



Search for long lifetime
stops or sbottoms at DELPHI
at \sqrt{s} from 189 to 208 GeV

DELPHI FORUM
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Presented by: J. ABDALLAH



Preliminary results

$$L_{\text{tot}} = 608.7 \text{ pb}^{-1}$$

DATA & MC SAMPLES

98/99 data:

189 GeV; $L = 158 \text{ pb}^{-1}$
192 GeV; $L = 25.85 \text{ pb}^{-1}$
196 GeV; $L = 76.42 \text{ pb}^{-1}$
200 GeV; $L = 83.37 \text{ pb}^{-1}$
202 GeV; $L = 40.64 \text{ pb}^{-1}$

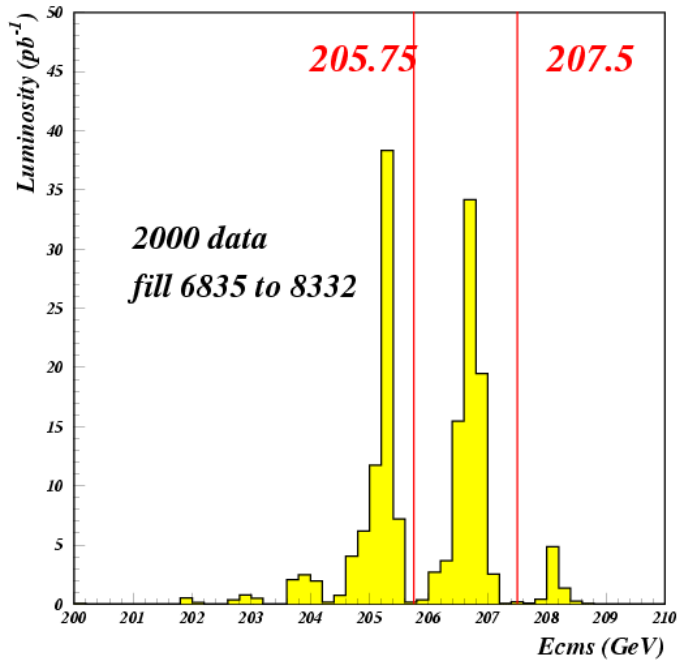
DATA & MC
are processed
with the new version of
SUSANA (V106)



2000 data



2000 data with C1 processing:



3 Ecms windows :

204 GeV; $L= 78.08 \text{ pb}^{-1}$
206 GeV; $L= 78.49 \text{ pb}^{-1}$
208 GeV; $L= 7.28 \text{ pb}^{-1}$

2000 data without S6 (S1 processing):

206 GeV; $L= 60.6 \text{ pb}^{-1}$



MC SAMPLES



4 fermions:

$e^+e^- \rightarrow W^+W^-$ – like	189/192/196/200/202/204/206/208
$e^+e^- \rightarrow q\bar{q}e\nu$	189/196/200/202/204/206/208
$e^+e^- \rightarrow l^+l^-l^+l^-$	189/196/200/202/204/206/208
$e^+e^- \rightarrow e^+e^-\mu^+\mu^-$	189/196/200/202/204/206/208
$e^+e^- \rightarrow e^+e^-\tau^+\tau^-$	189/196/200/202/204/206/208
$e^+e^- \rightarrow e^+e^-q\bar{q}$	189/192/196/200/202/204/206/208
$e^+e^- \rightarrow \mu^+\mu^-q\bar{q}$	189/192/196/200/202/204/206/208
$e^+e^- \rightarrow \tau^+\tau^-q\bar{q}$	189/192/196/200/202/204/206/208
$e^+e^- \rightarrow \nu\nu q\bar{q}$	189/192/196/200/202/204/206/208
$e^+e^- \rightarrow Z(q\bar{q})e^+e^-$	189/196/200/202/204/206/208
Simples 1 2 3 4 5	



All statistics are used
for the C1 & S1 processings



MC SAMPLES



2 fermions:

$e^+e^- \rightarrow q\bar{q}$	189/192/196/200/202/204/206/208
$e^+e^- \rightarrow \mu^+\mu^-$	189/ /196/200/202/204/206/208
$e^+e^- \rightarrow \tau^+\tau^-$	189/192/196/200/202/204/206/208
$e^+e^- \rightarrow \nu\bar{\nu}(\gamma\gamma)$	189/192/196/200/202 /204/206/208
$e^+e^- \rightarrow \gamma^+\gamma^-$ QED	189/ /196/200/202/204/206/208
$e^+e^- \rightarrow e^+e^-$ (bhabha)	189/ /196/200/ /204/206/208
Compton	189/192/196/200/202/204/206/208

Two photons:

$e^+e^- \rightarrow e^+e^-X$ (TwoGam)	189/ / /200/
$e^+e^- \rightarrow e^+e^-X$ (PYTHIA)	/200/ /206/
$e^+e^- \rightarrow e^+e^-e^+e^-$ biased	189/ /196/200/ /204/
$e^+e^- \rightarrow e^+e^-\mu^+\mu^-$ biased	189/ /196/200/ /204/
$e^+e^- \rightarrow e^+e^-\tau^+\tau^-$	189/ /196/200/ /204/



Phenomenology of stable squarks



Decay width:

$$\Gamma(\tilde{t} \rightarrow c\tilde{\chi}_1^0) \propto 10^{-10} m_{\tilde{t}} \left(1 - \frac{m_{\tilde{\chi}_1^0}^2}{m_{\tilde{t}}^2} \right)^2$$

If $\Delta m \rightarrow m_c$; $\tau_{\tilde{t}} \approx 10^{-10} \Rightarrow c\tau_{\tilde{t}} > 2m$

($\Delta m \rightarrow m_b$ for sbottoms)

Formation of colorless s-hadrons

Process:

$$e^+ e^- \rightarrow \tilde{t} \tilde{t}^- \xrightarrow{\text{hadronisation}} \tilde{T}^{0,\pm} \tilde{T}^{0,\pm} + X$$

Three possible final states:

Double neutral: $\tilde{T}^0 \tilde{T}^0$

Mixed: $\tilde{T}^0 \tilde{T}^\pm$

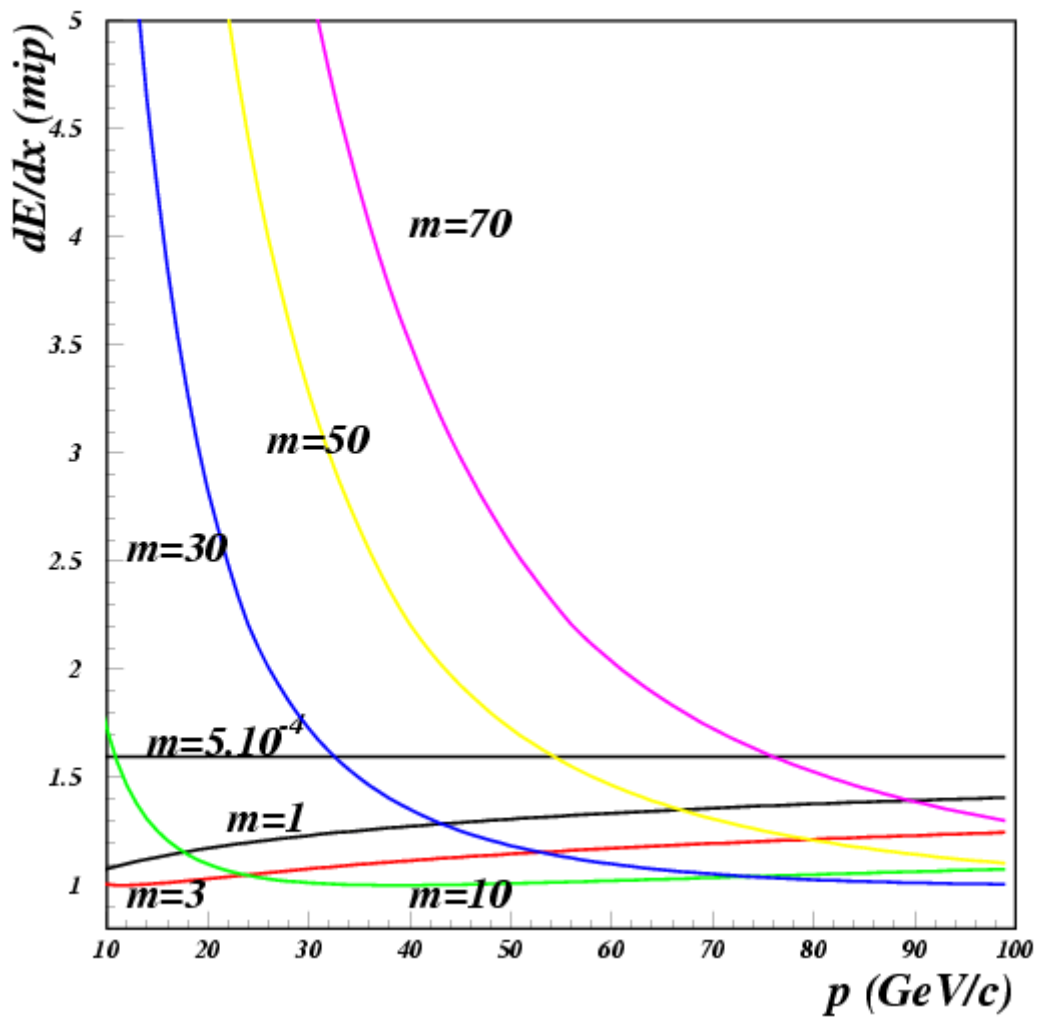
Double charged: $\tilde{T}^\pm \tilde{T}^\pm, \tilde{T}^\pm \tilde{T}^\mp$

Topologies:

- 2 acoplanar jets with one energetic particle in each jet
- Anomalous ionization loss dE/dx for the charged s-hadrons in the TPC



dE/dx for several mass hypotheses





Monte Carlo simulation

- Squark events are generated with SUSYGEN and passed through the detector simulation program.
- 1000 stop and sbottom events are produced for the following set of mass:
5,10,20,30,40,50,60,70,80,85,90,94,95,97,99,100 and 101 GeV for each sqrt(s) from 189 to 208 GeV
- The hadronization of squarks was implemented in SUSYGEN* using the Peterson fragmentation function with a squark fragmentation parameter $\epsilon_{\tilde{t}}$ scaled from the b-fragmentation parameter:

$$\epsilon_{\tilde{t}} = \epsilon_b (m_b / m_{\tilde{t}})^2 \text{ with } m_b = 5 \text{ GeV} / c^2$$
$$\text{and } \epsilon_b = 0.003$$

* for details, see:

*A Search for Heavy Stable and Long-Lived Squarks and Sleptons
in e+e- Collisions at Energies from 130 to 183 GeV
DELPHI collaboration - CERN-EP/98-171*



Relative composition of the $\tilde{T}\tilde{T}$ charge configurations

SUSYGEN

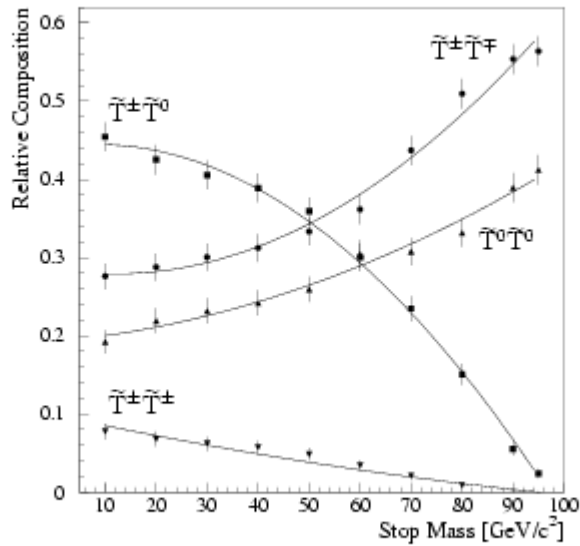
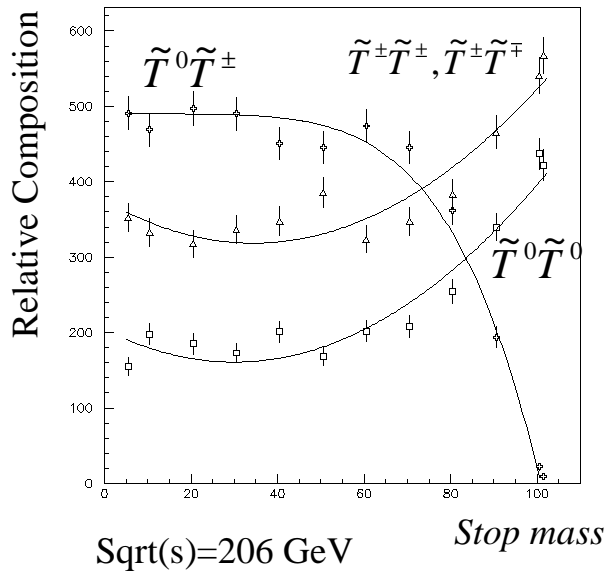


Figure 2: Relative composition of the possible $\tilde{T}\tilde{T}$ charge configurations as a function of the stop mass at $\sqrt{s} = 200$ GeV.

ALEPH collaboration - CERN-EP/2000-085



Analysis



Global preselection

SUSANA Preselection:

$$N_{ch} \geq 2$$

$$E_t > 4 \text{ GeV}$$

{ At least one charged particle with
Pt > 1.5 GeV

Quality cuts:

$$\text{IDELAN.EQ.1}$$

$$\text{IHER(1).EQ.0}$$

$$\text{IHER(2).EQ.0}$$

Preselection:

$$\text{NTP.GE.1}$$

$$\text{NJLU.GE.2}$$

$$\text{NCHA.LE.40}$$

$$\text{DCHA/ECHA.LT.0.15}$$

$$\text{EVIS/ECM.LE.1.}$$

$$\text{PTPC/ECHA.GE.0.5}$$

$$\text{ECONE(6)/EVIS.LE.0.9}$$

$$\text{ECONE(10)/EVIS.LT.1.}$$

$$\text{ETOTEM/EVIS.LE.0.7}$$

$$\text{PTMX.GE.10.}$$

$$\text{EVIS.GE.25.}$$

$$\text{ETRA.GE.25.}$$

$$\text{ETRA/EVIS.GE.0.3}$$

$$\text{PTRA/EVIS.LE.0.6}$$



Data MC comparison at preselection level



Comparison of the number of events for Data and MC:

98/99 data:

\sqrt{s}	189 GeV	192 GeV	196 GeV	200 GeV	202 GeV
Data	9660	1439	4367	4470	2155
MC	9616	1545	4328	4544	2152

2000 data processing C1

\sqrt{s}	204 GeV	206 GeV	208 GeV
Data	3965	3950	357
MC	4082	4025	365

2000 data processing S1

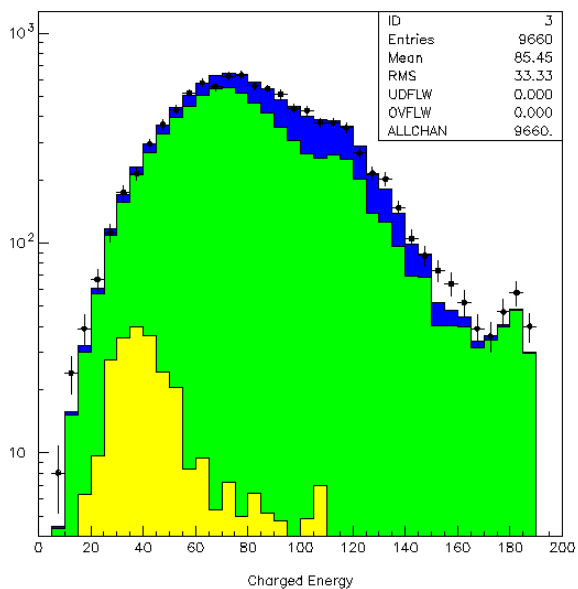
\sqrt{s}	206 GeV
Data	2741
MC	2889



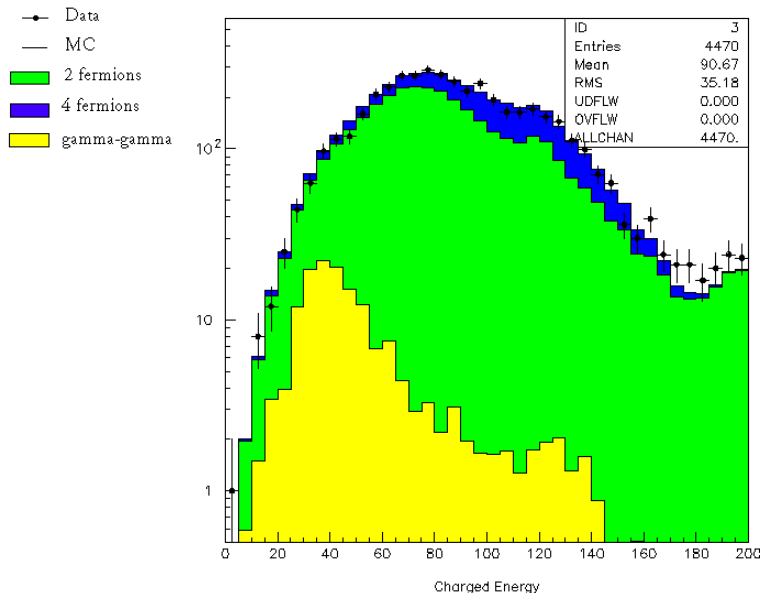
Data MC comparison at preselection level



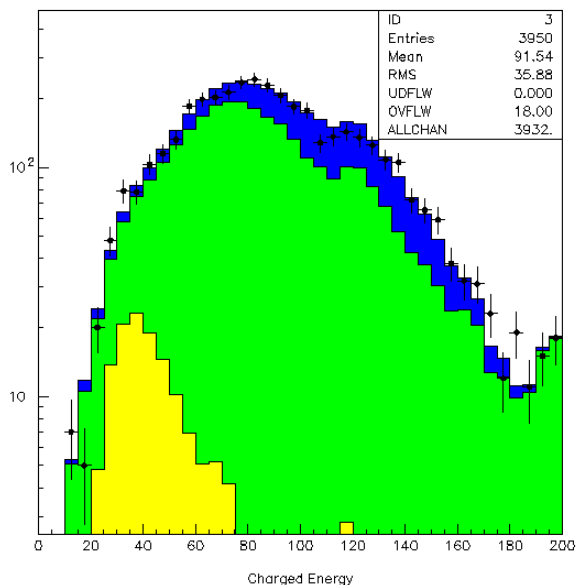
Data @ 189 GeV



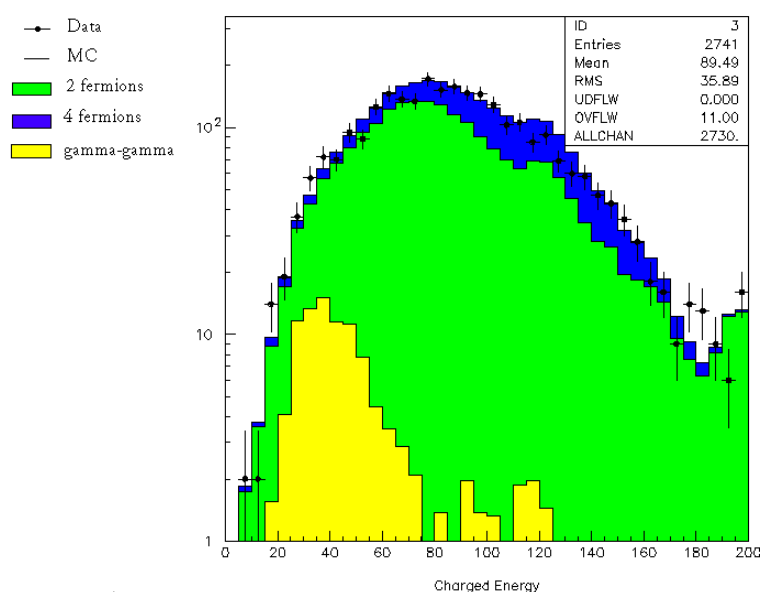
Data @ 200 GeV



2000 data in the 206 GeV window



2000 data without TPC S6 (206 GeV)



Charged energy

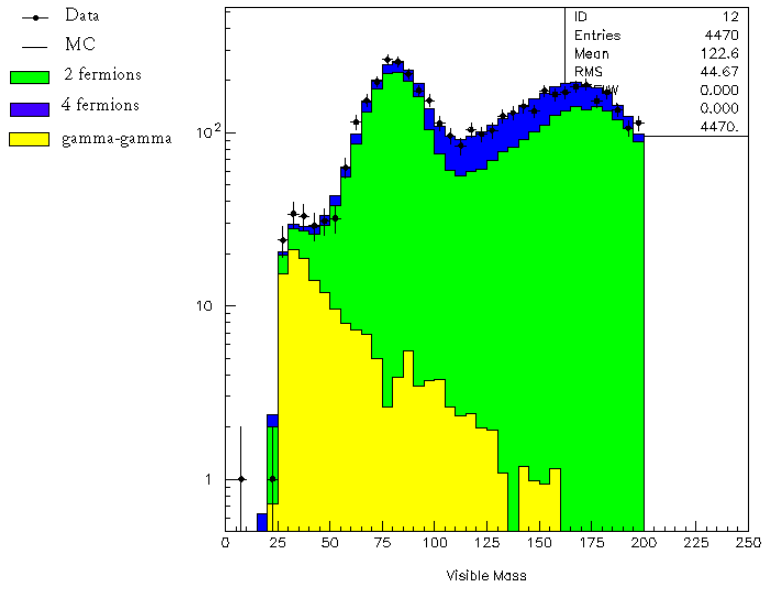
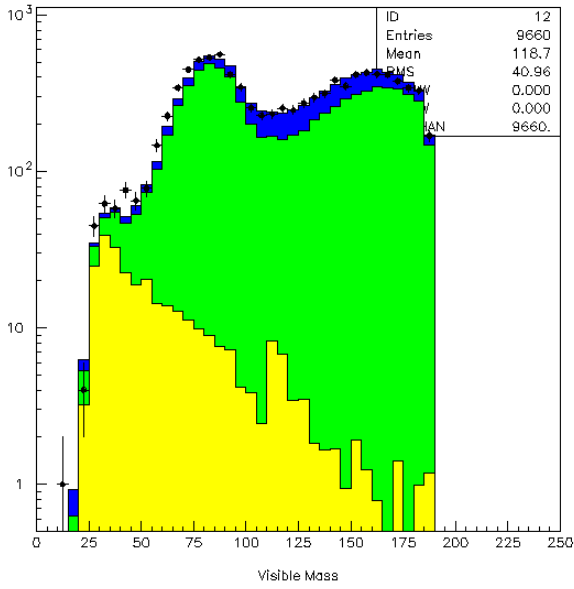


Data MC comparison at preselection level



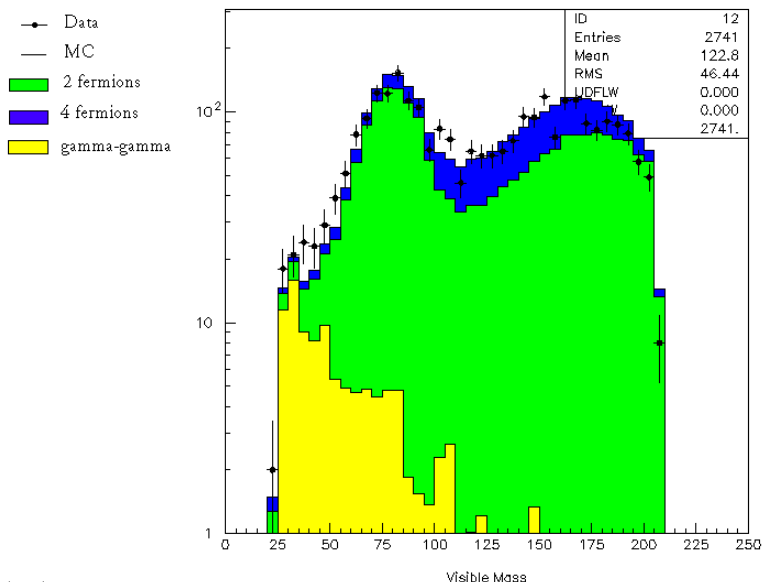
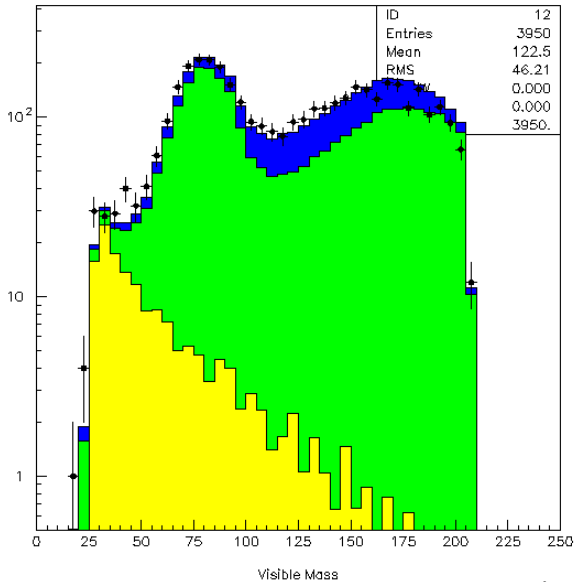
Data @ 189 GeV

Data @ 200 GeV



2000 data in the 206 GeV window

2000 data without TPC S6 (206 GeV)



Visible mass

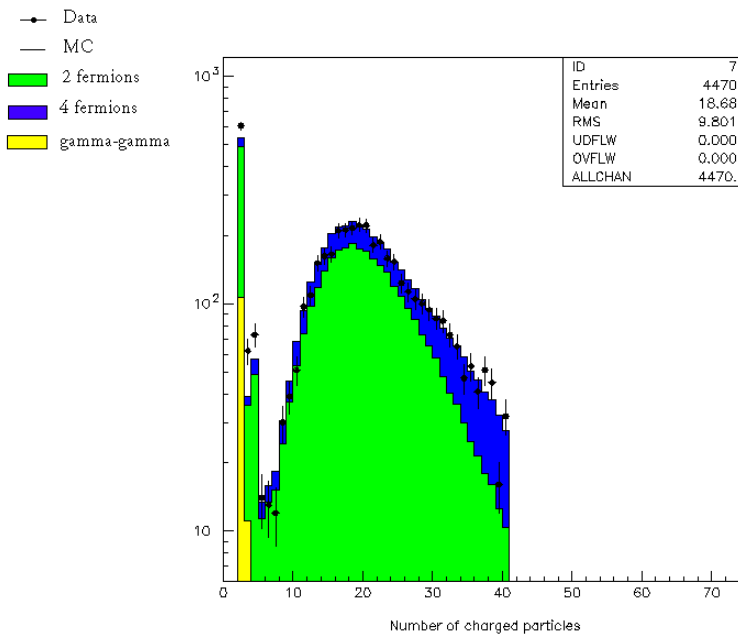
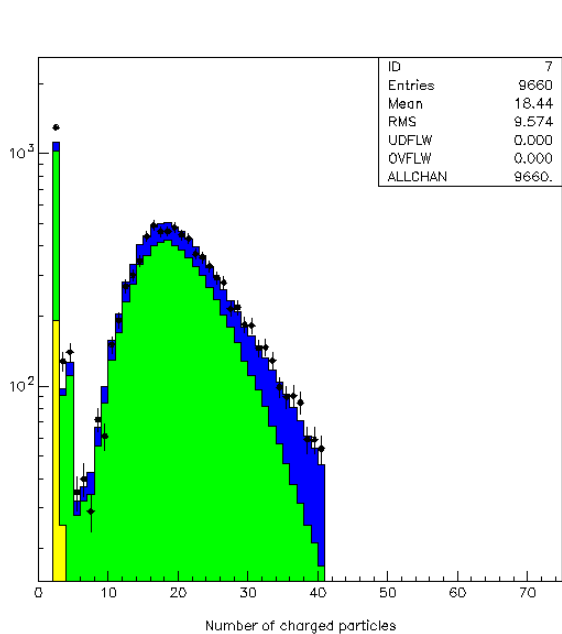


Data MC comparison at preselection level



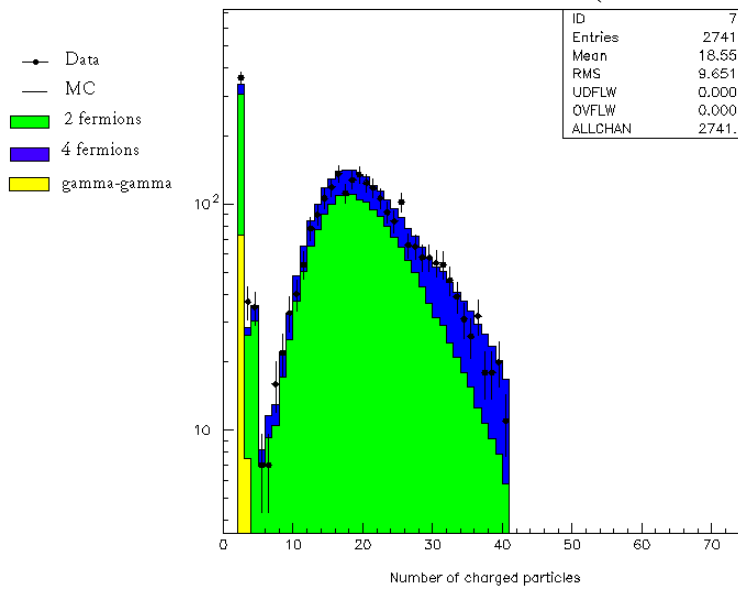
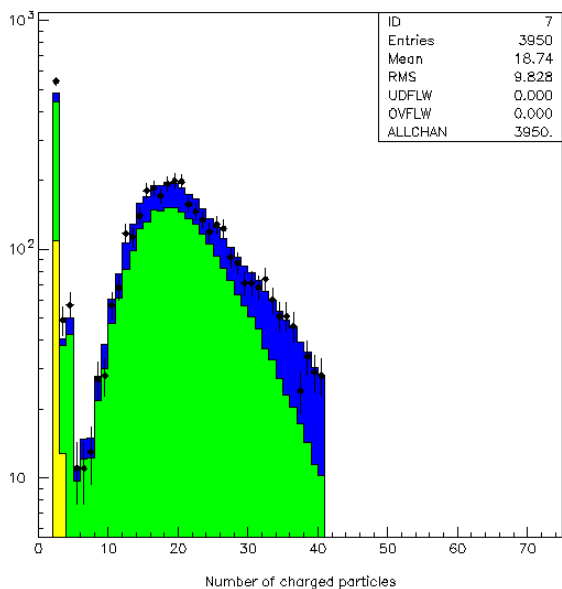
Data @ 189 GeV

Data @ 200 GeV



2000 data in the 206 GeV window

2000 data without TPC S6 (206 GeV)



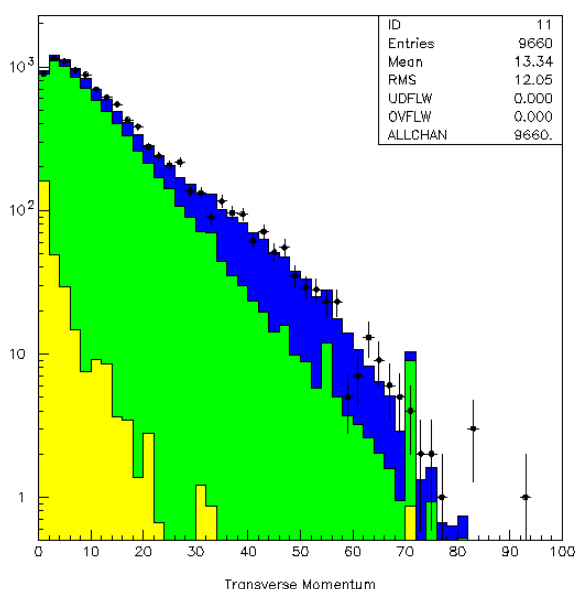
Charged multiplicity



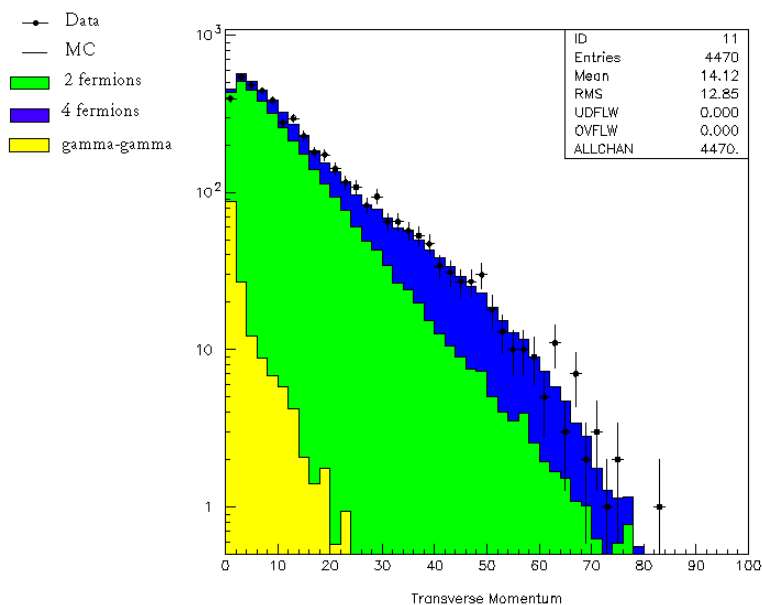
Data MC comparison at preselection level



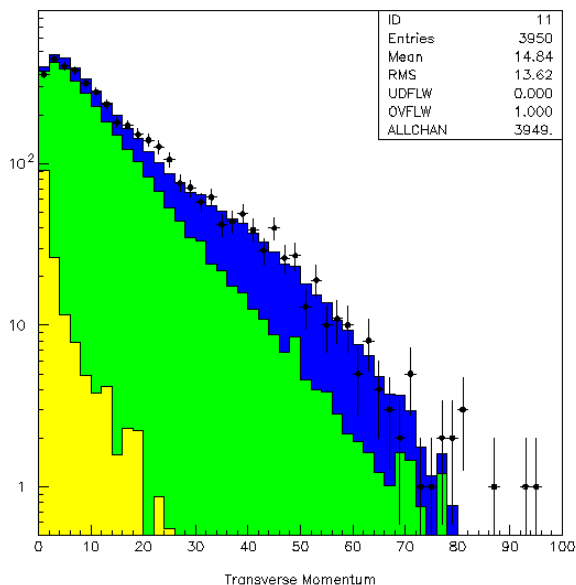
Data @ 189 GeV



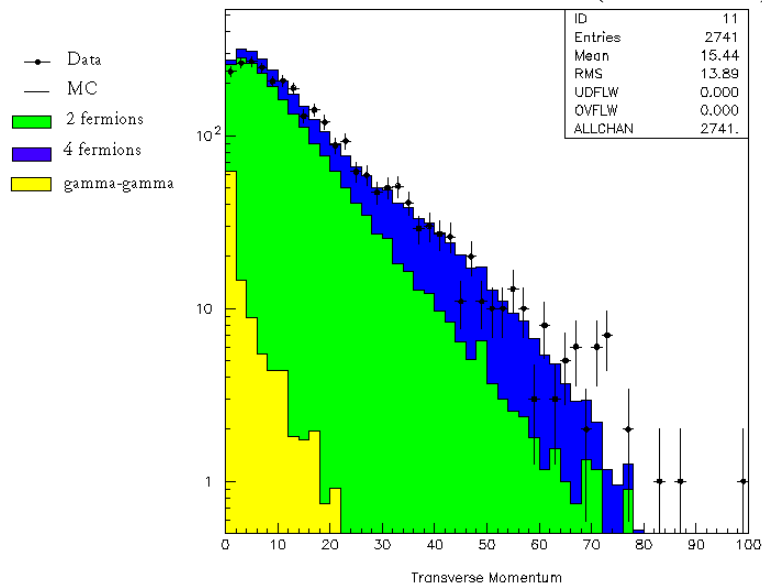
Data @ 200 GeV



2000 data in the 206 GeV window



2000 data without TPC S6 (206 GeV)



Transverse momentum



Selection of Heavy stable particles in the event with well measured dE/dx



Loop on all particles in the event:

DO I=1,NTC

```
IF ( (ITPC(I) .EQ. 1) .AND. (TPC HIT)
      (IVD(I) .EQ. 1) .AND. (VD HIT)
      (IID(I) .EQ. 1) .AND. (ID HIT)
      (PC(1,I) .GE. 10.) .AND. (momentum)
      (DPPC(I) .LT. 0.2) .AND. (error on p)
      (EC(1,I) .LT. 10.) .AND. (e.m. energy)
      (DEDX(8,I) .GT. 1.) .AND. (quality flag)
      (DEDX(7,I) .GE. 80.)) THEN (Nb of wires)
```

(For 2000 data, particle are rejected if his momentum are reconstructed in the sector 6 of the TPC)

NHEAVY=NHEAVY+1

IH(NHEAVY)=I

ENDDO

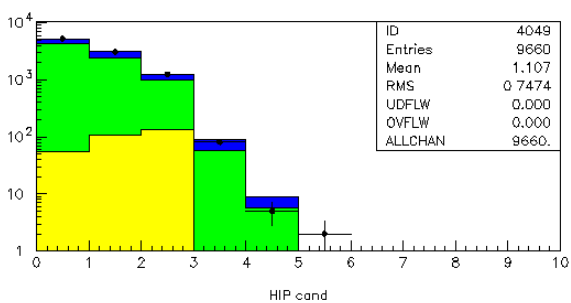


Plots of Heavy particles candidates

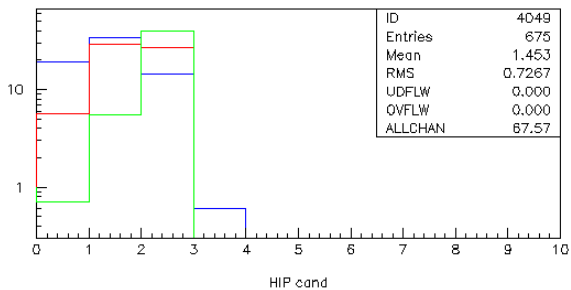
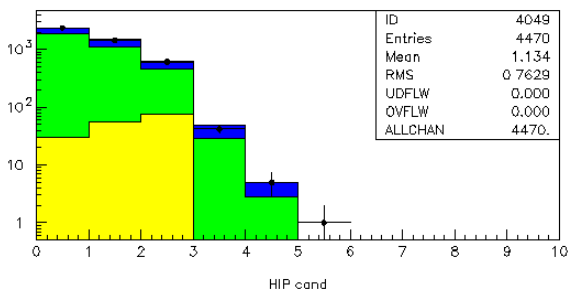


Data @ 189 GeV

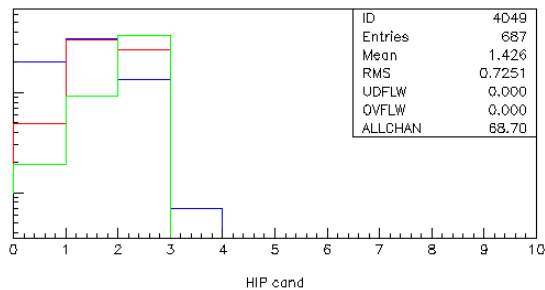
Data @ 200 GeV



● Data
 — MC
■ 2 fermions
■ 4 fermions
■ gamma-gamma

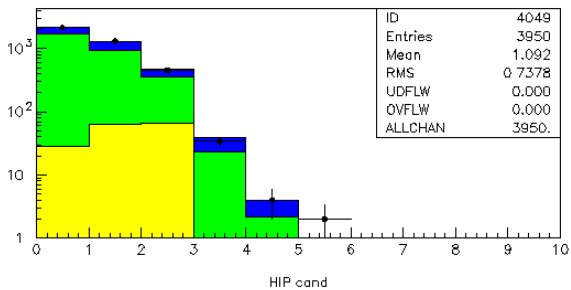


— M=10 GeV
— M=60 GeV
— M=90 GeV

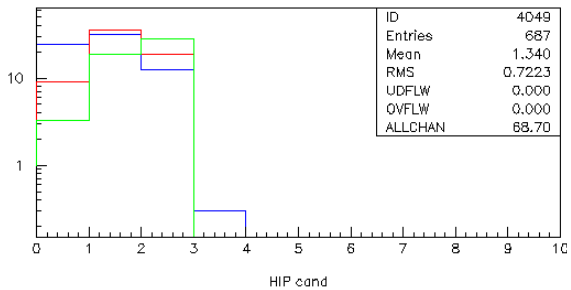
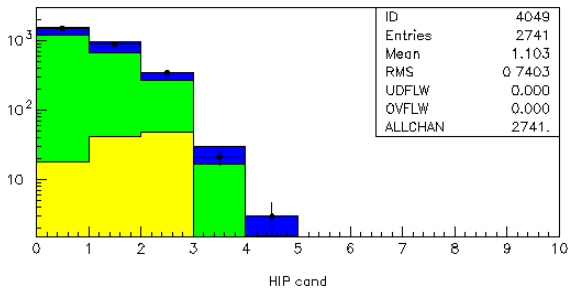


2000 data in the 206 GeV window

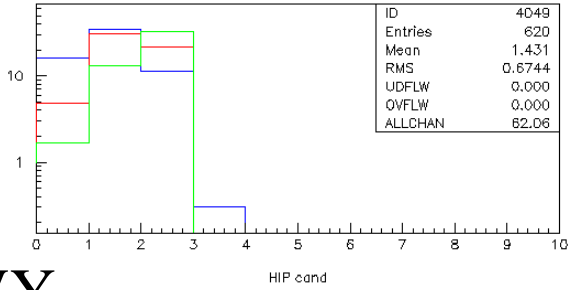
2000 data without TPC S6 (206 GeV)



● Data
 — MC
■ 2 fermions
■ 4 fermions
■ gamma-gamma



— M=10 GeV
— M=60 GeV
— M=90 GeV



NHEAVY



At least one Heavy particle



Comparison of the number of events for Data and MC after the NHEAVY.GE.1 cut:

98/99 data:

\sqrt{s}	189 GeV	192 GeV	196 GeV	200 GeV	202 GeV
Data	4427	690	1986	2113	1058
MC	4508	726	2067	2182	1037

2000 data processing C1

\sqrt{s}	204 GeV	206 GeV	208 GeV
Data	1759	1797	164
MC	1849	1819	165

2000 data processing S1

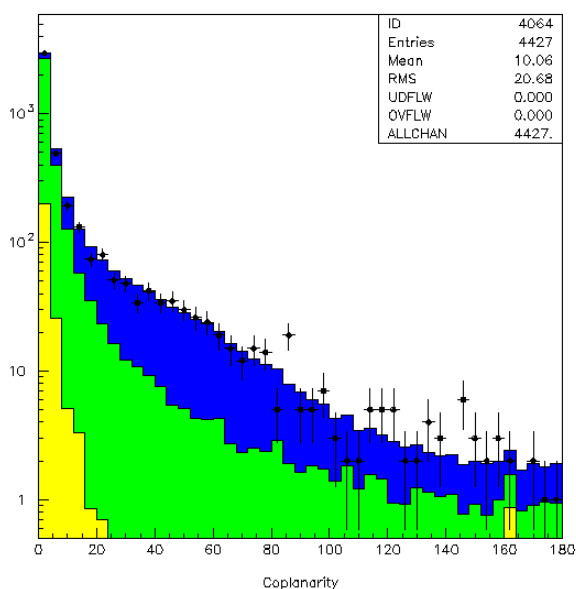
\sqrt{s}	206 GeV
Data	1260
MC	1342



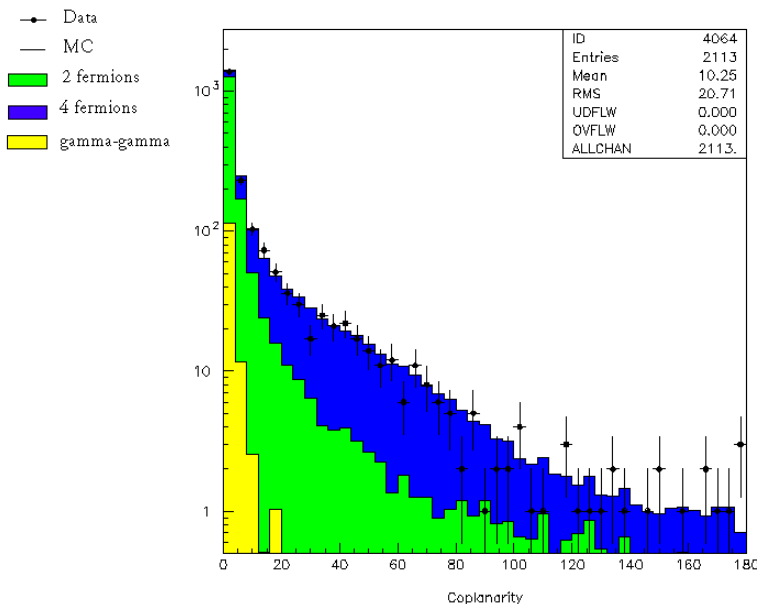
At least one Heavy particle



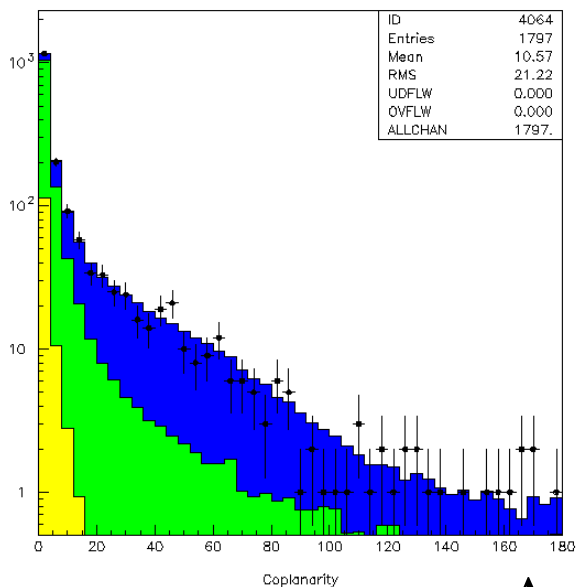
Data @ 189 GeV



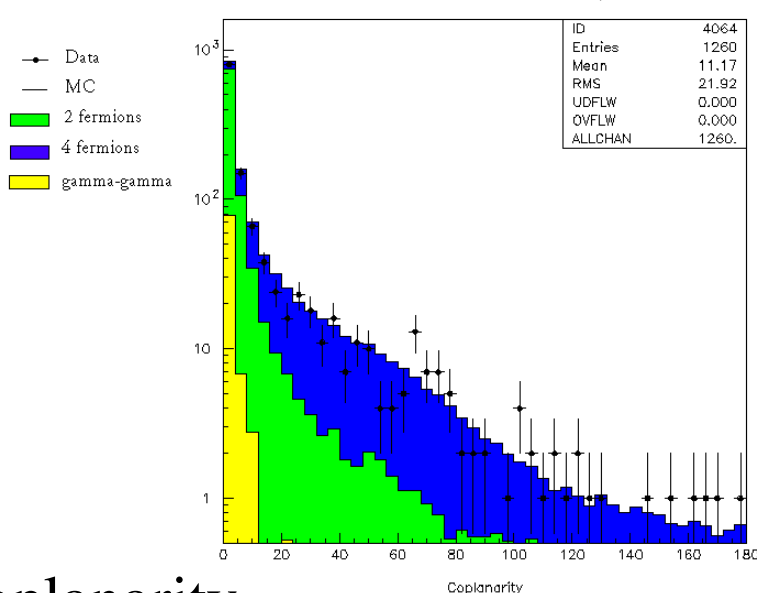
Data @ 200 GeV



2000 data in the 206 GeV window



2000 data without TPC S6 (206 GeV)



Acoplanarity

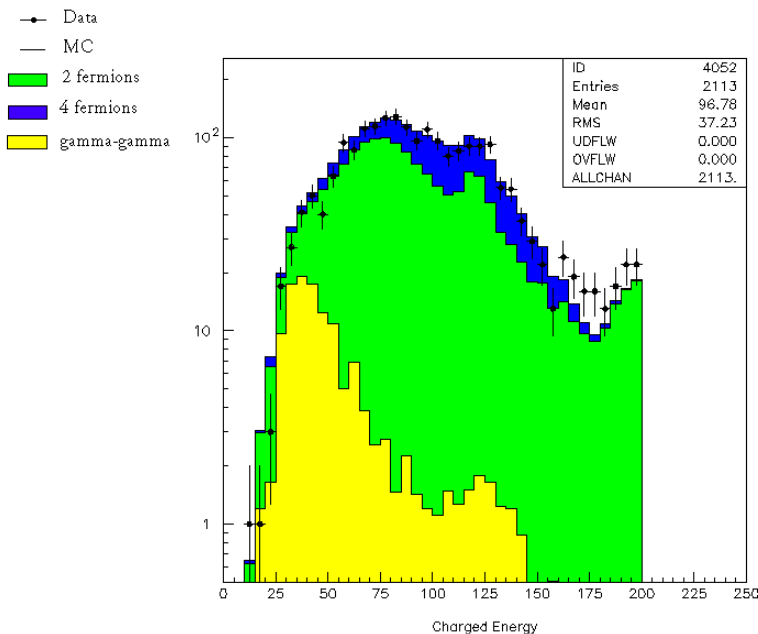
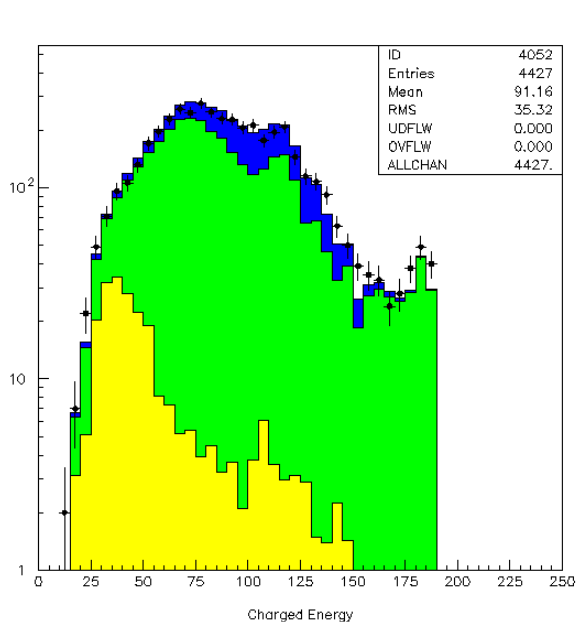


At least one Heavy particle



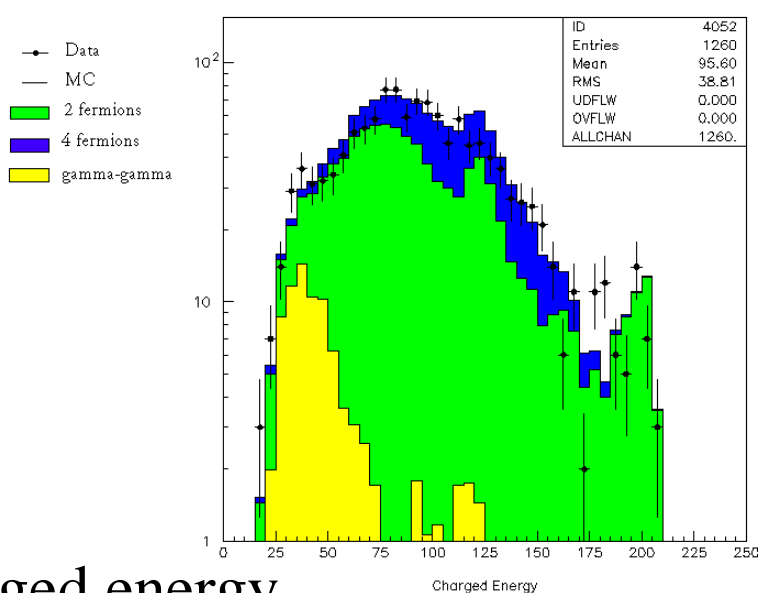
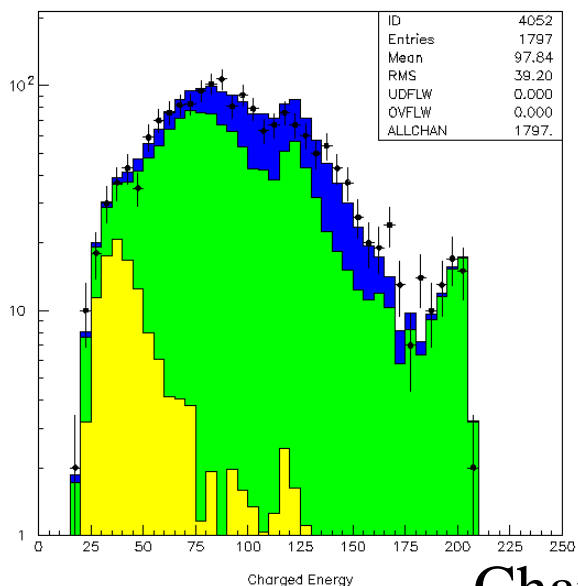
Data @ 189 GeV

Data @ 200 GeV



2000 data in the 206 GeV window

2000 data without TPC S6 (206 GeV)



Charged energy

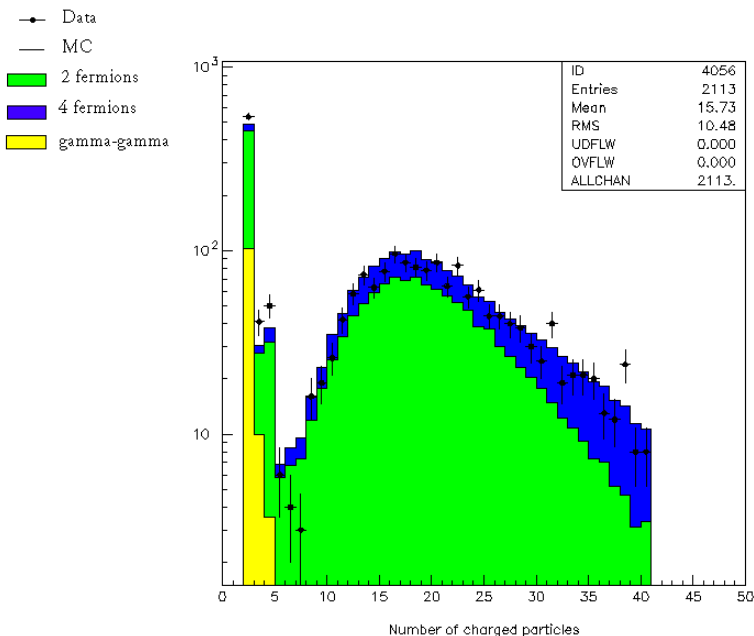
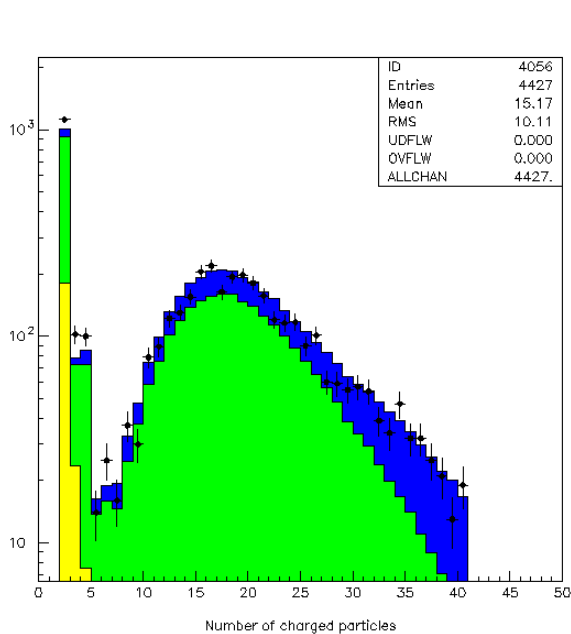


At least one Heavy particle



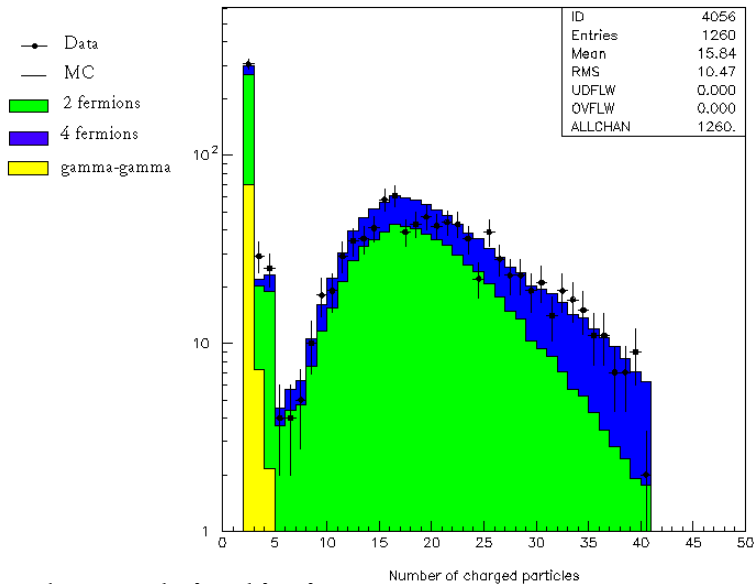
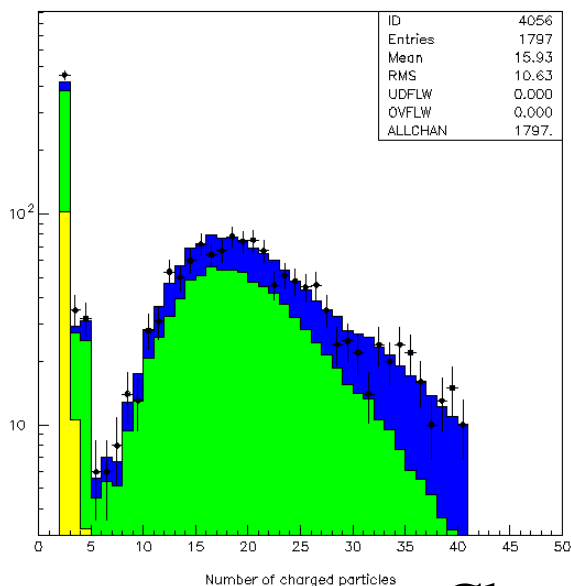
Data @ 189 GeV

Data @ 200 GeV



2000 data in the 206 GeV window

2000 data without TPC S6 (206 GeV)



Charged multiplicity



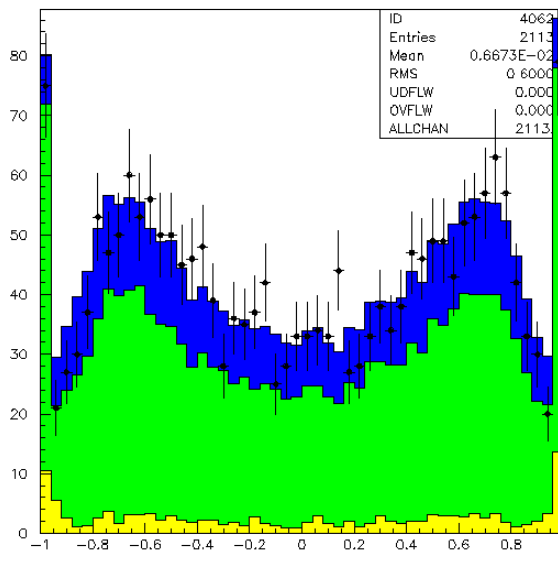
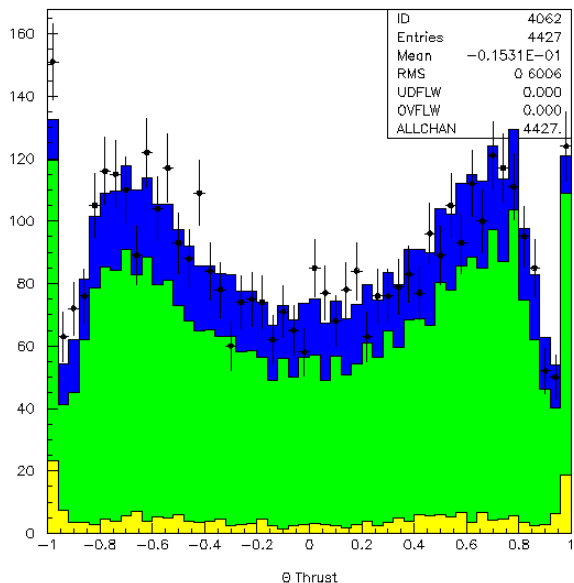
At least one Heavy particle



Data @ 189 GeV

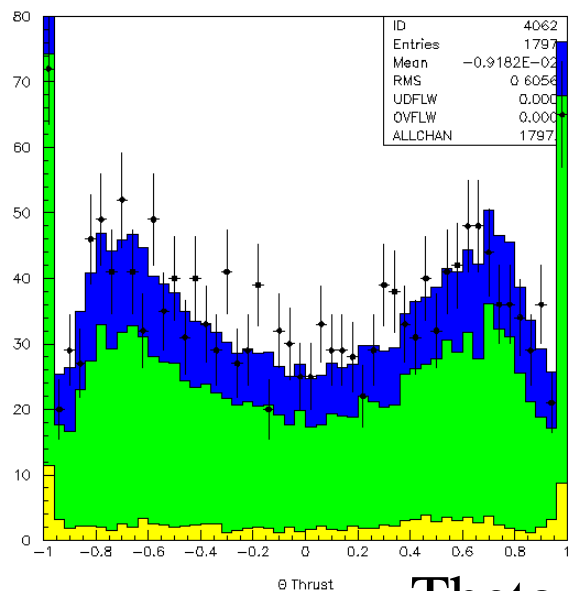
Data @ 200 GeV

● Data
— MC
■ 2 fermions
■ 4 fermions
■ gamma-gamma

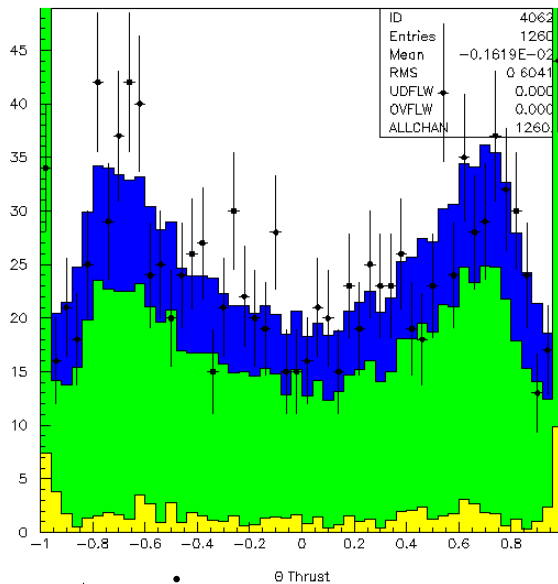


2000 data in the 206 GeV window

2000 data without TPC S6 (206 GeV)



● Data
— MC
■ 2 fermions
■ 4 fermions
■ gamma-gamma



Theta of the thrust axis



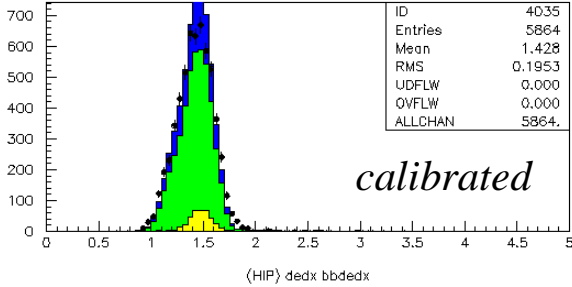
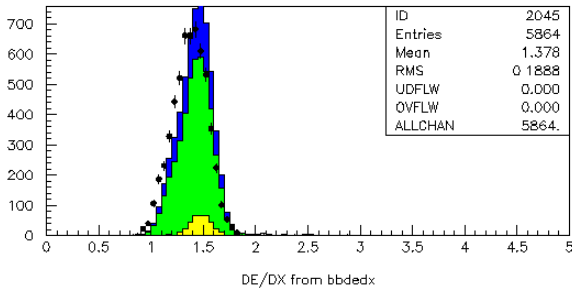
At least one Heavy particle: dE/dx calibration



$$(dE / dx)_{corrected} = \frac{(dE / dx)_{measured}}{correction\ factor}$$

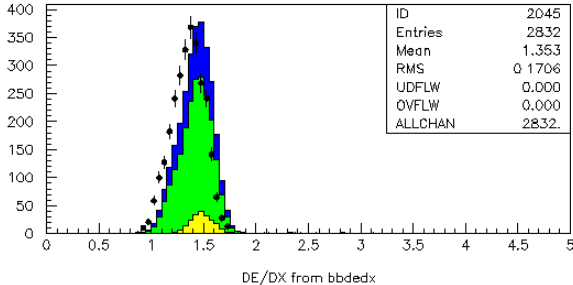
Sqrt(s)	correction factor
189 GeV	0.9651
192 GeV	0.9553
196 GeV	0.9510
200 GeV	0.9469
202 GeV	0.9464
2000 data	0.9312

Data @ 189 GeV

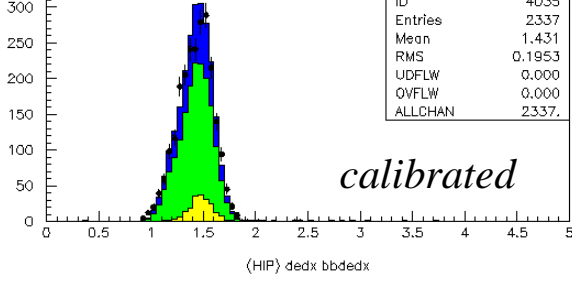
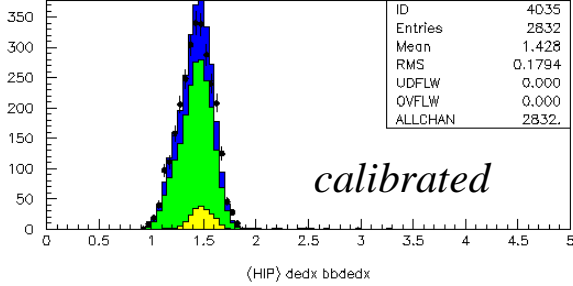
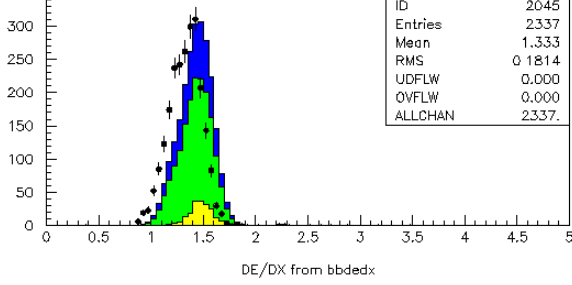


Data @ 200 GeV

2000 data (206 GeV bin)



- Data
- MC
- 2 fermions
- 4 fermions
- gamma-gamma





Low dE/dx selection



DO I=1,NHEAVY

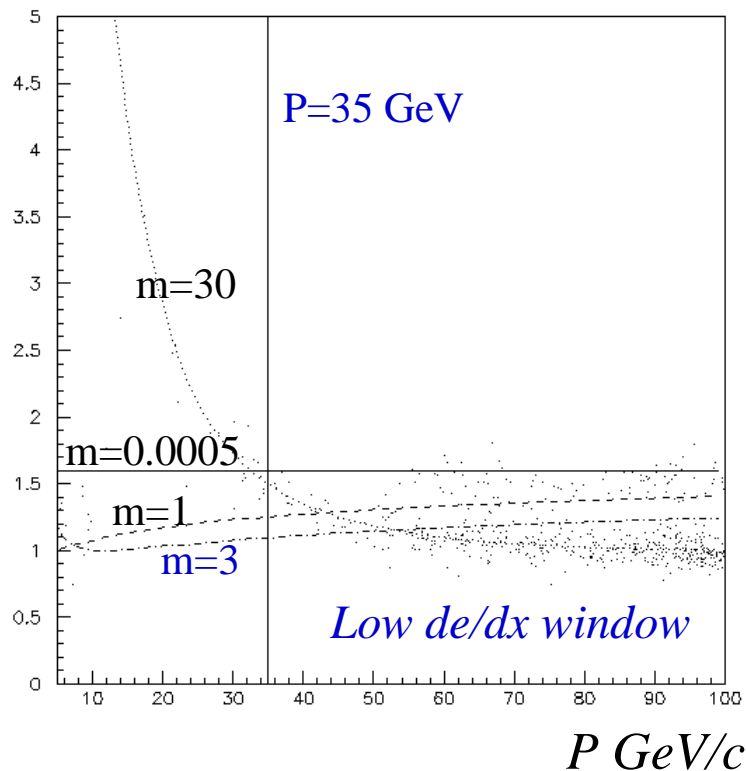
```
II = IH(I) ; PP = PC(1, II)
IF ( (RDEDX(4, II) .LT. RDEDX03) .AND.
      (PP.GE.35.) ) THEN
      NT1=NT1+1
      ICAND1(NT1) = II
ENDIF
```

ENDDO

*Stop signal of 30 GeV mass
at sqrt(s)= 206 GeV*

dedx (mip)

Window 1 definition:





High dE/dx selection



```
DO I=1,NHEAVY
```

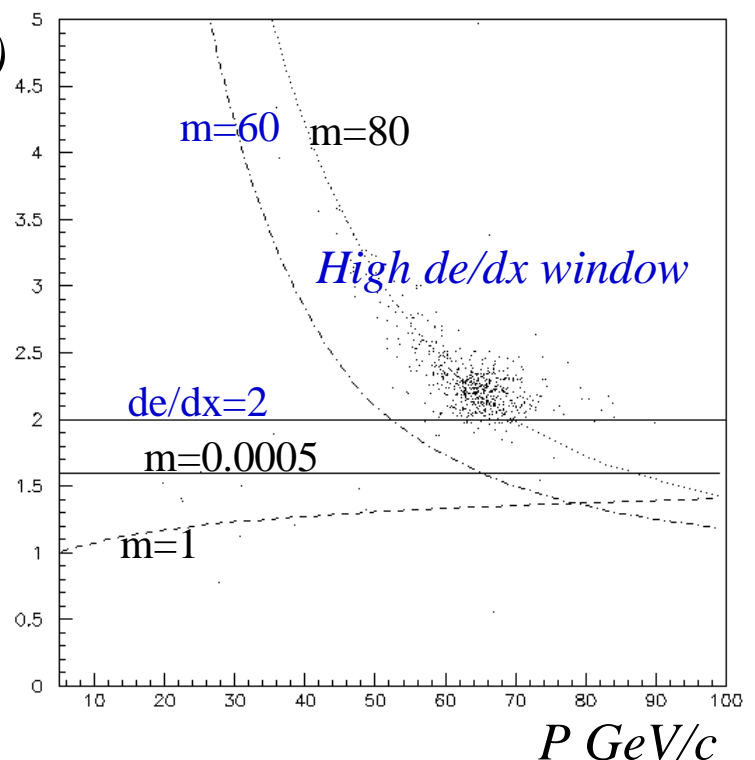
```
  II = IH(I) ; PP = PC(1,II)  
  IF ( (RDEDX(4,II) .GT. 2.) .AND.  
        (RDEDX(4,II) .GT. RDEDX60) .AND.  
        (DPPC(II) .LT. 0.1) .AND.  
        (PTPC .LT. 135.) .AND (NCHA .LE. 8) ) THEN  
    NT3=NT3+1  
    ICAND3 (NT3) = II
```

```
  ENDDO
```

```
ENDDO
```

*Stop signal of 80 GeV mass
at sqrt(s) = 206 GeV*

dedx (mip)



Window 3 definition:



Intermediate dE/dx selection



DO I=1,NHEAVY

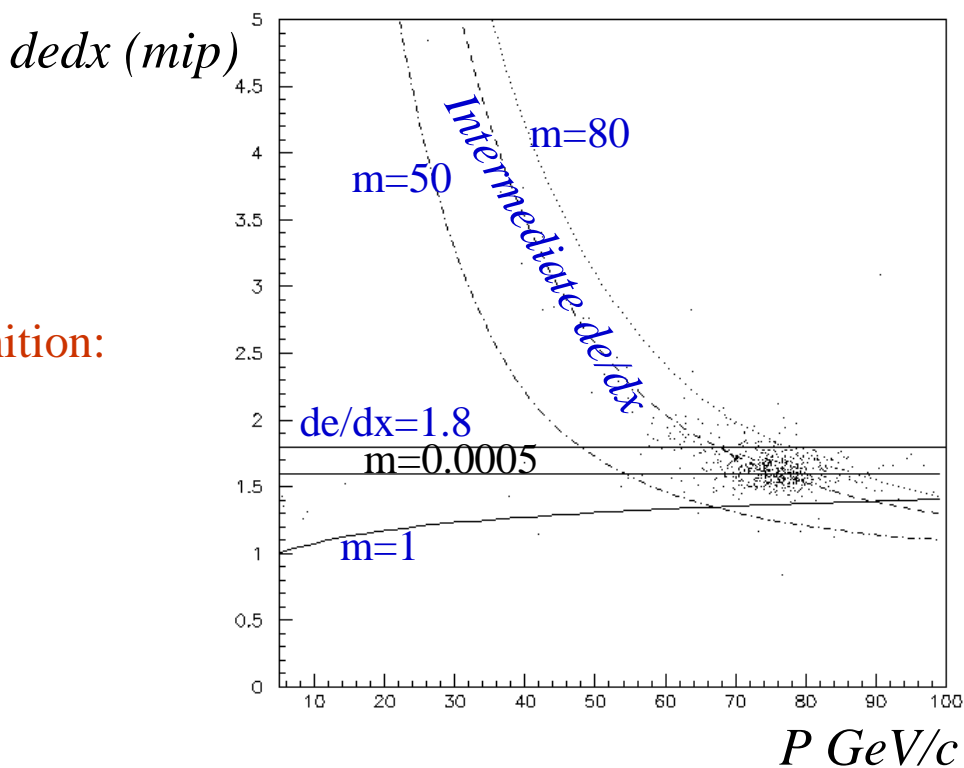
```

II = IH(I);PP = PC(1,II)
IF((PTPC.LT.170.) .AND. (ACOL.LT.10.) .AND.
   (THRUS(4) .GT.0.99) .AND.
   (EC(1,II) .LT.4.) .AND. (DPPC(II) .LT.0.1) .AND.
   (RDEDX(4,II) .GT.RDEDX50) .AND.
   (RDEDX(4,II) .LT.RDEDX80) .AND.
   ((RDEDX(4,II) .GT.1.8) .OR. (RDEDX(4,II) .LT.RDEDX01)) ) THEN
    NT2=NT2+1
    ICAND2(NT2)=II
ENDIF

```

ENDDO

Stop signal of 70 GeV mass
at sqrt(s)= 206 GeV



Window 2 definition:

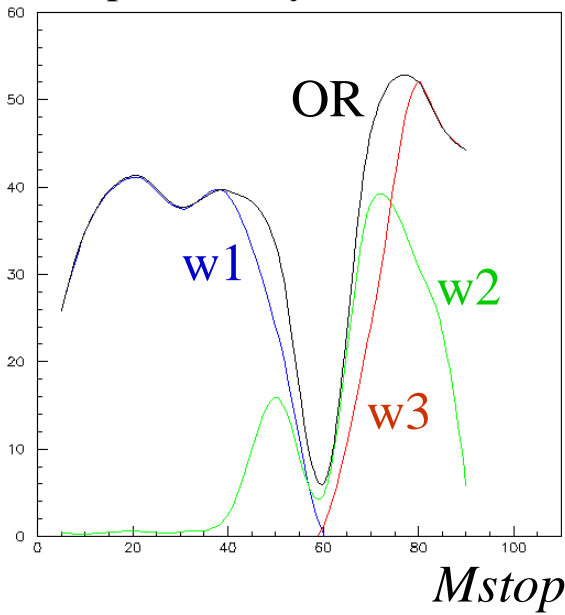


Signal efficiency

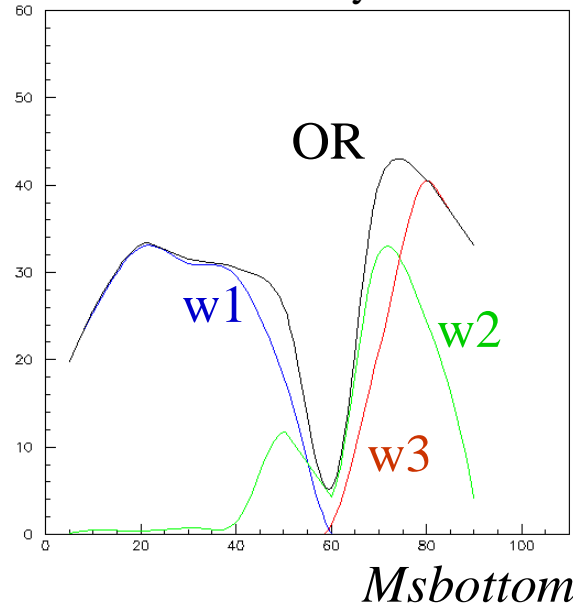


Preliminary

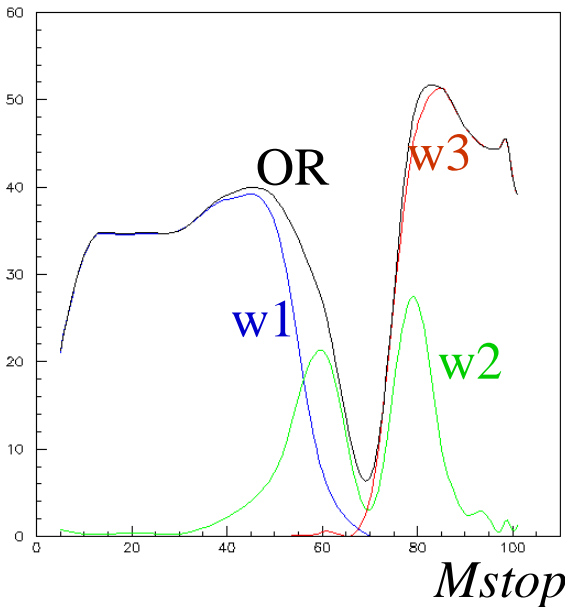
Stop efficiency @ 189 GeV



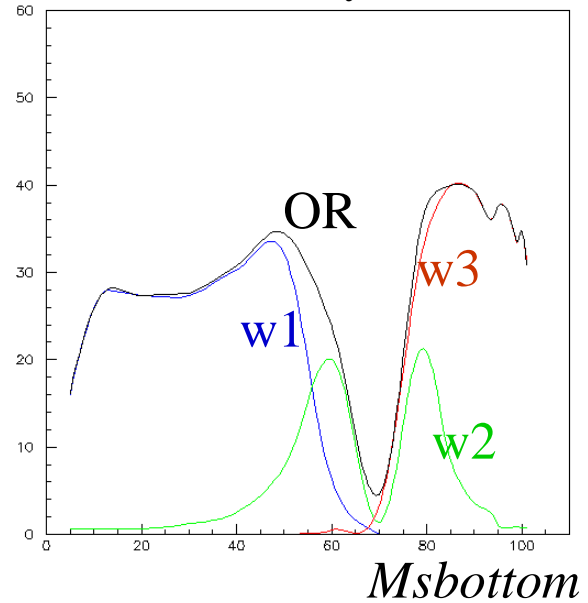
Sbottom efficiency @ 189 GeV



Stop efficiency @ 206 GeV



Sbottom efficiency @ 206 GeV





Preliminary Results



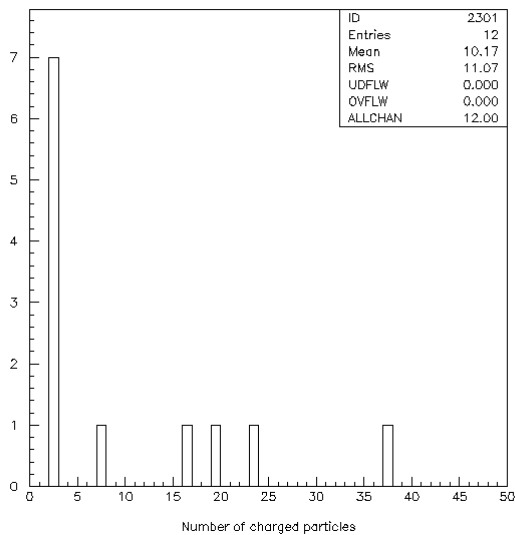
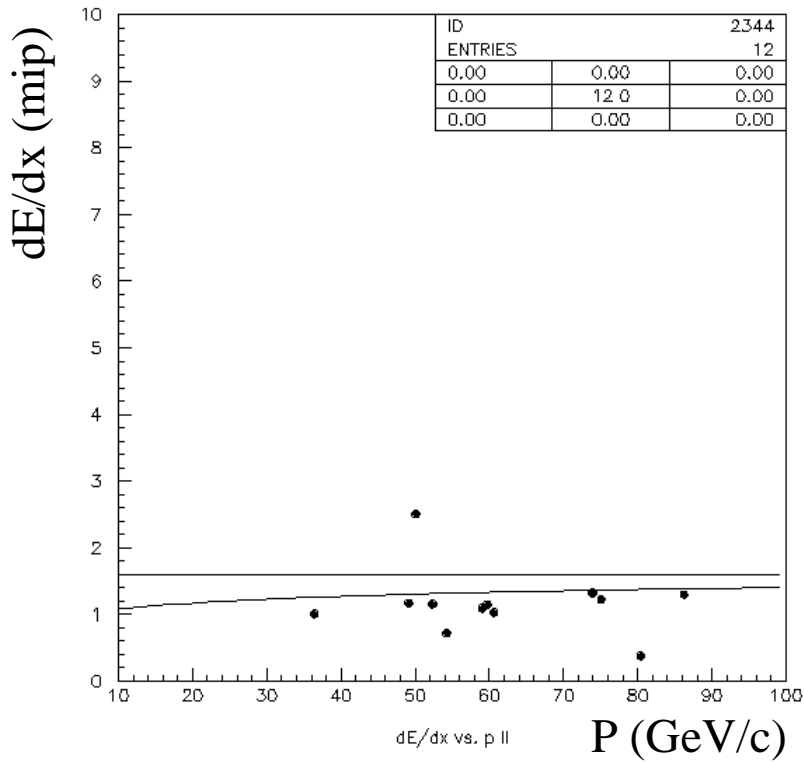
Data and background results:

sqrt(s)		189 GeV	192 GeV	196 GeV	200 GeV	202 GeV
Window 1	Data	3	0	1	0	0
	MC	1.38±0.15	0.09±0.06	0.54±0.10	0.35±0.09	0.22±0.05
Window 2	Data	2	0	0	0	0
	MC	2.13±0.47	0.66±0.28	1.33±0.77	0.72±0.16	0.37±0.06
Window 3	Data	0	0	0	0	1
	MC	0.19±0.12	0.08±0.06	0.35±0.11	0.26±0.13	0.09±0.02
1 OR 2 OR 3	Data	5	0	1	0	1
	MC	3.66±0.51	0.79±0.29	2.14±0.78	1.30±0.22	0.65±0.08

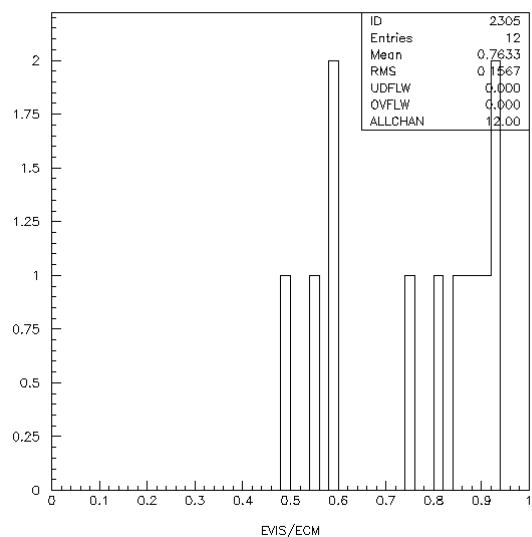
sqrt(s)		204 GeV	206 GeV	208 GeV	206s1 GeV	All
Window 1	Data	1	2	0	1	8
	MC	0.35±0.07	0.49±0.08	0.04±0.01	0.36±0.07	3.82±0.68
Window 2	Data	0	1	0	0	3
	MC	0.43±0.10	0.46±0.11	0.03±0.01	0.39±0.07	6.52±2.03
Window 3	Data	0	0	0	0	1
	MC	0.06±0.04	0.19±0.07	0.02±0.01	0.20±0.05	1.44±0.61
1 OR 2 OR 3	Data	1	3	0	1	12
	MC	0.84±0.13	1.11±0.15	0.09±0.02	0.89±0.01	11.47±2.19



Characteristics of the candidates



Multiplicity



Visible energy / E_{cm}



Conclusion



- **Preliminary results on long lived stop and sbottom search:**
 - No excess in the data up to 208 GeV is observed.
 - A lower limit of 94/82 GeV is obtained for the stop/sbottom mass, independently of the mixing angle.

Exclusion limits @ 95% CL

	Stop		Sbottom	
	Theta=0°	Theta=56°	Theta=0°	Theta=68°
Expected	96	94	95	82
Observed	96	94	94	82

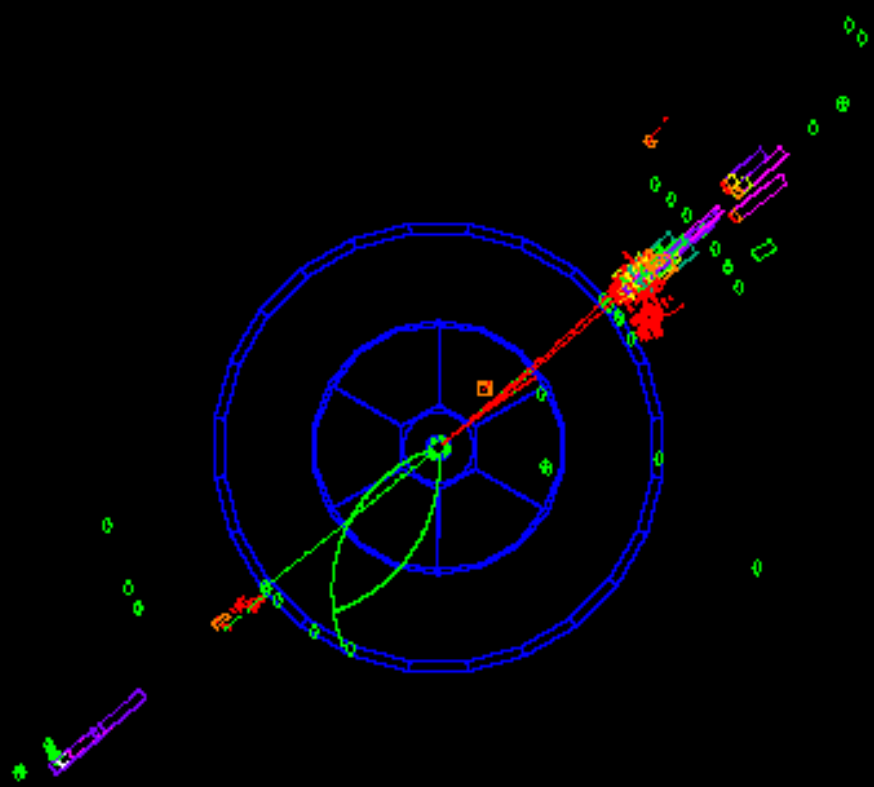
- **To do ...**

Generate MC for some squark masses between 60 and 70 GeV (but it should not change the results)
Main goal: To Study the intermediate lifetime case (kinks)



DELPHI Run: 107674 Evt: 13417
Beam: 101.0 GeV Proc: 24-Oct-2001
DAS: 7-NOV-1999 Scan: 6-NOV-2001
14:03:11 Tsh+DST

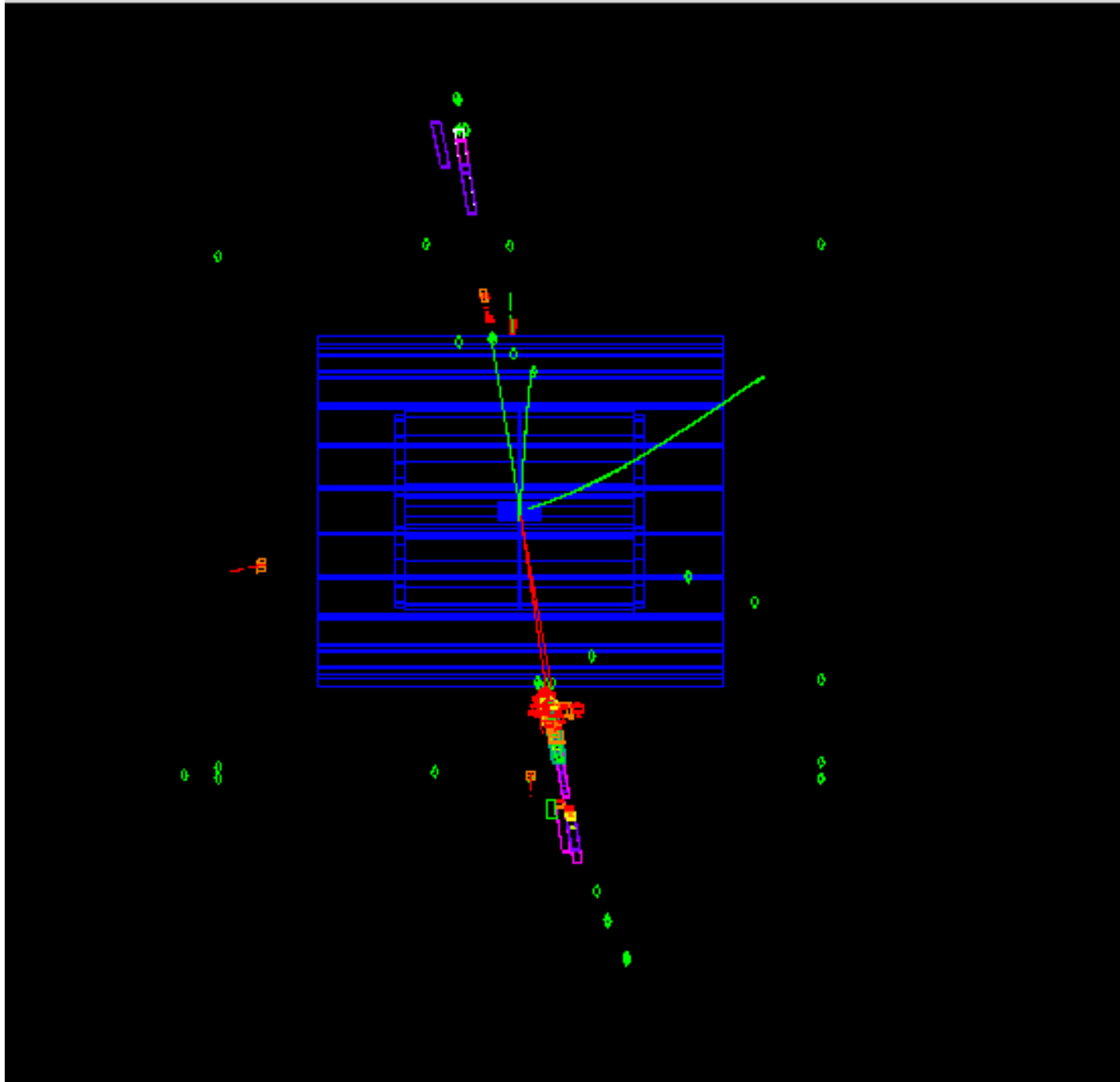
	TD	TE	TR	TK	TY	TF	TA
Act	0	137	0	0	0	0	0
	(0)	(137 I 0)	(0 I 0)	(0 I 0)	(0 I 0)	(0 I 0)	(0 I 0)
Deact	0	0	0	0	0	0	0
	(0 I 0)	(0 I 0)	(0 I 0)	(0 I 0)	(0 I 0)	(0 I 0)	(0 I 0)



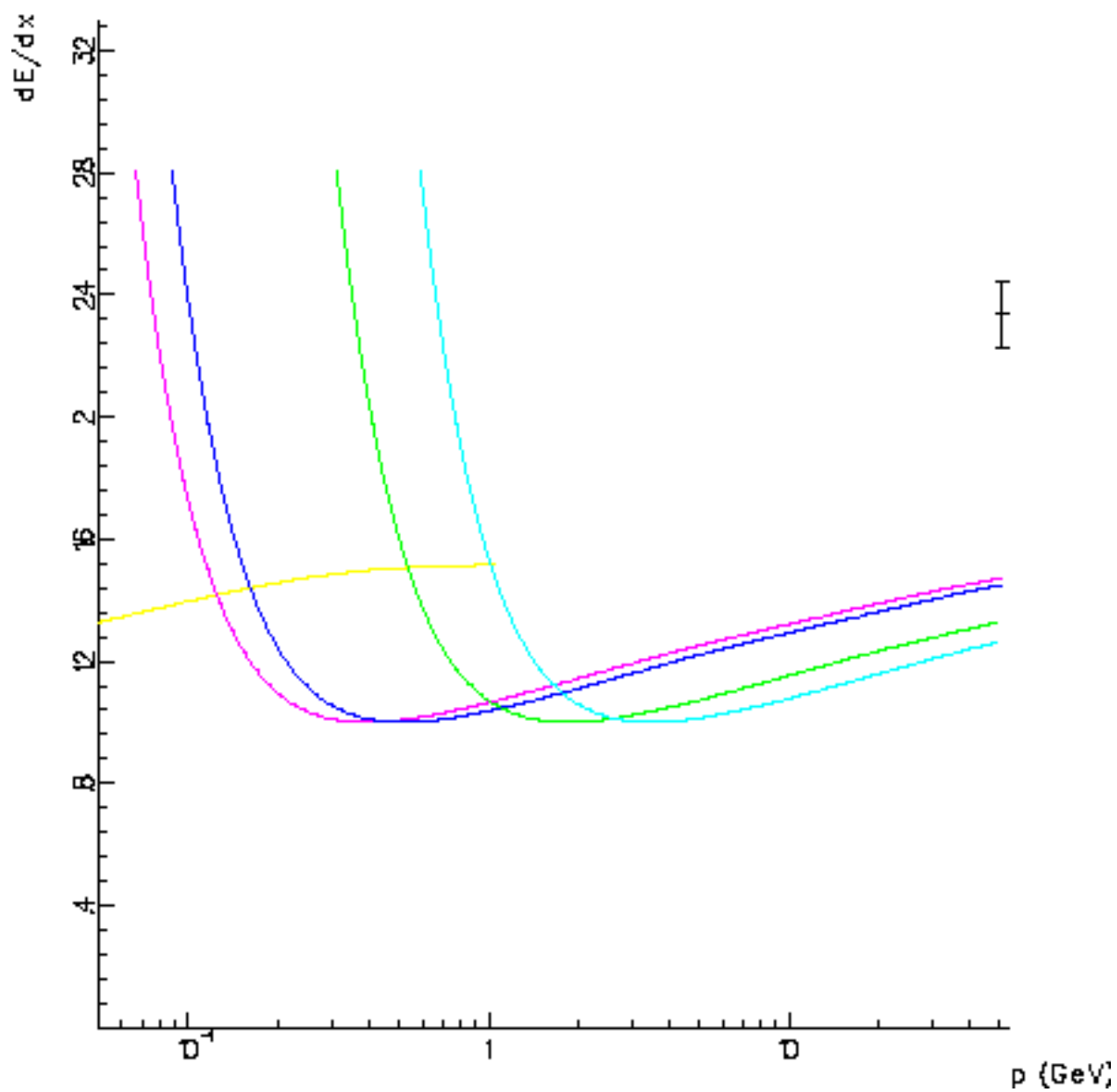


DELPHI Run: 107674 Evt: 13417
Beam: 101.0 GeV Proc: 24-Oct-2001
DAS: 7-NOV-1999 Scan: 6-NOV-2001
14:03:11 Tsh+DST

	TD	TE	TR	TK	TV	TV	DA
Act	0	137	0	0	0	0	0
	(0)	(137)	(0)	(0)	(0)	(0)	(0)
Deact	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)



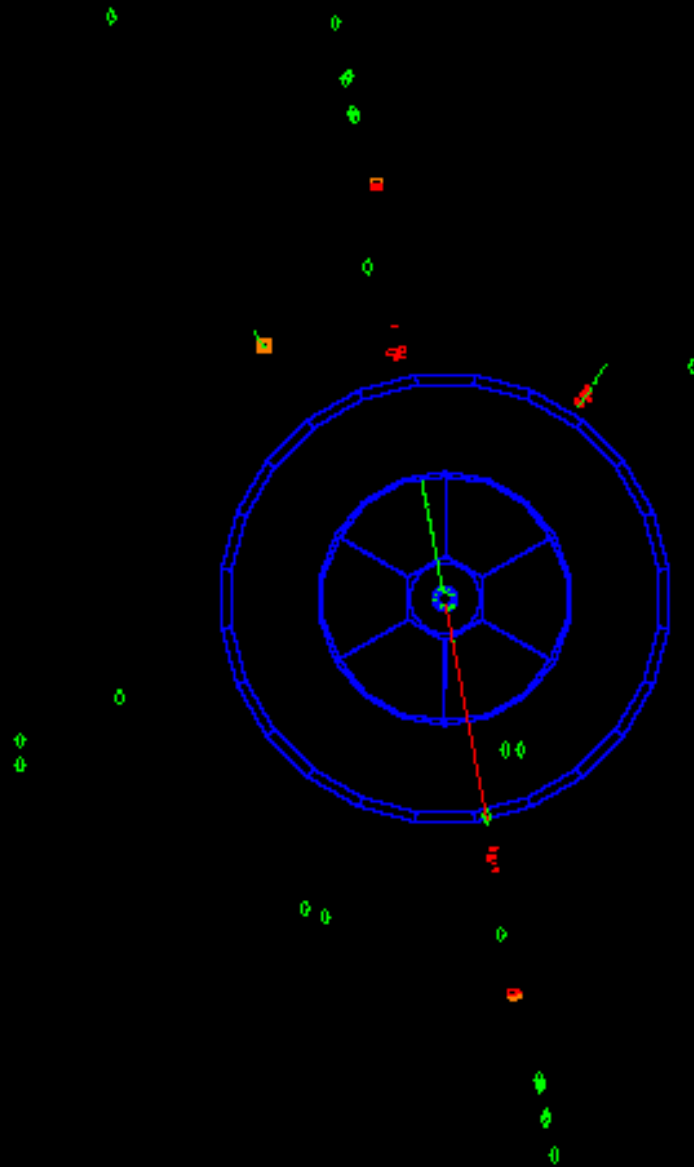
1. TK 11, run 107e74, event 13417, type Tan+DST





DELPHI Run: 110176 Evt: 8228
Beam: 100.0 GeV Proc: 24-Oct-2001
DAS: 19-May-2000 Scan: 6-Nov-2001
22:47:36 Tsh+DST

	TD	TE	TR	TK	TV	TV	TA
Act	0	27	0	4	0	0	0
	(0 X 20 I 0]			4 I 0 I 0 I 0)			
Deact	0	0	0	0	0	0	0
	(0 I 0 I 0 I 0 I 0 I 0)						



1. TK 2. run 110176, event 8228, type Tan+DST

