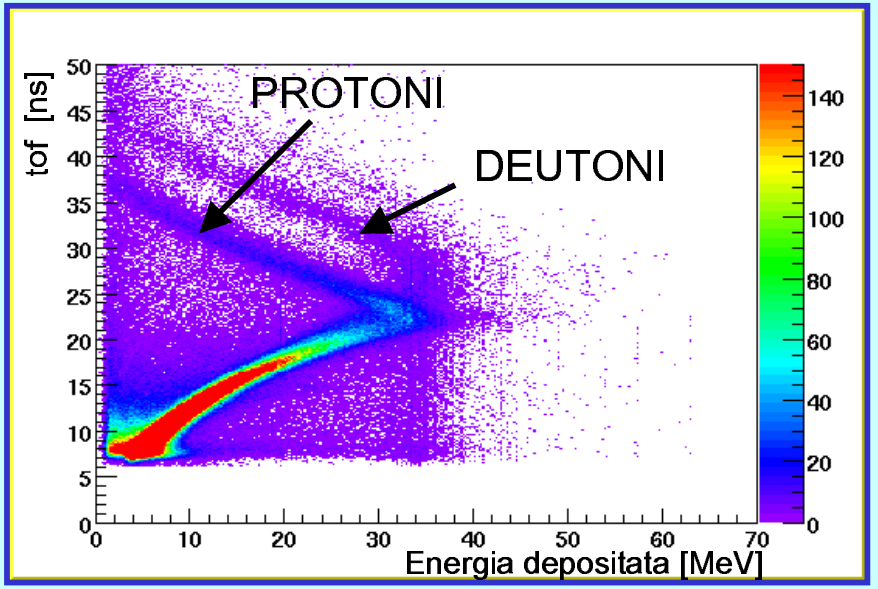
BARRE SPESSE

Sezione: 30 x 30 mm^2
Angolo θ: 62° ÷ 88°

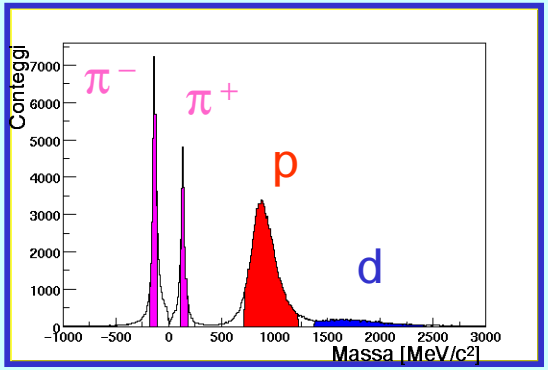


BARRE SOTTILI

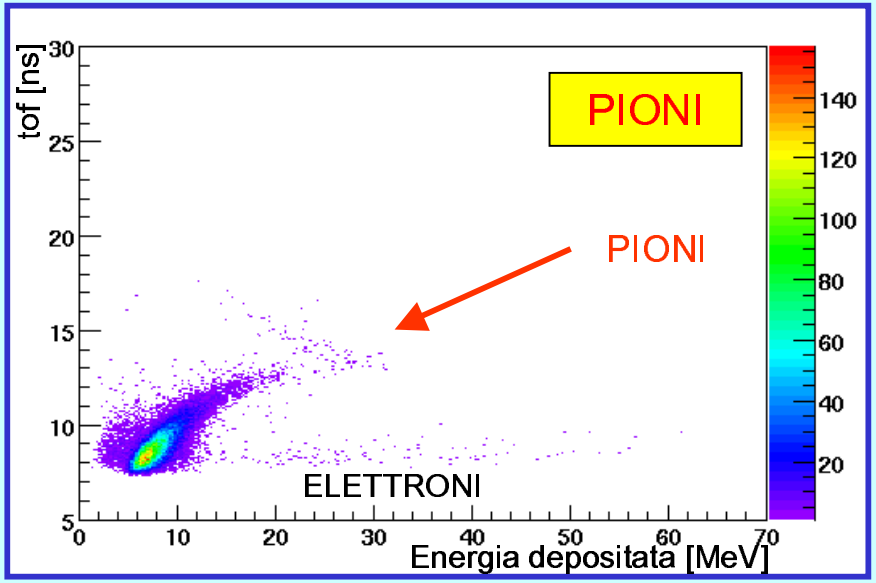
Sezione: 20 x 20 mm^2
Angolo θ: 44° ÷ 62°

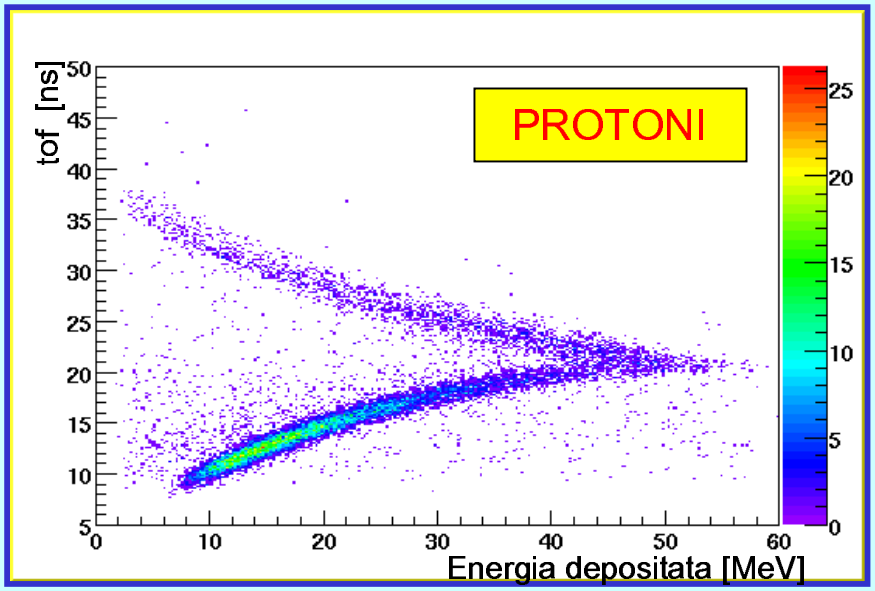


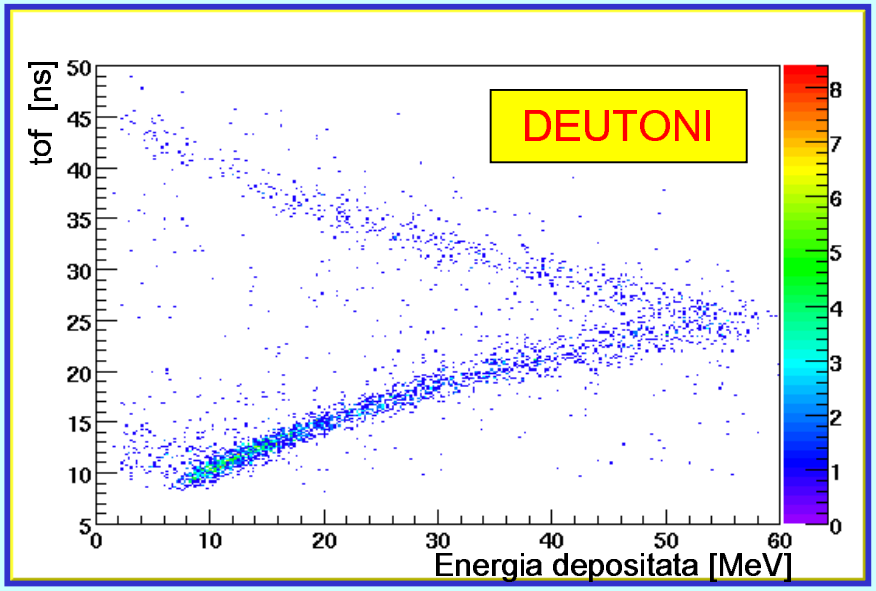
Selezione in massa



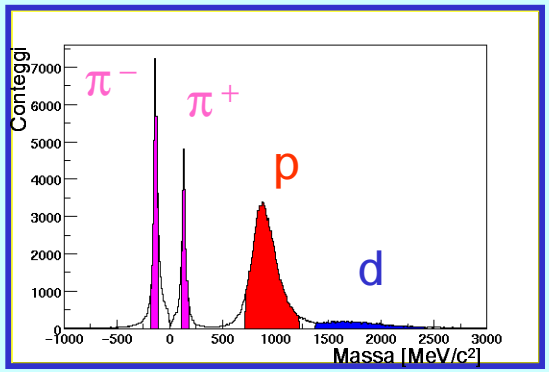
BARRE SPESSE: Sezione: 30 x 30 mm^2
Angolo θ: 62° ÷ 88°

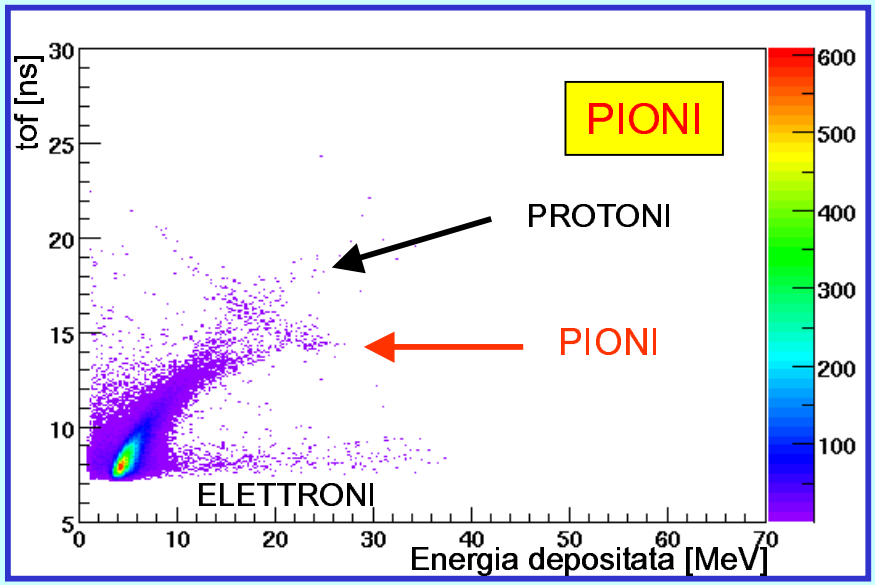




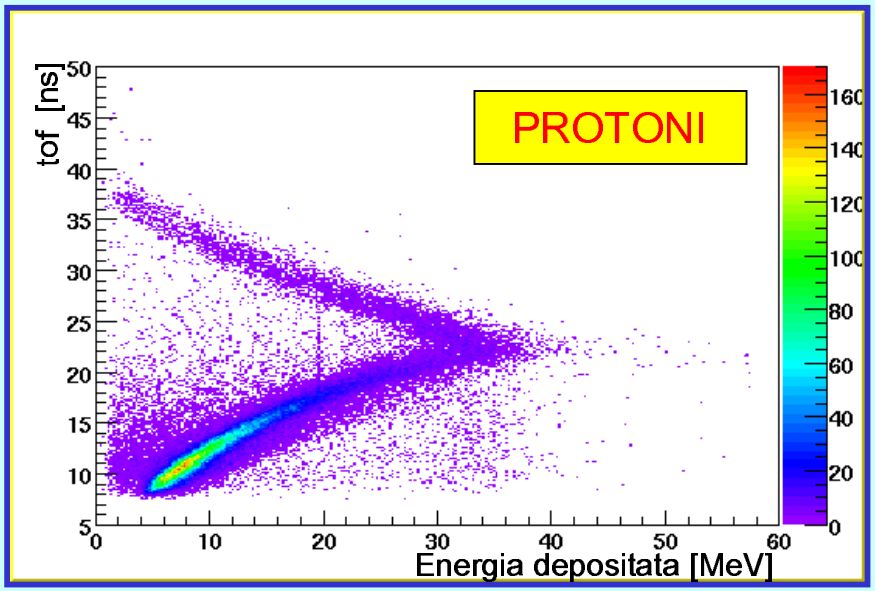


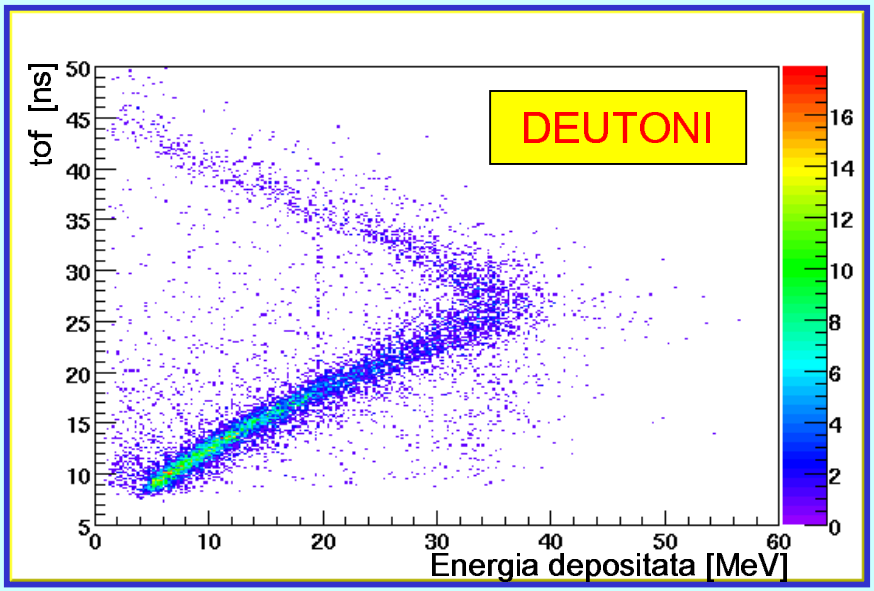
Selezione in massa





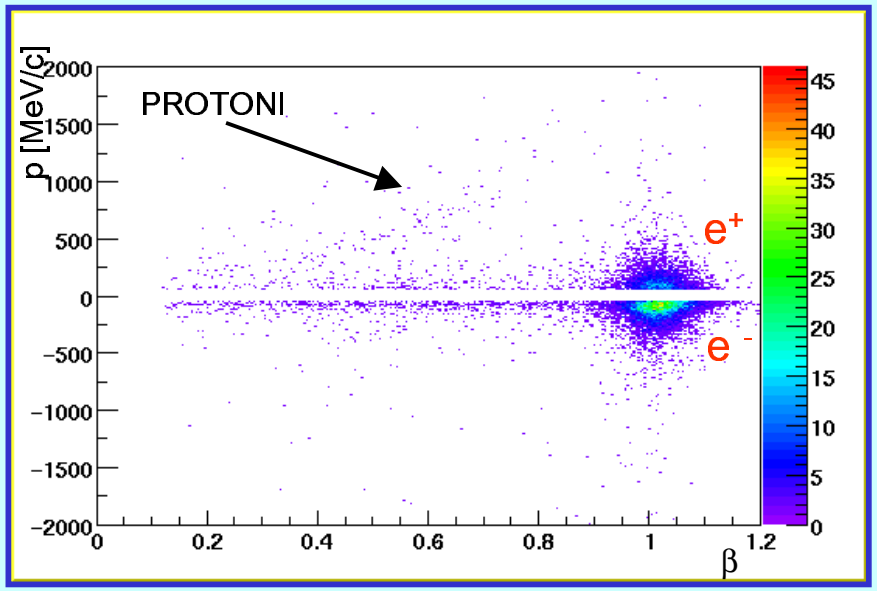
BARRE SOTTILI: Sezione: 20 x 20 mm^2
Angolo θ: 44° ÷ 62°

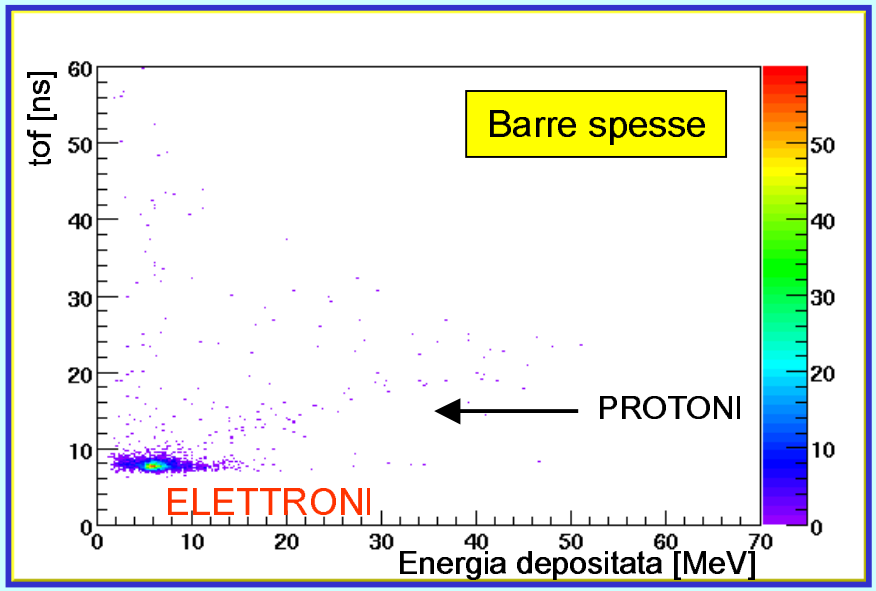


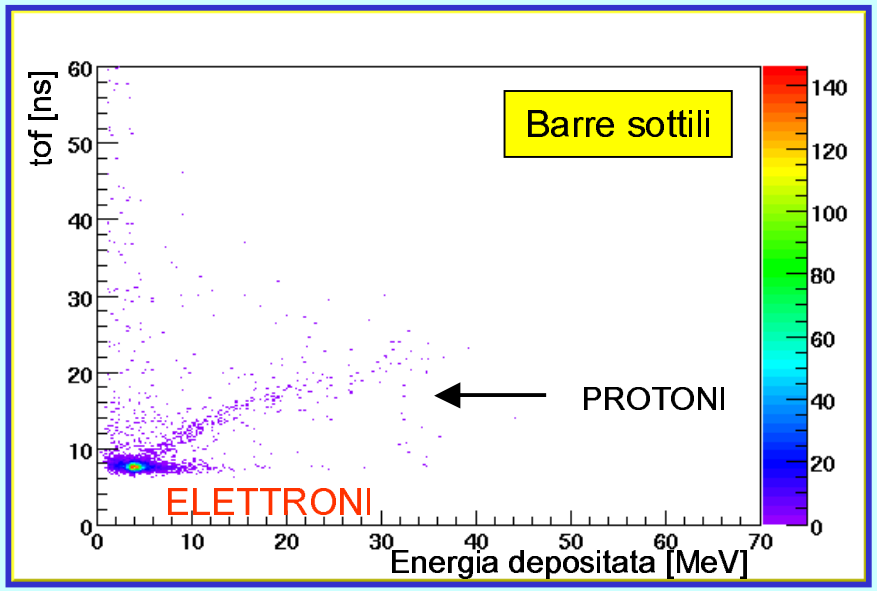


ELETTRONI

Correlazione col RICH







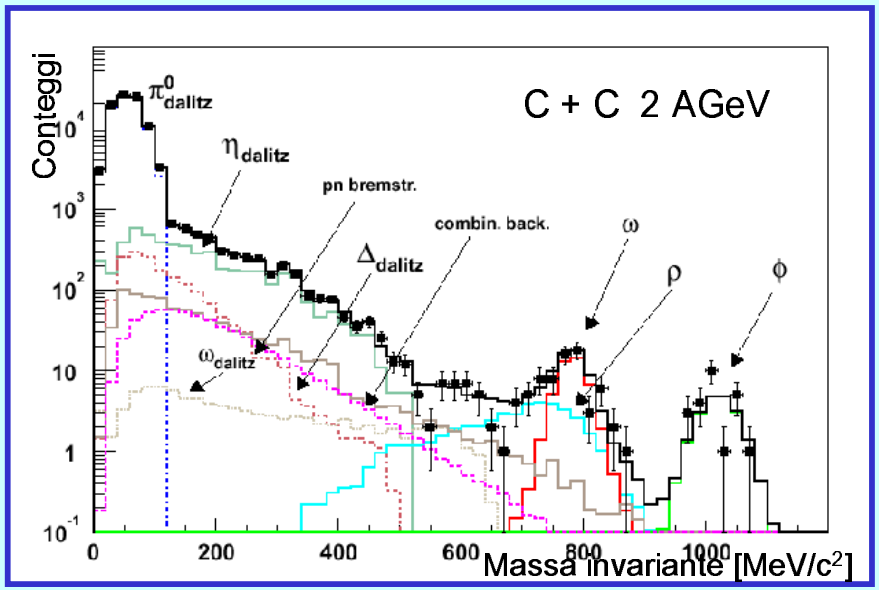
DILEPTONI ⇒ **MASSA INVARIANTE**

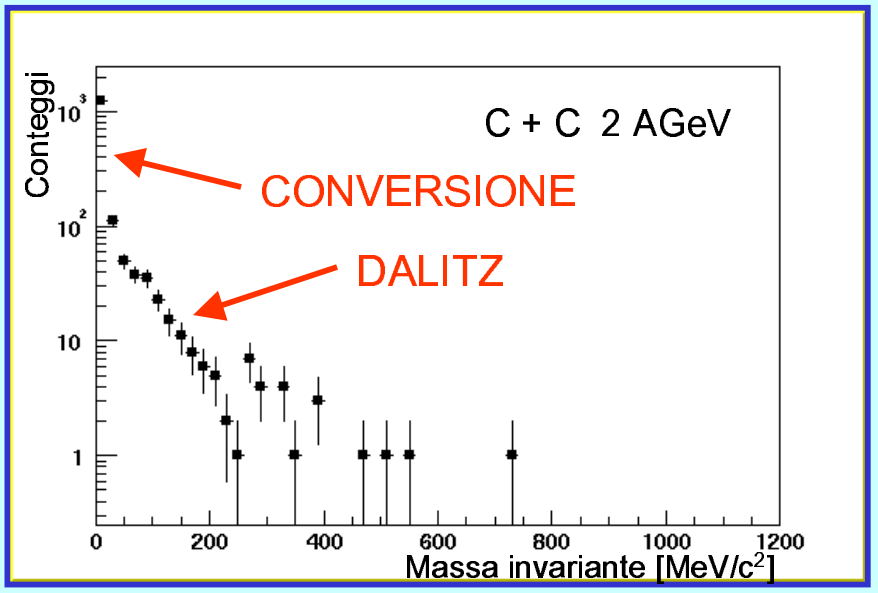
Spettro simulato:

- 3 camere MDC
- Target sottile
- 180000 coppie

Spettro misurato:

- 2 camere MDC
- Target spesso
- 1578 coppie



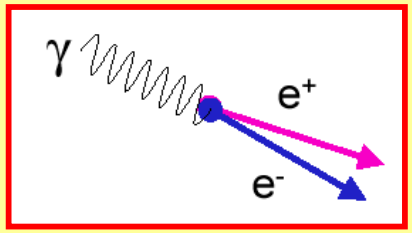


DILEPTONI

Canali di decadimento principali

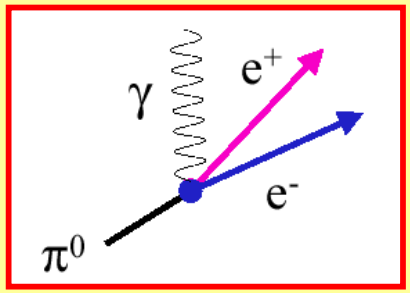
Conversione

$\langle \omega \rangle \approx 2°$

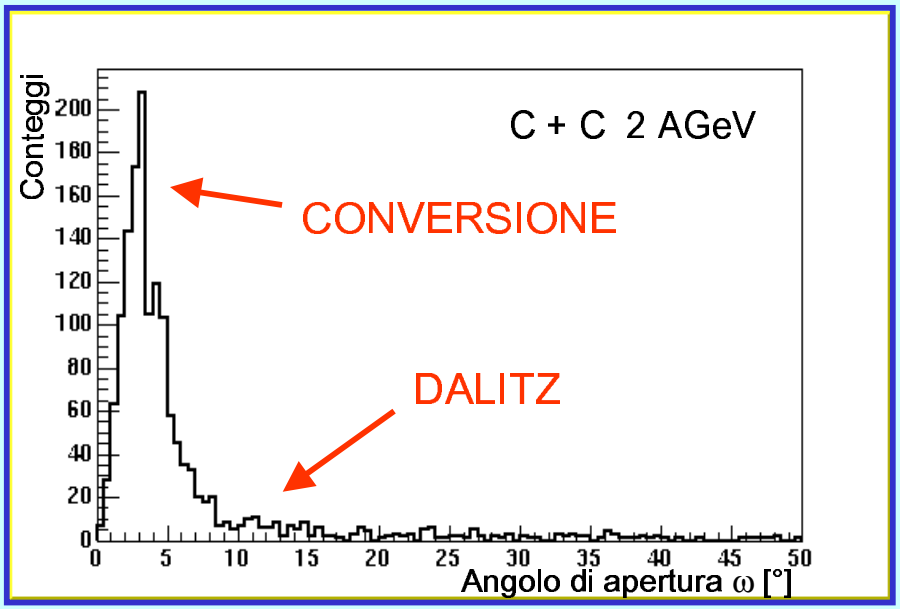


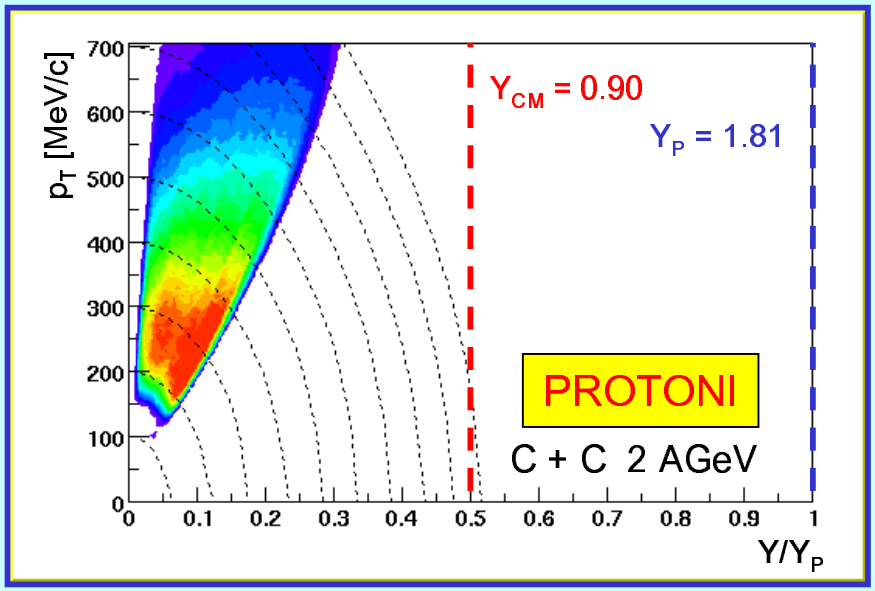
Dalitz

$\langle \omega \rangle \approx 13°$



ANGOLO DI APERTURA

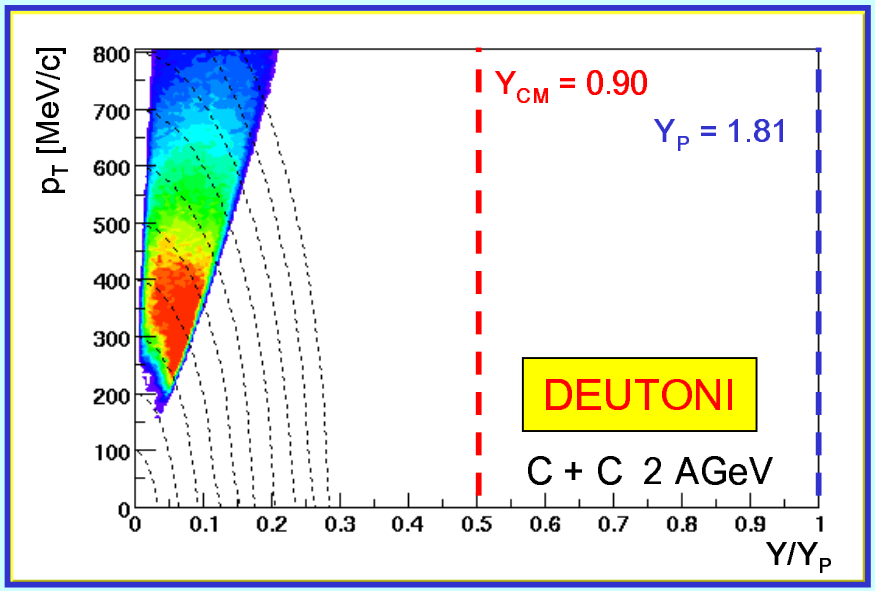


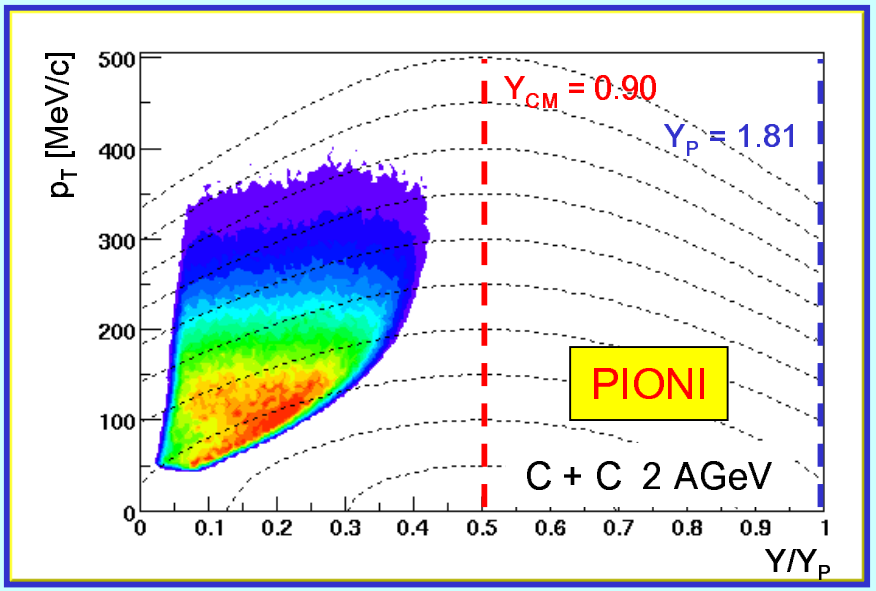


DIAGRAMMI DI RAPIDITA'

Rapidità

$$Y = \frac{1}{2}\ln\frac{E + p_z}{E - p_z}$$

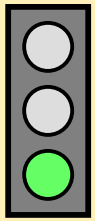




CONCLUSIONI

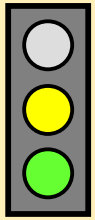
Prestazioni del TOF
- Risoluzione
- Efficienza

→ Accordo coi dati di progettazione



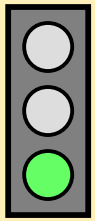
Spettro di massa invariante

→ Accordo con previsioni teoriche
Statistica non sufficiente
Risoluzione non ottimale

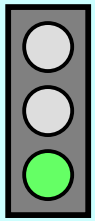


Diagrammi di rapidità

→ Accordo con le previsioni teoriche



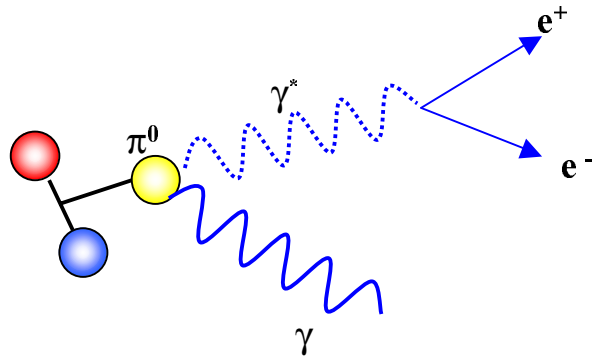
Il rivelatore TOF funziona in maniera ottimale



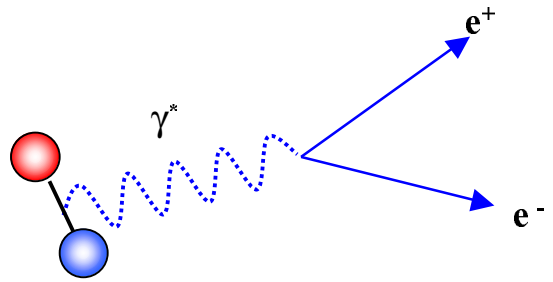
----- RISERVE --------

Principali canali di decadimento dileptonici

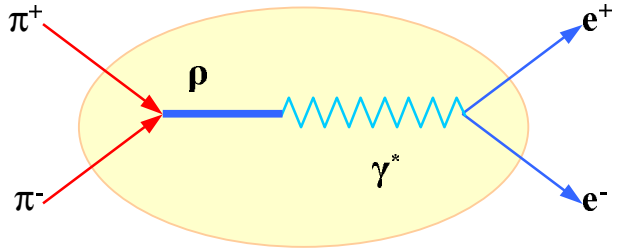
Decadimento Dalitz del π°

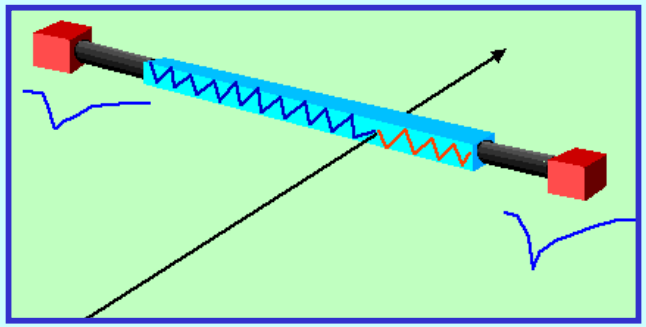


Brehmsstrahlung



Annichilazione π–π





TDC

START

START

STOP

CFD

Delay

Fotomoltiplicatore

Shaper

ADC

START

GATE

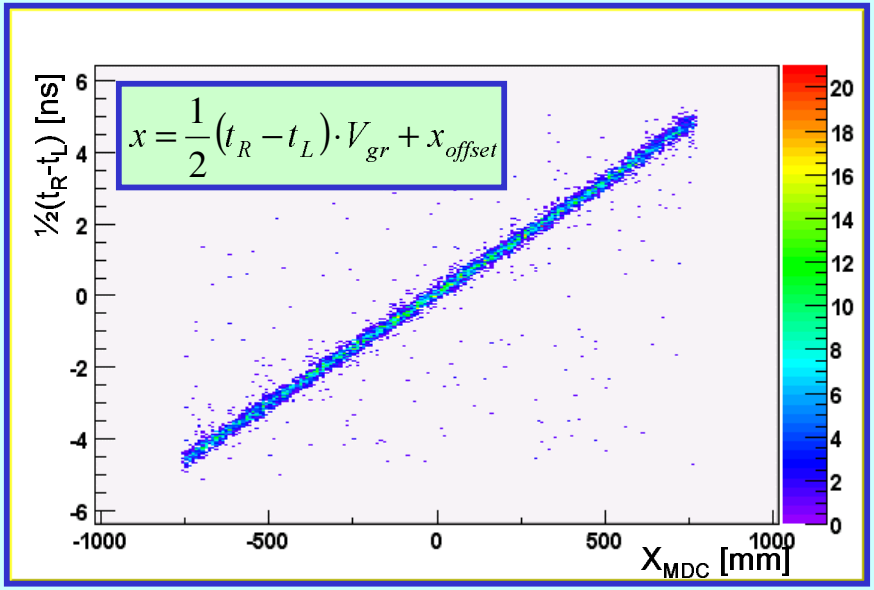
MDC & TOF

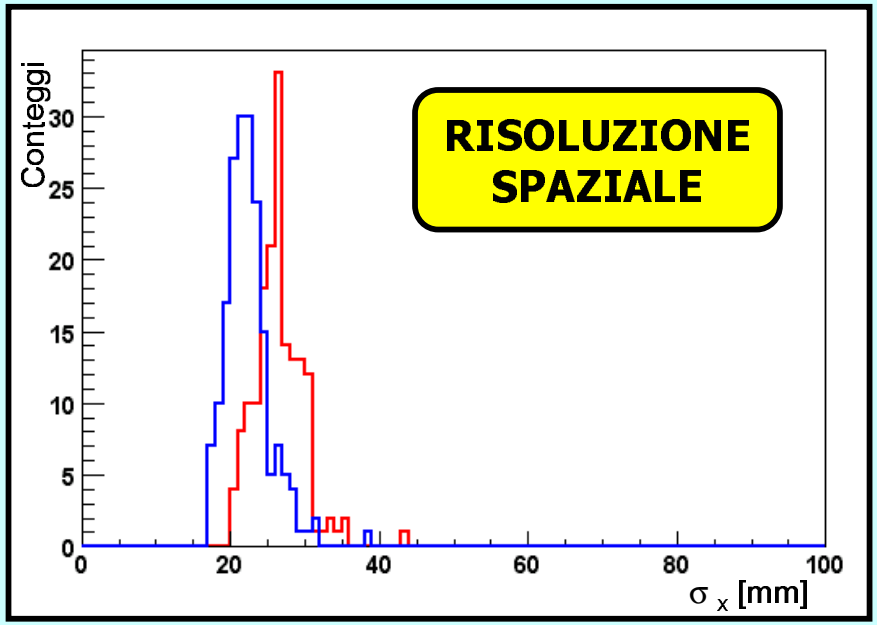
↓

X_{reale} vs $X_{misurato}$

↓

Calibrazione in posizione





BARRE SPESSE

V_{gr} = 164.9 ± 2.5 mm/ns

σ_{pos} = 25.9 ± 2.7 mm

σ_{TOF} = 158 ± 16 ps

BARRE SOTTILI

V_{gr} = 162.9 ± 2.5 mm/ns

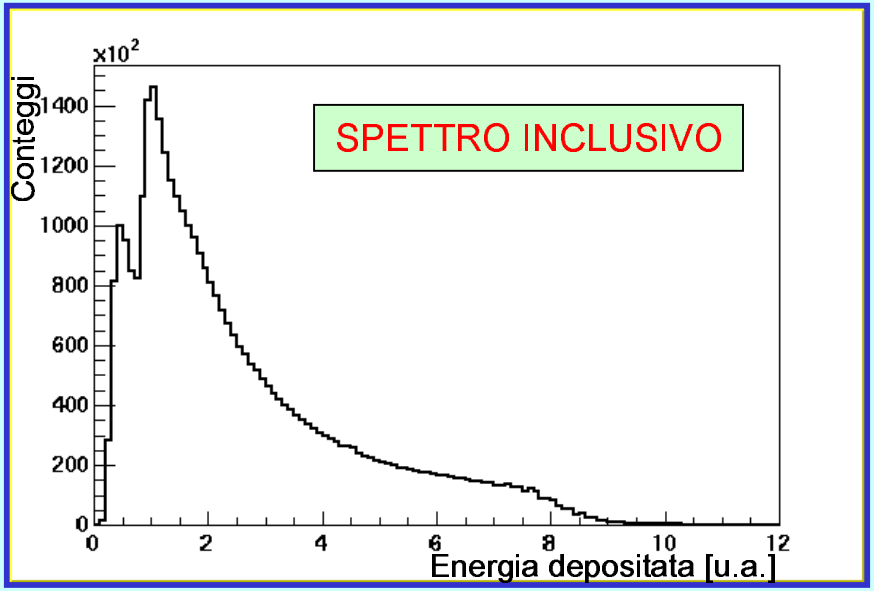
σ_{pos} = 21.7 ± 2.3 mm

σ_{TOF} = 140 ± 14 ps

RICH & TOF

↓

Calibrazione in energia

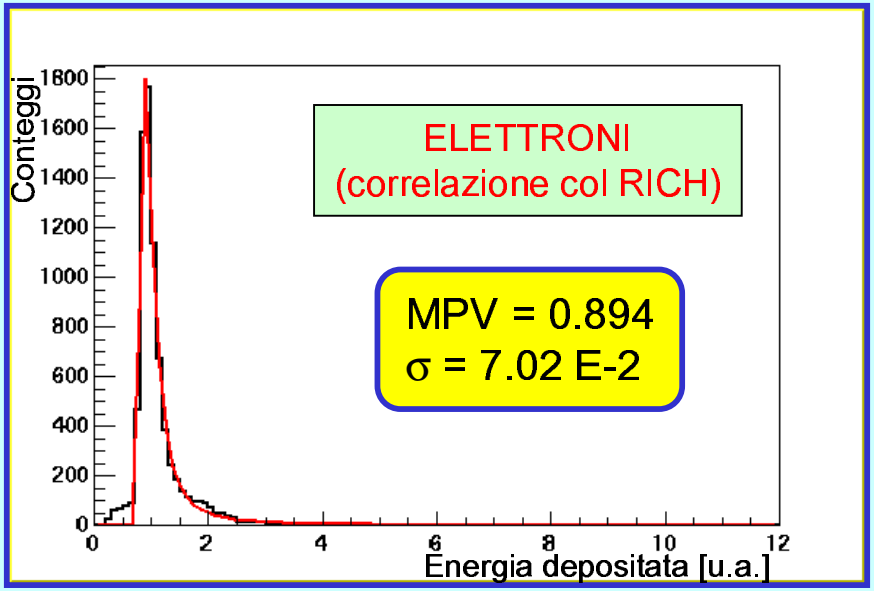


Valori di conversione

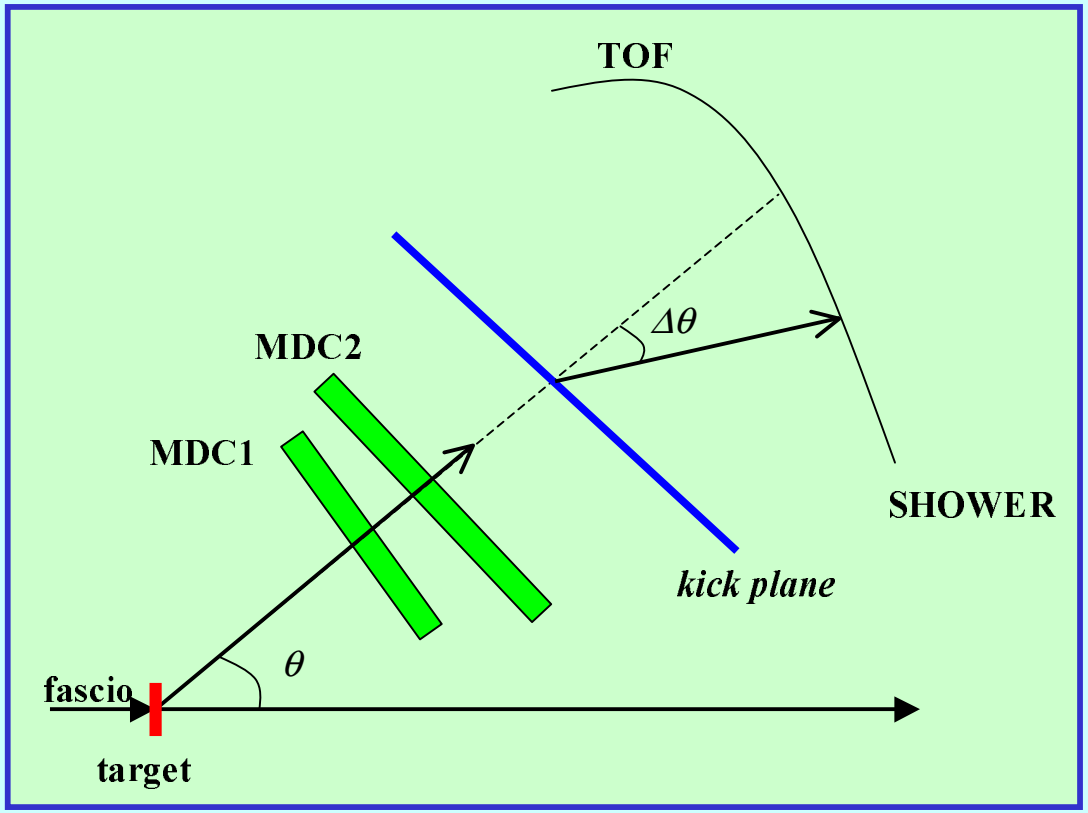
↓

(30x30 mm²): k_E = 6.19 MeV

(20x20 mm²): k_E = 4.13 MeV



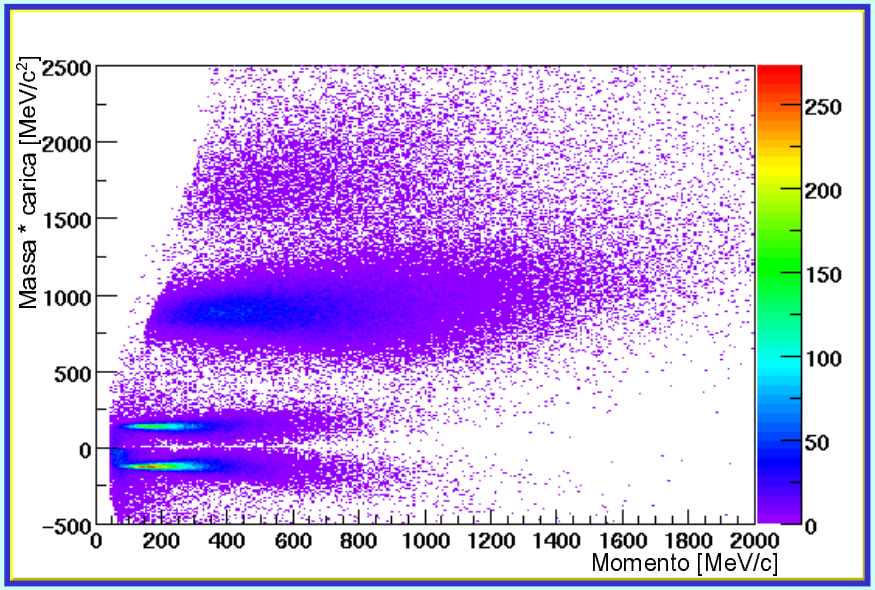
Deflessione delle particelle → Ricostruzione del momento

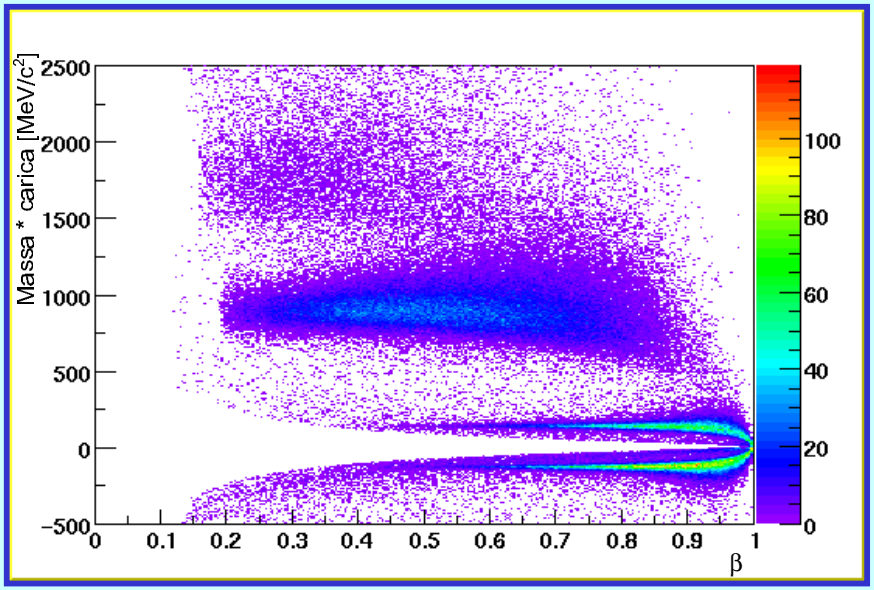


$$\frac{p}{z} = \frac{P_T(\theta,\phi)}{2sen\left(\frac{\Delta\theta}{2}\right)}$$

Pioni e protoni sono distribuiti lungo linee ben separate tra di loro

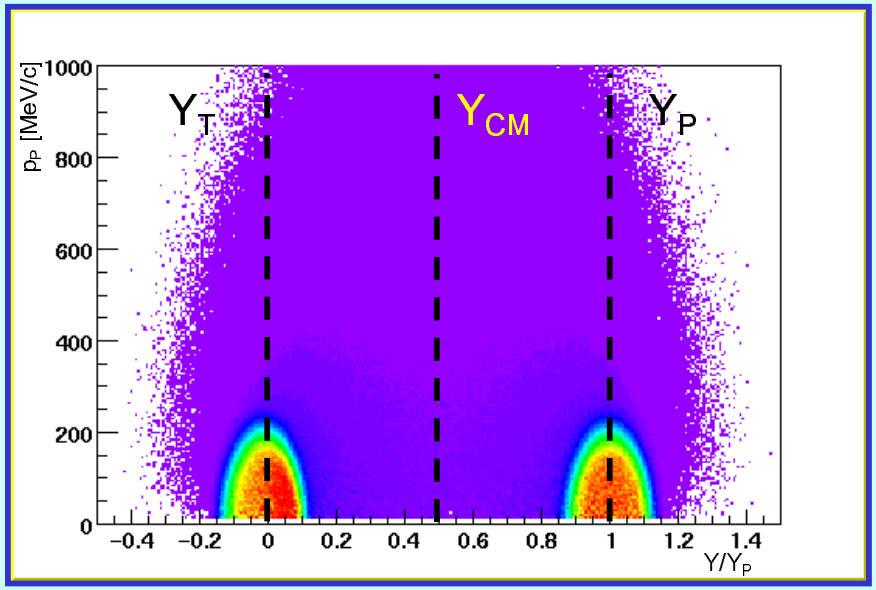
Diminuzione di efficienza per pioni con valori elevati di β





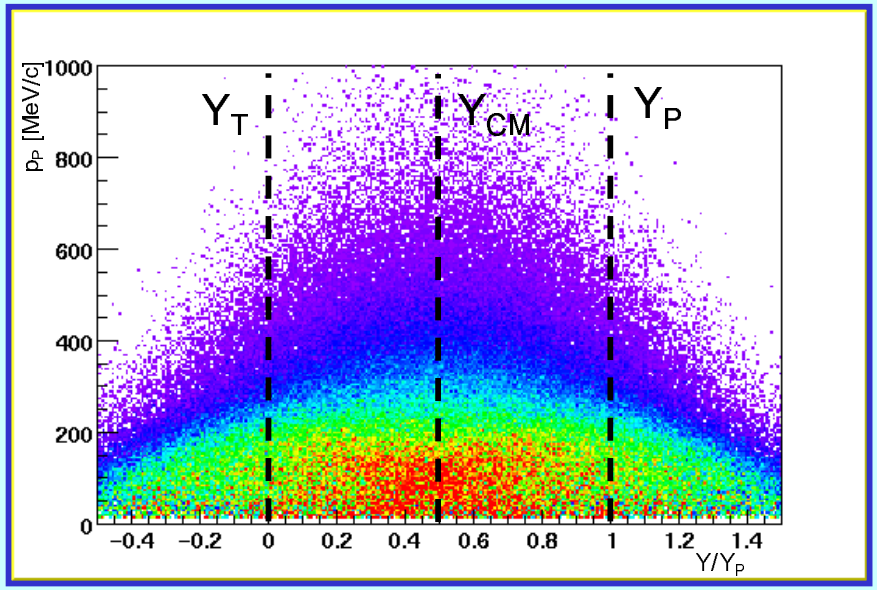
SIMULAZIONI

PROTONI



Emissione prevalentemente dalle regioni del bersaglio e del proiettile

PIONI



Emissione dalla regione di interazione

----- VECCHIE -------

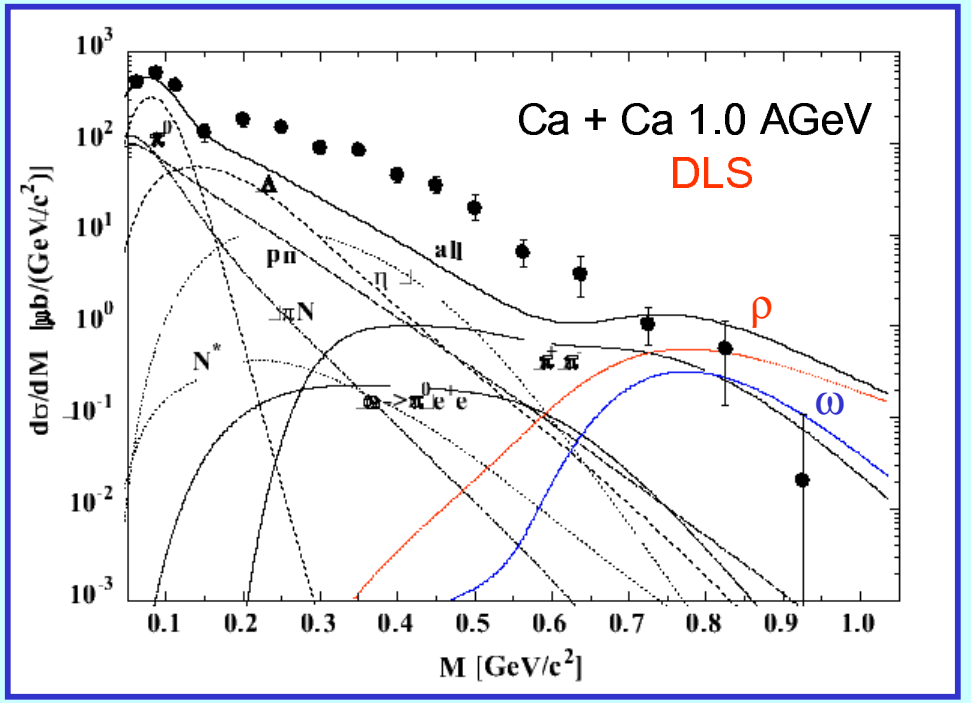
Risultati di altri esperimenti

CERES

- E incidenti 200 ÷ 450 AGeV
- Elevato numero di canali di reazione aperti

DLS

- E incidenti 1 ÷ 2 AGeV
- Accettanza geometrica ~ 5%
- Risoluzione in massa ~ 15%
- Bassa statistica



Sovrapproduzione di dileptoni

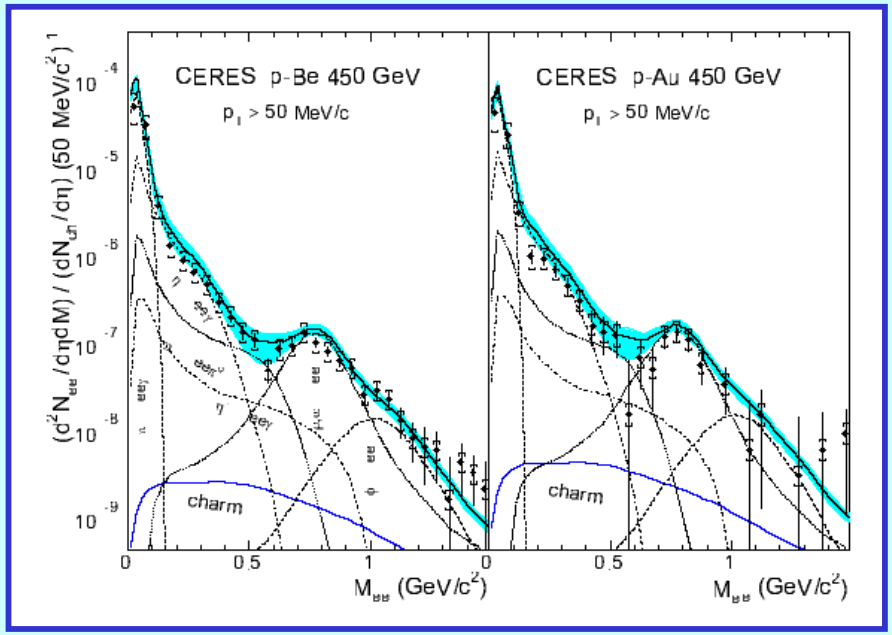
?

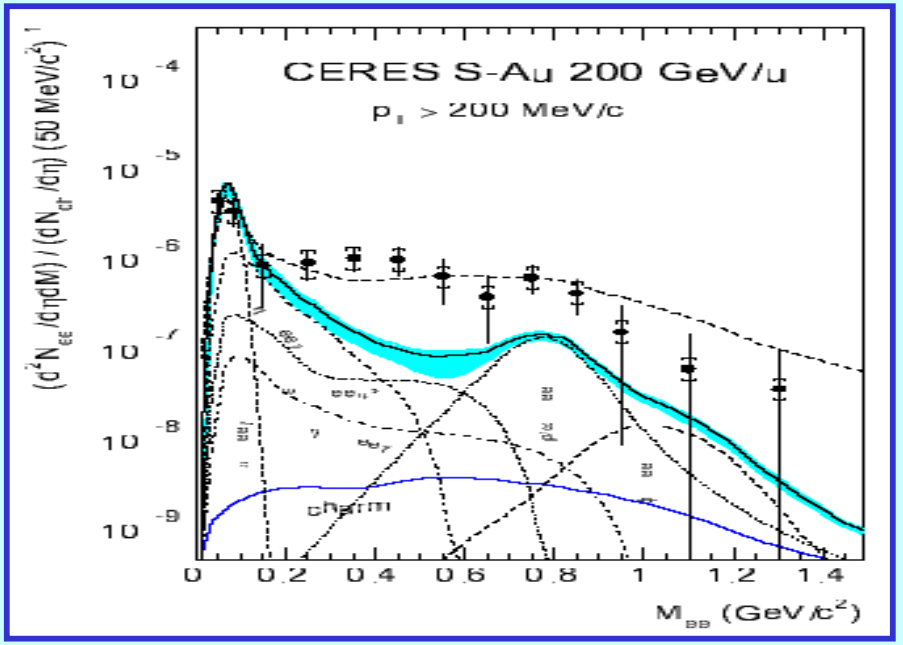
- Diminuzione della massa dei mesoni
- Allargamento della distribuzione di massa

CERES

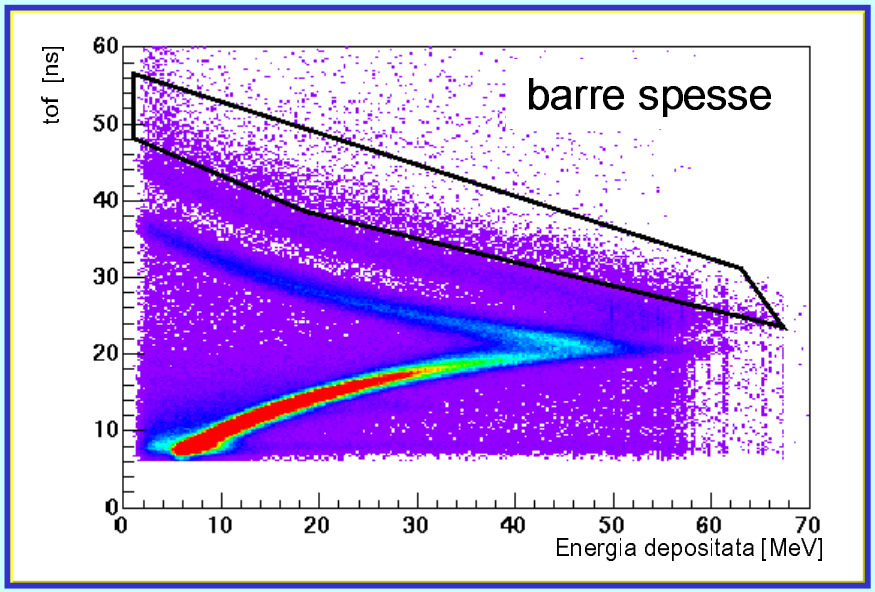
Accordo con le simulazioni

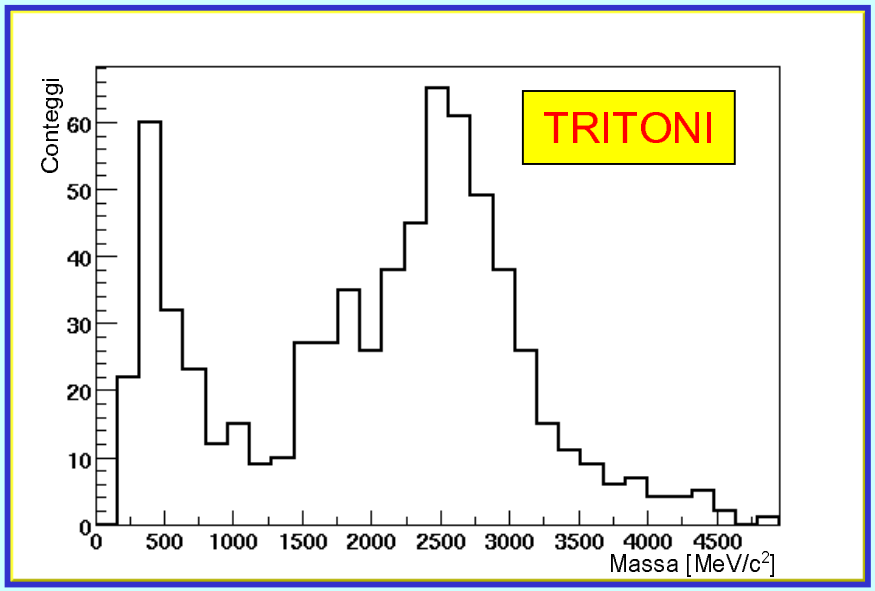
Eccesso di dileptoni
Diminuzione della massa del mesone ρ
?





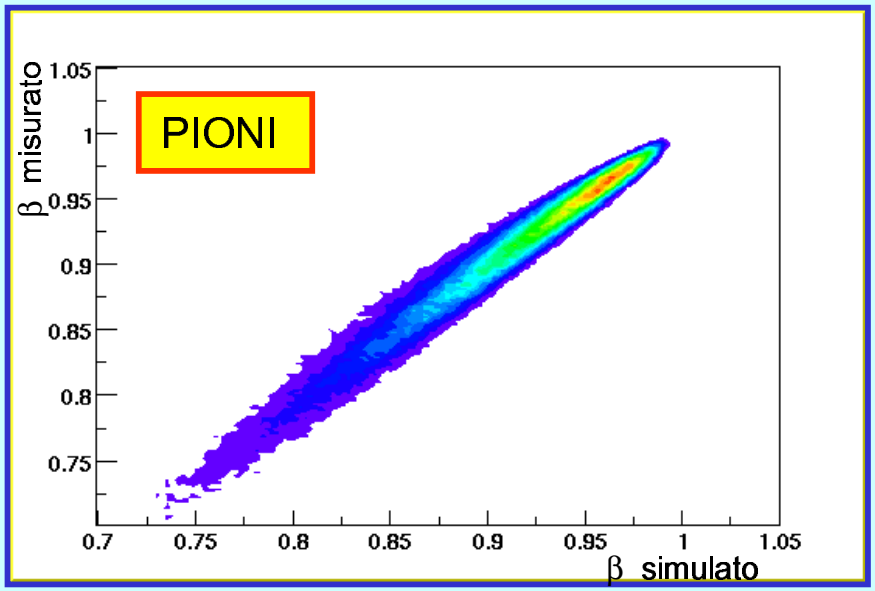
Imponendo un taglio grafico è possibile distinguere la presenza di tritoni

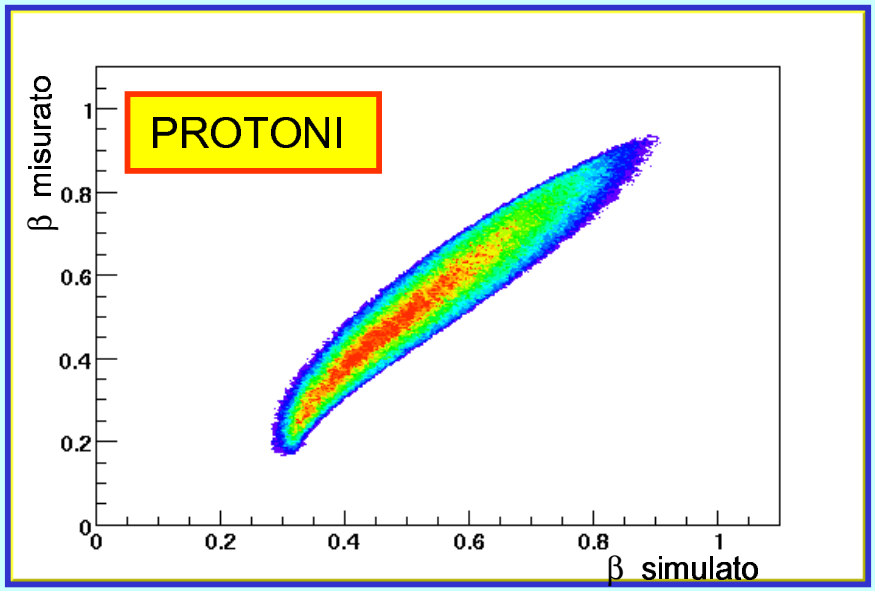


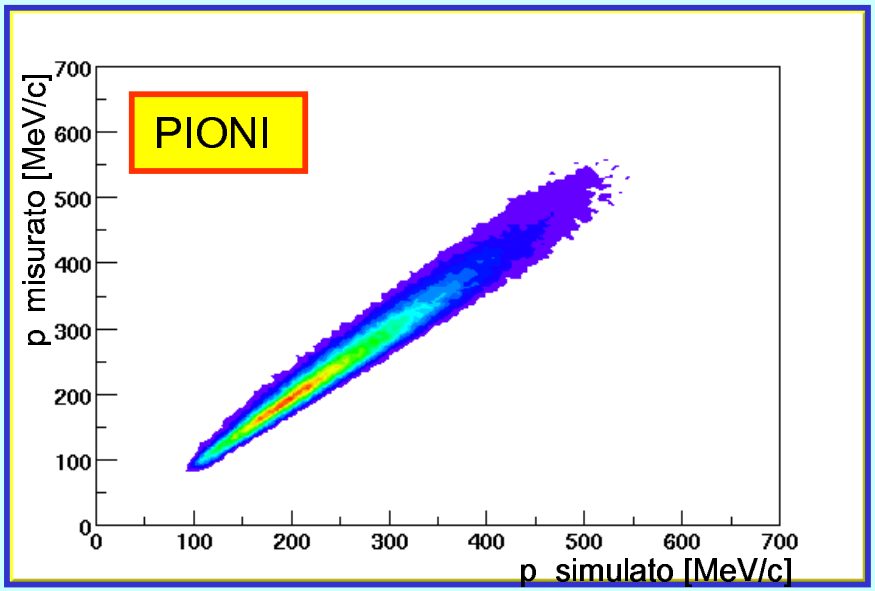


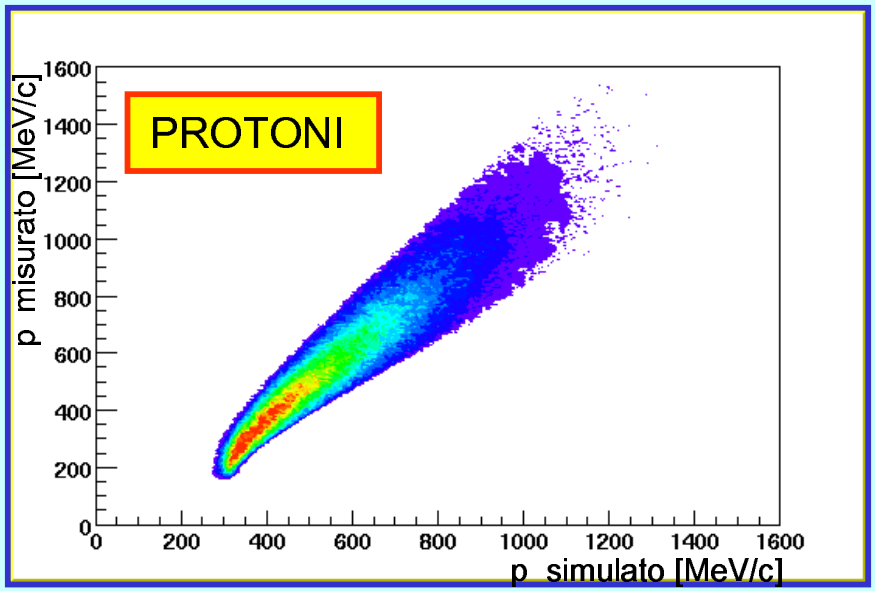
Massa ~ 2630 MeV/c²

La statistica non è sufficiente per una analisi significativa


PIONI
β misurato
β simulato
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05


PROTONI
β misurato
β simulato
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1


PIONI
p misurato [MeV/c]
p simulato [MeV/c]
700
600
500
400
300
200
100
0
100
200
300
400
500
600
700


PROTONI
p misurato [MeV/c]
p simulato [MeV/c]
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
1000
1200
1400
1600