Bkg impact on FP420

G4 simulation for FP420 in CMSSW

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FP420 Bkg meeting

14/11/2008

Overview

Background sources for FP420

1) overlap background:

                MBPU(beam1,2 rates:r1,2=0.32),

                Late2ndturnPU(r1=0.,r2=0.039)

2) secondaries from MB interactions in B11B (lost MBPU) correlate
    in time with IP interaction with rate 0.00265 for mainly photons and
      average number of 29 particles per event at Z=420m

3) beam-gas particles: collisions between beam protons and residual gas
      occurs close to FP420 set up -> DistantGas(r1=0.005,r2=0.008)

4) beam-halo particles: tails of momentum cleaning halo, circulating in the
    machine and not correlated in time with IP particles -> MC(r1,2=0.)

MB overlap Bkg

- the file with digi level response in detector was prepared using 20K MinBias($\sigma \sim 80$ mb) single pp interactions at IP generated by *PYTHIA*

- mixing of Signal and MB Bkg take into account Lumi=10^{34} sm-2 s-1 which provide digi response in detector from $>\sim$ **25** MB interactions per one bunch crossing (*no ToF cuts*)

(dedicated MixModule is available in CMSSW)

--> MB MARS files cfp420.b1 & cfp420.b2 :

- 20M inelastic interactions (σ_{inel}=84.5mb) in IP5 per beam
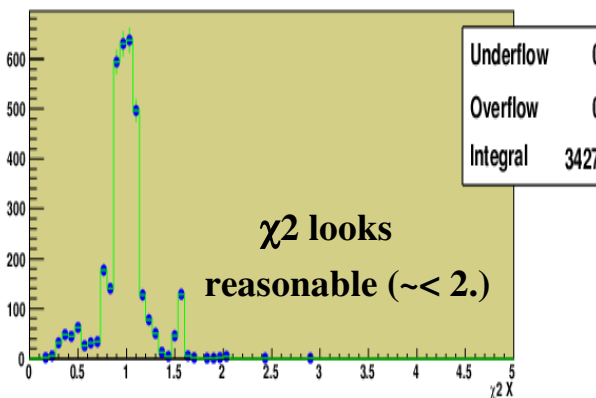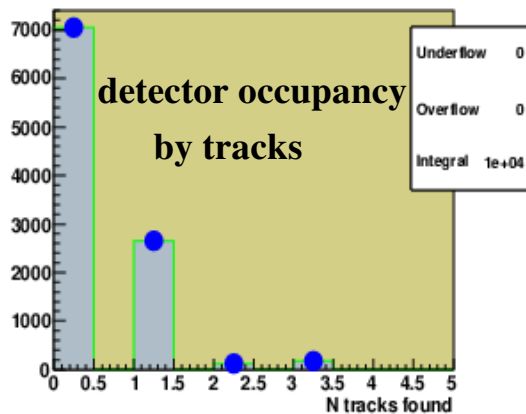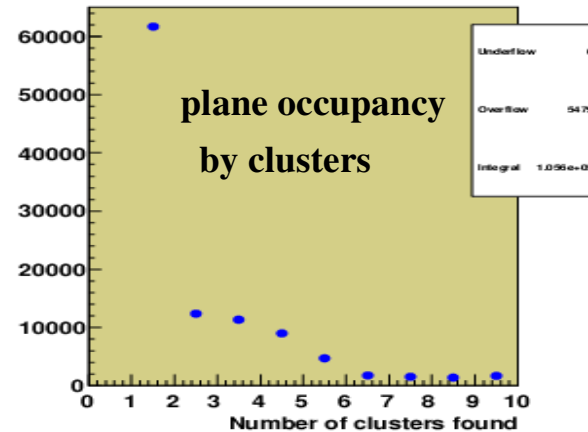- "Hit" records with $|x| > 7\sigma x$ and $|y| > 7\sigma y$ at 420.0 m downstream of IP5
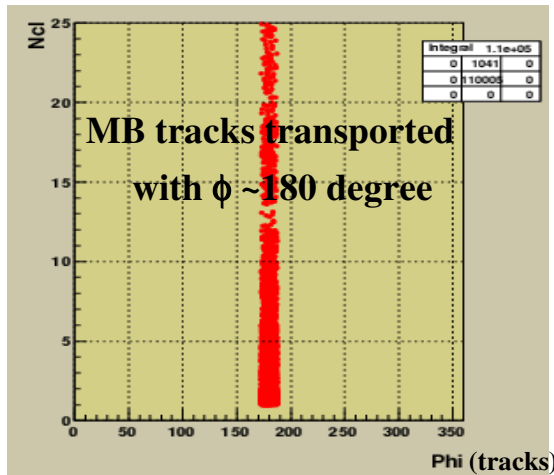
(?)

but not so clear how to mix Signal with MB info available in these files

for L=10^{34} sm-2 s-1 with 25 interactions/bx

MB tracks transported with φ ~180 degree

Phi (tracks)

plane occupancy by clusters

Number of clusters found

detector occupancy by tracks

N tracks found

χ2 looks reasonable (~< 2.)

χ2 X

- MB rate to have at least one track in detector ~ 30%;

- multiplicity for MB particles in FP420 detector:
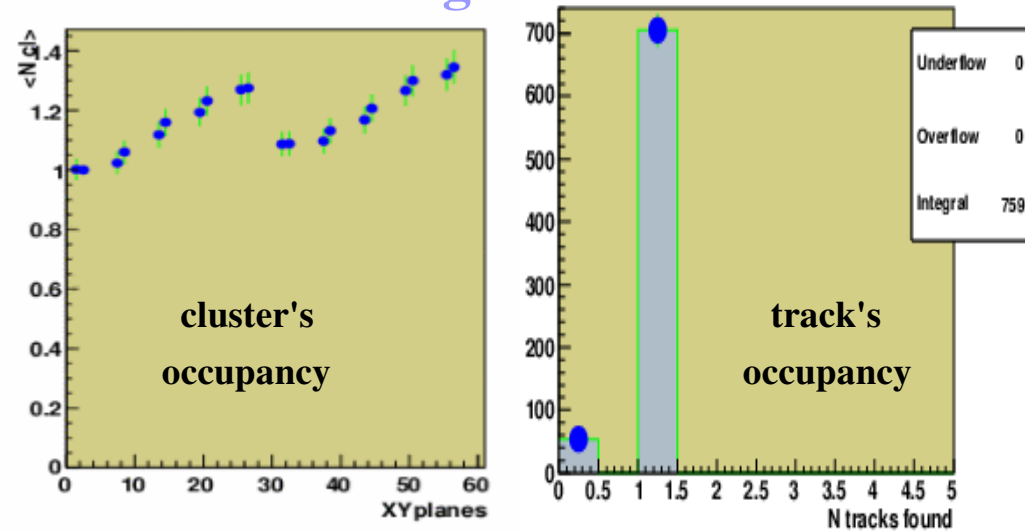
P1 = 26.%, P2 = 1.6%, P3 = 1.7%, P4 = 0.0% ...

(preliminary estimation of multiplicity rates r_i in FP420

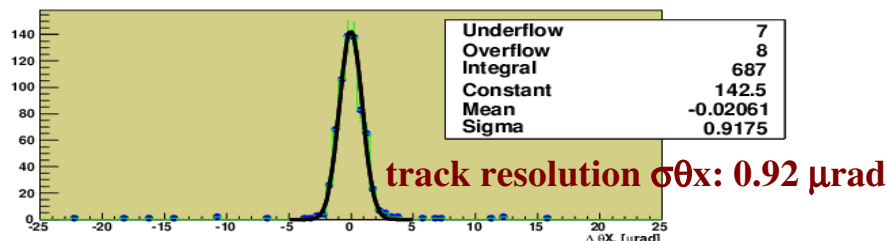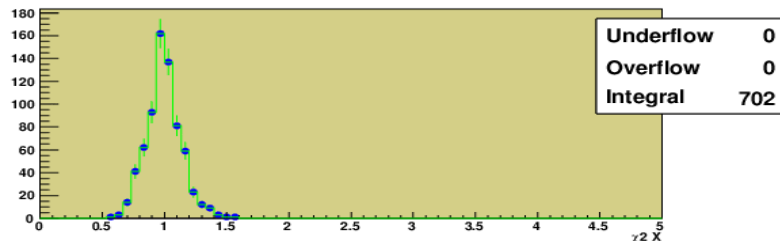(L=10^{34} cm-2 s-1): **P1=22.5%, P2=4.6%, P3=0.44%, p4=0.06%**)

(Signal) & (Signal(in detector acceptance))+MBPU(real rate))

2000 events of ExHuMe: gg->H(120)->bbar are generated;   For 759 events only the proton is available in +FP420 detector acceptance because of detector position, dimensions and HecTransport
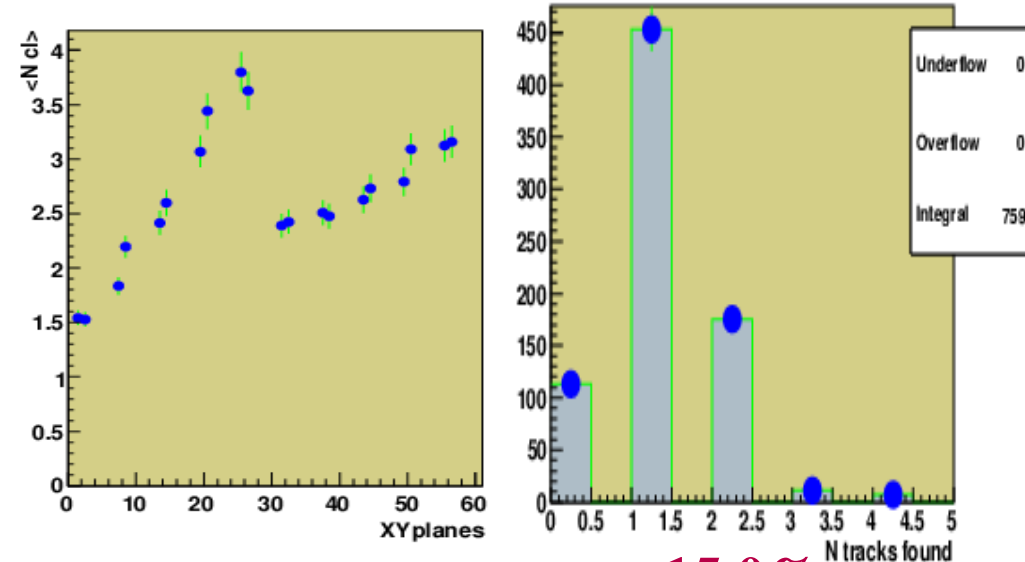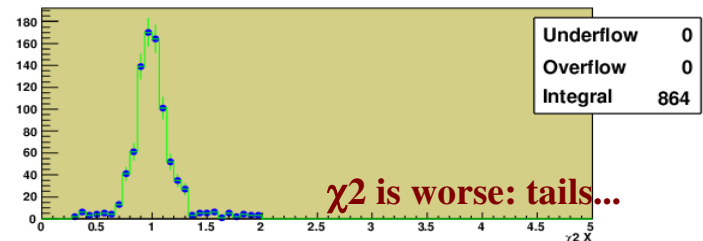
Signal
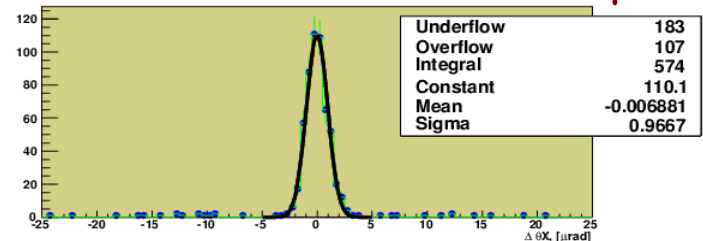
Both

57 + 702 -> events w/o tracks(losses): 57/759=7.5%

113+458+167+12+9 -> losses:113/759=15.0%

χ2 is worse: tails...

track resolution σθx: 0.92 --> 0.97 μrad

track resolution σθx: 0.92 μrad

update for MI rates

and events losses in reconstruction of single protons with

70%Si30%Al material for blades

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	2 station layout	3 station layout

MI rates (no MI means one SimHit per layer)

inline7TeVprotons	6.8%(was 5.4)	10.1%(was 8.1)
inline7TeVprotonsHecTransported	7.9%	
Hbb(VtxSmearedFlat)	7.5%	
Hbb(VtxSmearedEarly10TeVCollision)	**7.8%**	

Event losses (w/ $\chi 2$ cut < 2.0)

inline7TeVprotons	7.1%(was 5.2)	10.4%(was 7.8)
inline7TeVprotonsHecTransported	6.8%	
Hbb(VtxSmearedFlat)	7.1%	
Hbb(VtxSmearedEarly10TeVCollision)	**7.5%**	

comparable, but it does not mean that all MI events gone with applied $\chi 2$ cut: some of them survive in selected sample; some noMI events rejected by $\chi 2 < 2$ cut;

Eff. of 2 tracks reconstruction

	86%(was 90)	80%(was 85)

Estimation of detector occupancy by tracks for Signal+MBPU case

✔ Signal w/o MBPU, 759 protons are in detector acceptance:

   0   **1**   **->   tracks**

  57 + 702   -> 7.5% MI losses

✔ Signal with MBPU:

$759*(1-0.293)=537$ -> signal protons w/o MBPU   (=1track)

$537*(1-0.078)=495$ ->   w/o MI   (=1track)

$537-495=42$ ->   MI losses   (=0 tracks)

$759*0.26=197$ -> signal proton + one MB proton   (=2tracks)

$197*0.86=169$ ->   w/o MI   (=2tracks)

$197-169=28$ ->   MI losses   (0 or 1 tracks)

$759*0.016=12$ -> signal proton + 2 MB protons   (=3tracks)

$759*0.017=13$ -> signal proton + 3 MB protons   (=4tracks)

    3+4 ~= 7   ->   MI losses   (=0 tracks)

$42+28+7 = 77$ ->   (=0 tracks)

     0   **1**   **2**   **3**   **4**   **->**   **tracks**

✔ **77(+ ...χ2Cuts) + 495(- ...χ2Cuts) + 169 + 9 +   9 <-- track occupancy estimation**

   113   + 458   + 167 + 12 +   9 <-- tracks reconstructed with χ2 criteria

      so, estimation and simulation in 5% agreement (~ 35/700)
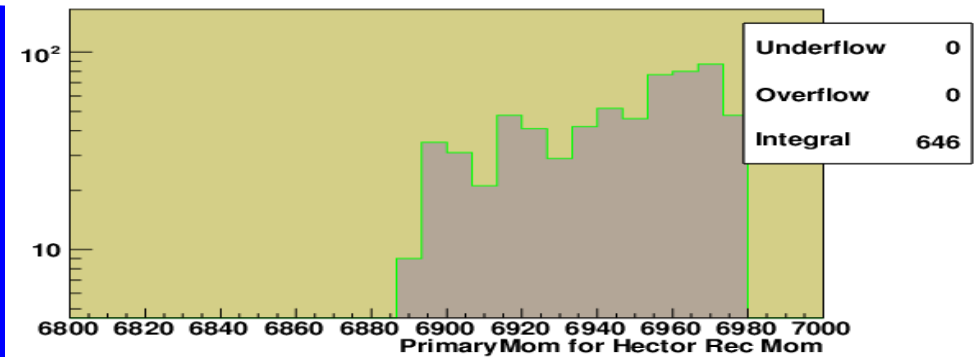
select one only track with highest momentum if #tr. > 1

Signal
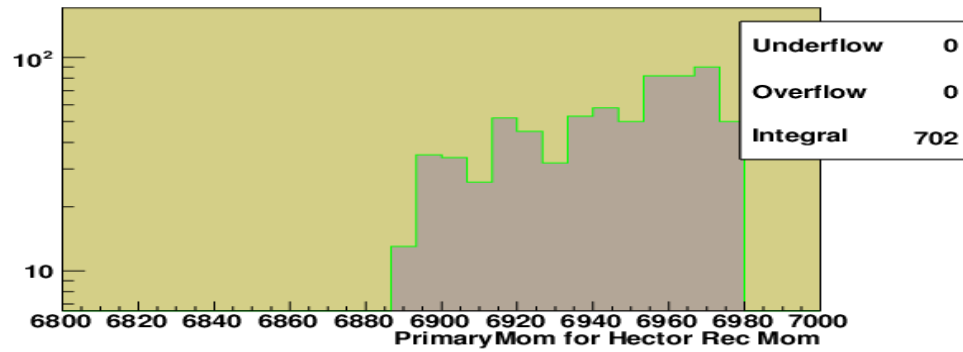
Both

#ev. with rec-ed tracks:458+167+12+9=646
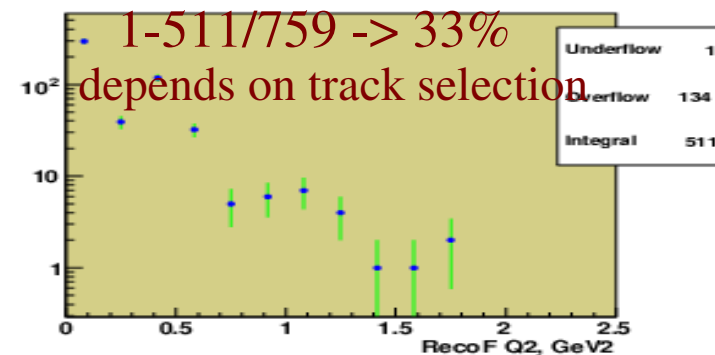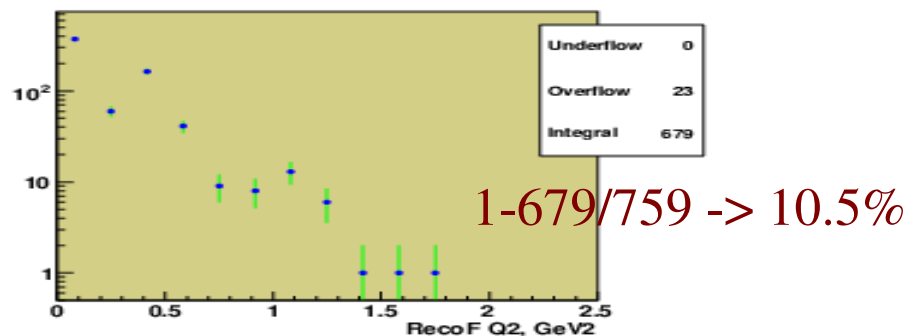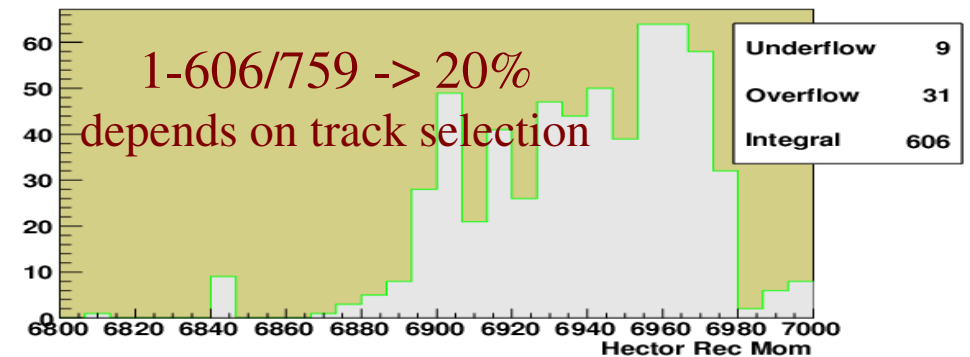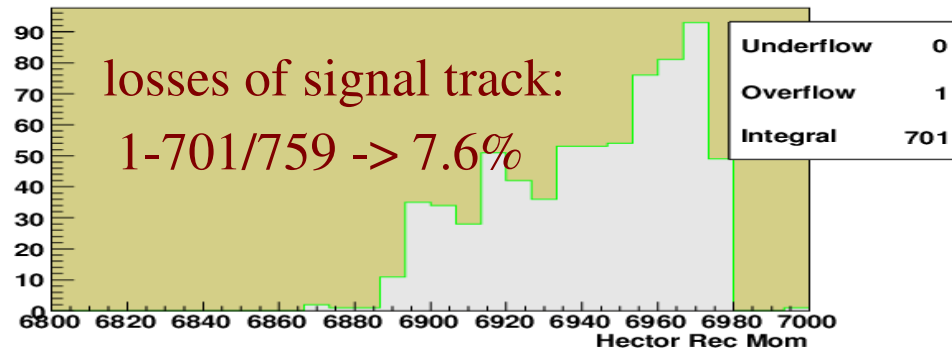
losses of signal track:
1-701/759 -> 7.6%

1-606/759 -> 20%
depends on track selection

1-511/759 -> 33%
depends on track selection

1-679/759 -> 10.5%

for 2000 events generated with ExHuMe: gg->H(120)->bbar, the 567 events are with _transported_ at 420m proton but _outside_ +FP420 detector _acceptance_ -> response in detector only from MB particles

occupancy by tracks from pure MB Bkg

Underflow	0
Overflow	0
Integral	567

Underflow	0
Overflow	0
Integral	203

Underflow	0
Overflow	0
Integral	170

Underflow	7
Overflow	24
Integral	139

Underflow	0
Overflow	102
Integral	68
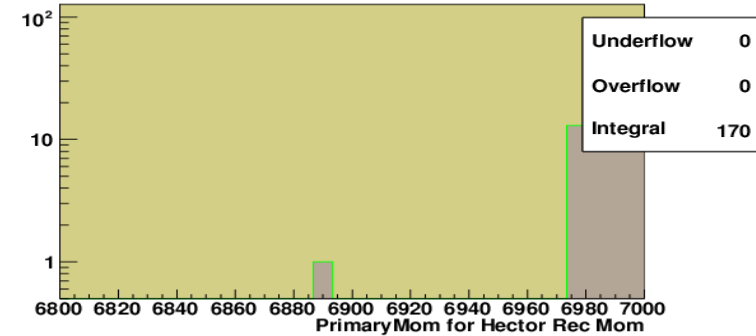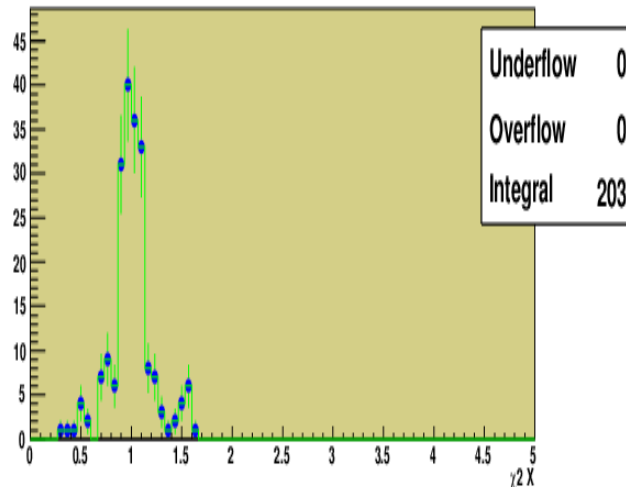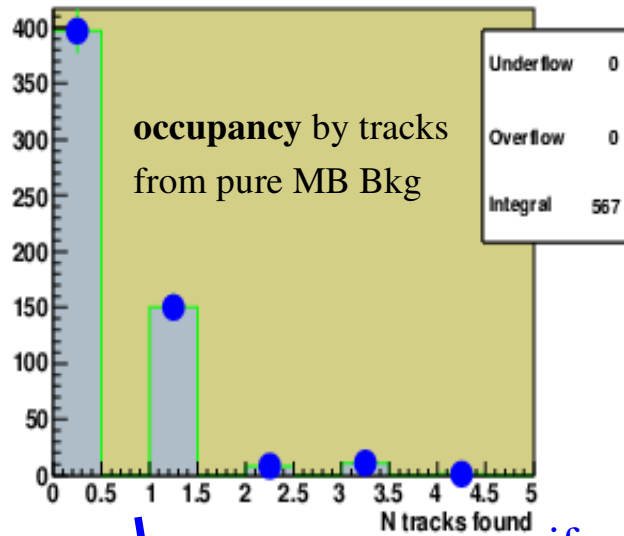
exercise: if we _can_ trigger Hbb sample and then sub-sample w/ transported only protons:

397+150+8+11+1 -> + additional

(150+8+11+1)/646~**26**% to signal track event sample

+ additional 139/606~**23**% to signal track event sample

+ additional 66/511~**13**% to signal track event sample

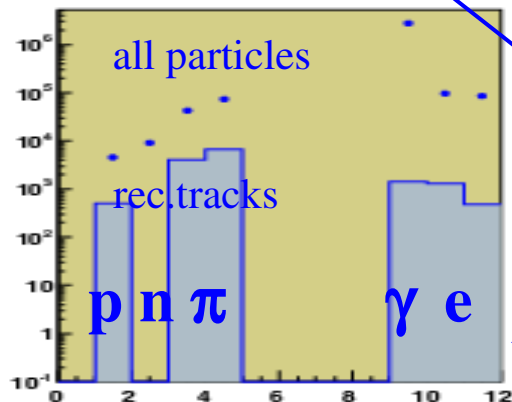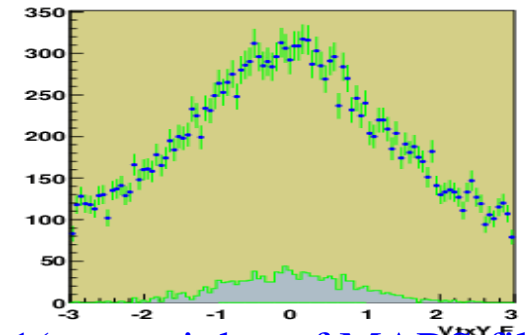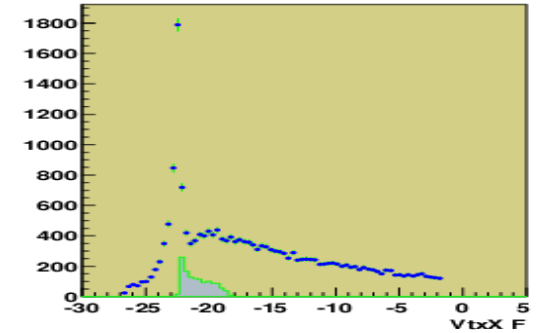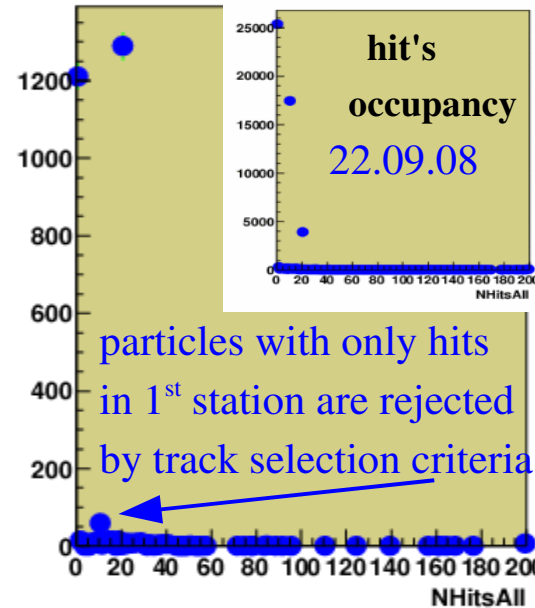so, fake signal contamination in all sample: 68/(68+511)=**12**%
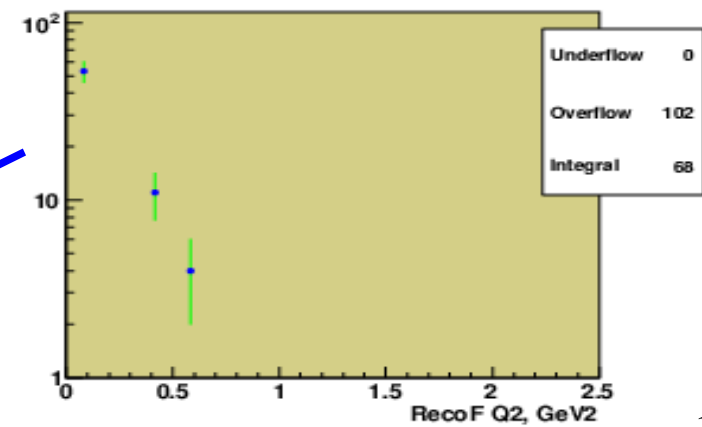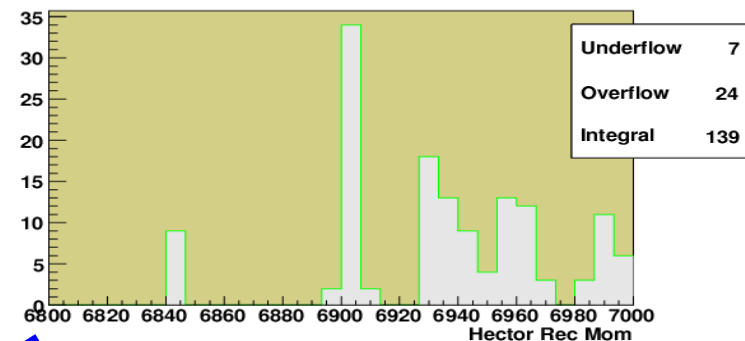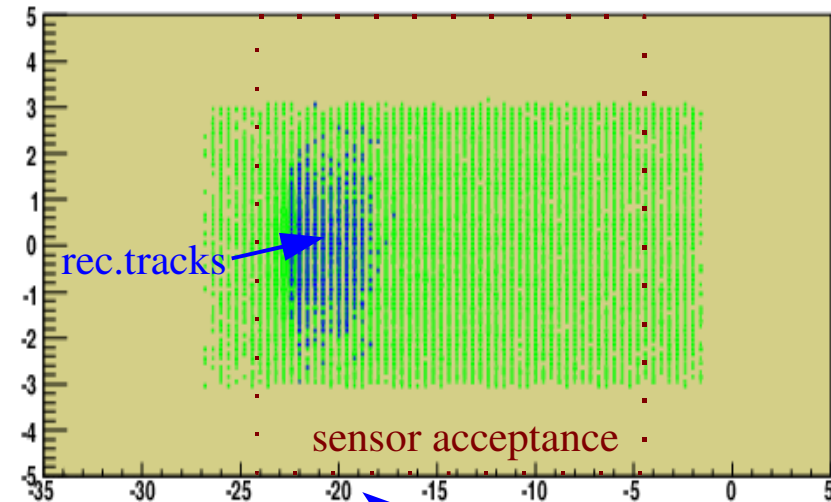
Single particles of B11B Bkg

track selection: – in detector acceptance and **χ2/ndof <2.**; no E_part. cut

[X:-24.7 -> -4.7; Y: -5. -> +5 mm at Z=420 & 428m]

(22.09.08: – all tracks and χ2/ndof <50.; E_part. > 10 GeV)

rec.tracks

sensor acceptance

hit's occupancy 22.09.08

particles with only hits in 1st station are rejected by track selection criteria

all particles

rec.tracks

p n π   γ e

- efficiency to detect particle by FP420 on beam 1(use weights of MARS file:
$ε = Σw\_tracks/Σw\_allParticles=0.0047=0.5\%$ (22.09.08:   3.5%)

- no tracks reconstructed in the detector at
|y| > 2mm and at x > -18mm due to large θx(>0.3mr)

- no tracks reconstructed from neutrons in detector;
- r_i=0.05% reconstructed tracks from photons (r_i=0.6% <-- 22.09.08)

Impact on detector from B11B Bkg
{estimation(I): Hbb Signal + B11B single particles mixed with rate 1.0}

Estimation of track's detector occupancy by 29 Bkg particles at Z=420m with X>20σx:

29*0.5%=0.2 (=1.0 for ε=3.5% with loose track selection)

(remember:20σx=5.2mm for beam1;=4.8mm for beam2 and 4.7mm – edge of detector)

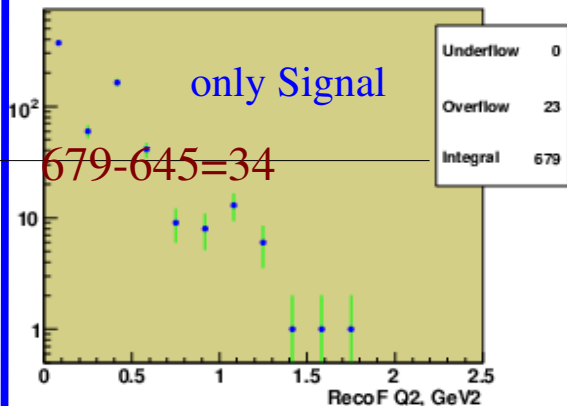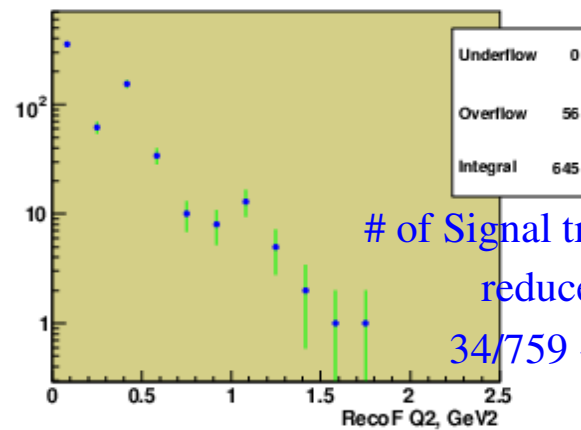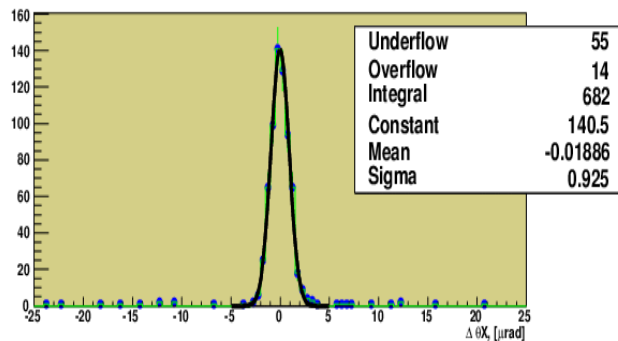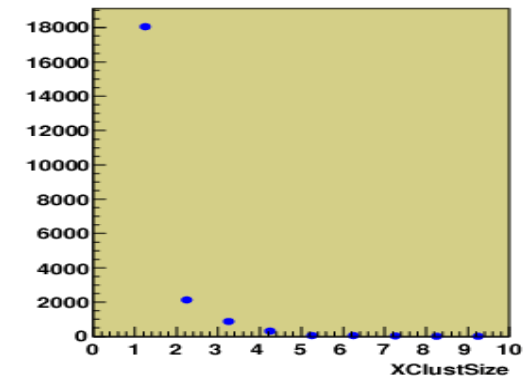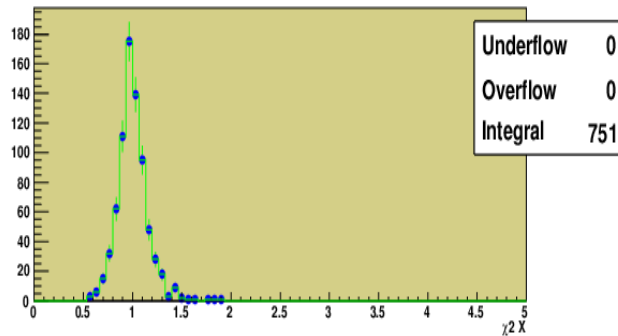**Rate of events with Signal track accompanied by track(s) of B11B Bkg is 0.00265 (0.27%).**
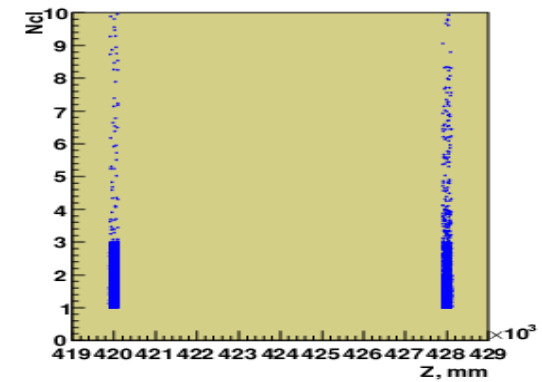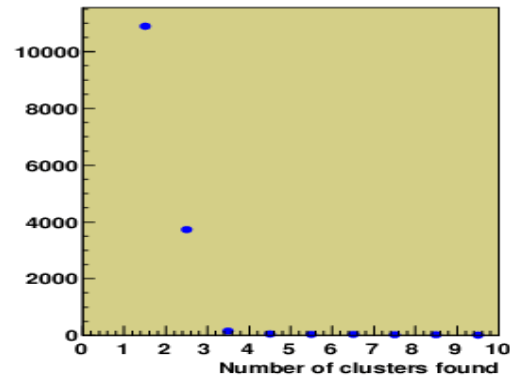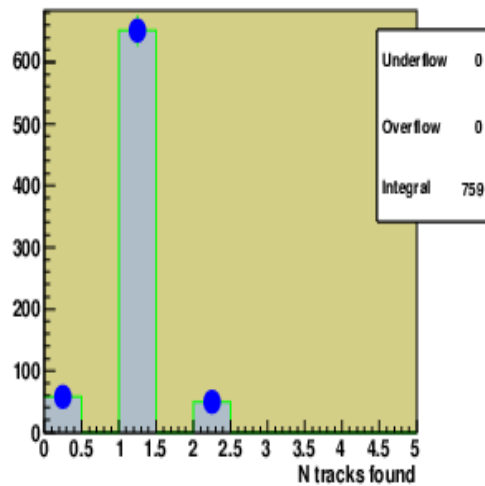
Hence, event losses are negligible if even Signal proton is not reconstructed in all such events.

Nevertheless, the estimation(I)* for rate of real losses is just 0.03%.

* One can mix Signal (Hbb) and B11B Bkg of M=29 at z=420m with rate:R=0.00265, M=29 .
However, we do not have file with M=29 in one Bkg event but can use file with events with
single Bkg particles increasing rate to R'=R*M=0.07685 . Besides, in this file there are weighted
events but we should admix single tracks with weight=1. Efficiency ε' calculated without use of
weights is 0.064 and we need to correct rate: R" = R'*(ε/ε') = 0.07685*0.0047/0.064 = 0.00564.
In MixingModule of CMSSW one can not mix B11B Bkg events to Signal with fractional rate
but only as whole #PU events. Admixing 1 PU event to signal we assume increase of R" by factor
1./0.00564~177. The 5% Signal loss obtained in this case should be decreased by this factor to be
equals 5%/177 = 0.03% .

for estimation(I):

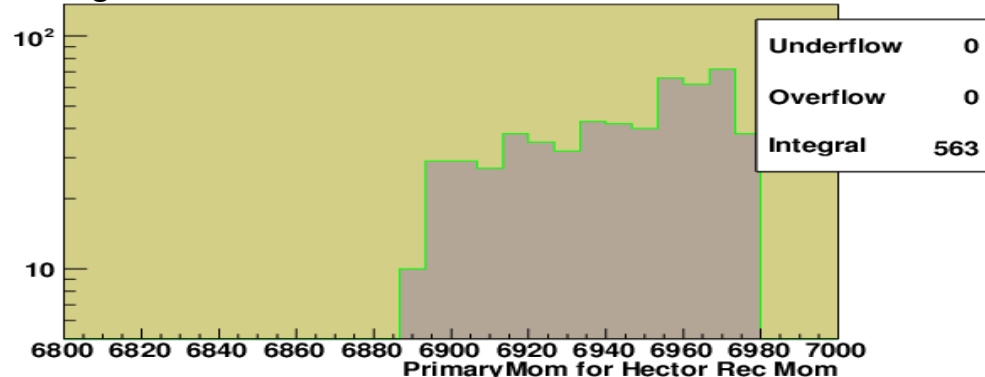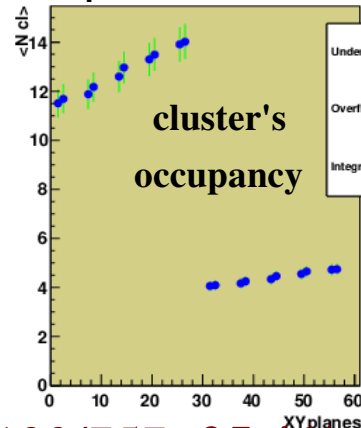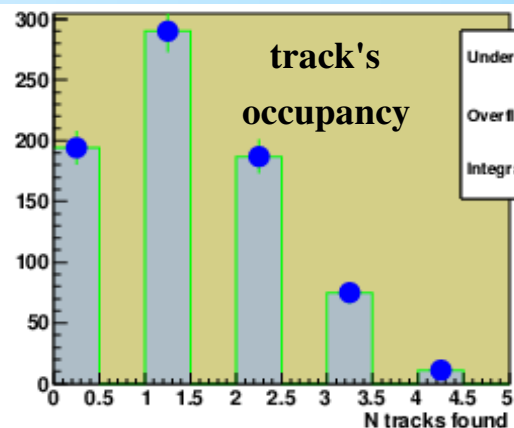Hbb signal in acceptance mixed with **one** B11B Bkg track of leak.out file (real rate increased by factor 177)

only Signal
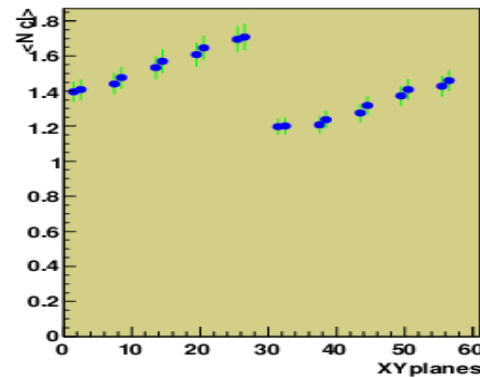
679-645=34

# of Signal tracks is reduced by

34/759 ~ < **5%**

/to be more precise --> the file w/o weights need to be used/

track's occupancy

Underflow	0
Overflow	2
Integral	757

cluster's occupancy

Underf	
Overflo	
Integra	

Underflow	0
Overflow	0
Integral	563

$192+290+189+74+10+2$ -> losses:$192/757=$**25.4%**, hence, rate of real losses: $0.254*0.27\%=$**0.07%**
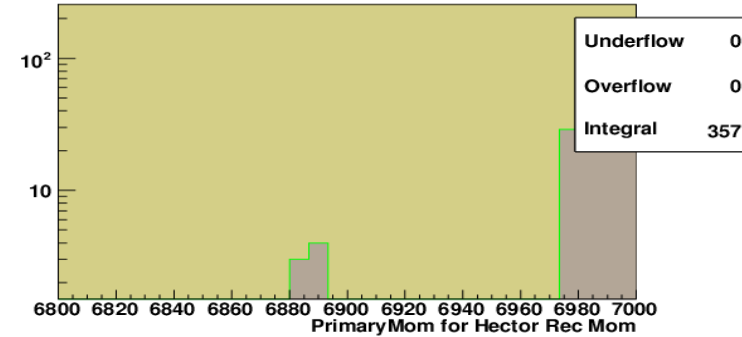
~38% of events with one track occupancy

~36% of events with occupancy >=2 tracks

Underflow	0
Overflow	0
Integral	943

losses: 1-364/757 -> 52%

depends on track selection

Underflow	94
Overflow	105
Integral	364

Underflow	617
Overflow	86
Integral	240
Constant	41.57
Mean	-0.07175
Sigma	0.9153

losses: 1-161/757 -> 79%

depends on track selection

Underflow	0
Overflow	402
Integral	161
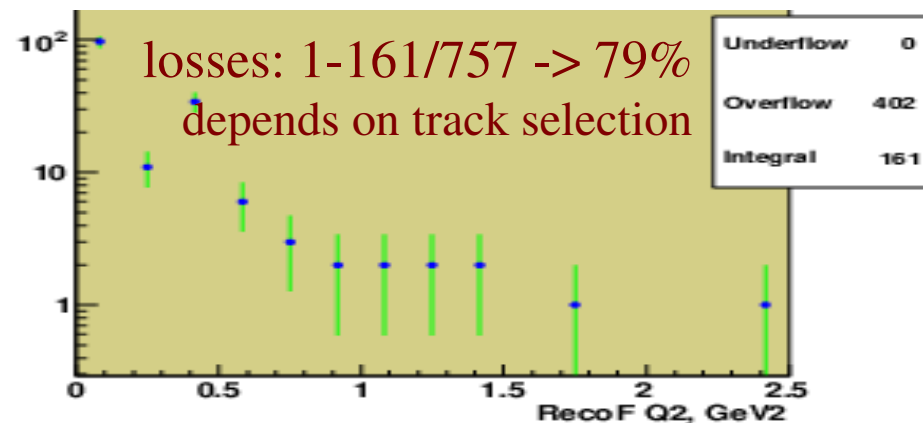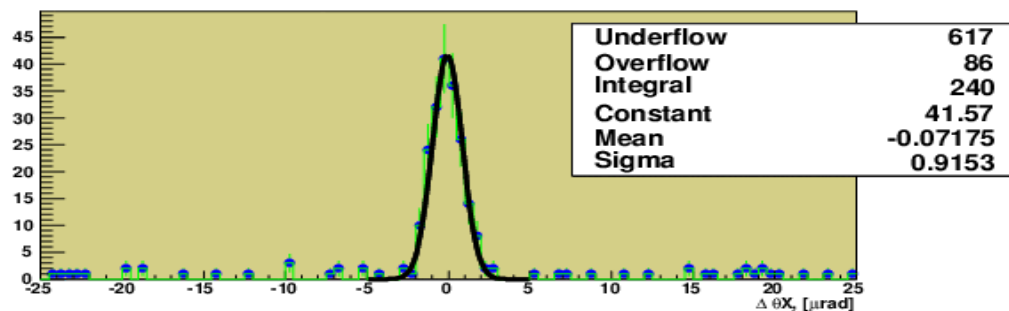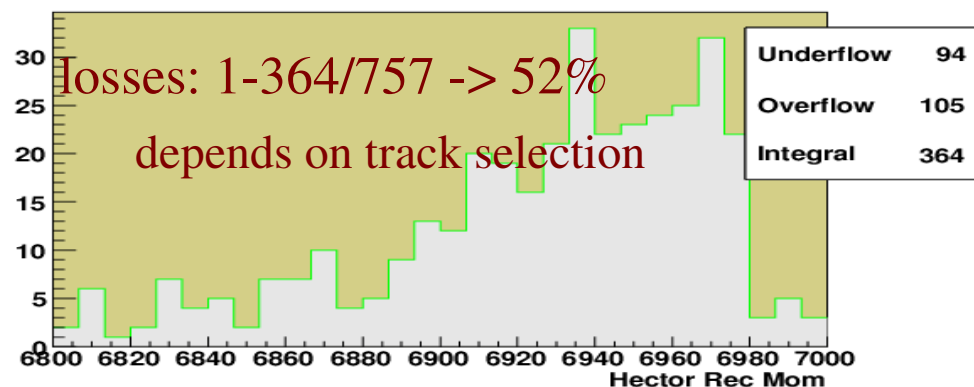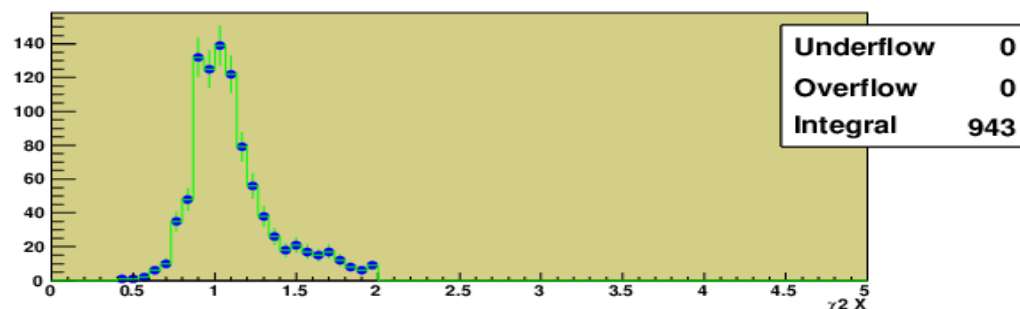
(Signal(out of detector acceptance)+B11B) -> fake signal from secondaries

for 2000 events generated with ExHuMe: gg->H(120)->bbar, the 578 events are with *transported* at 420m

proton but *outside* +FP420 detector *acceptance* -> response in detector only from B11B Bkg
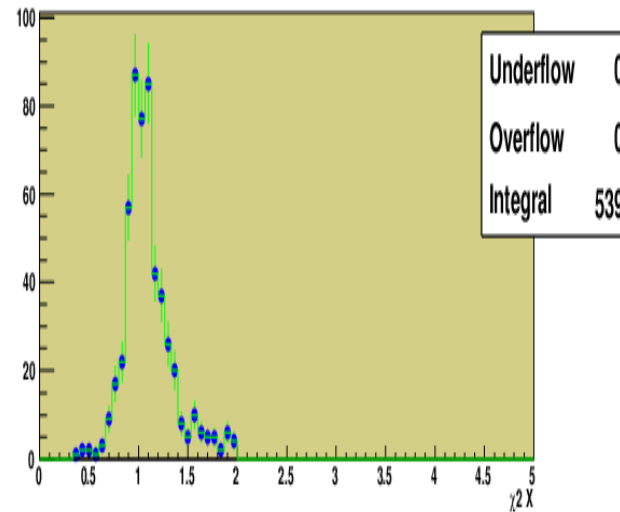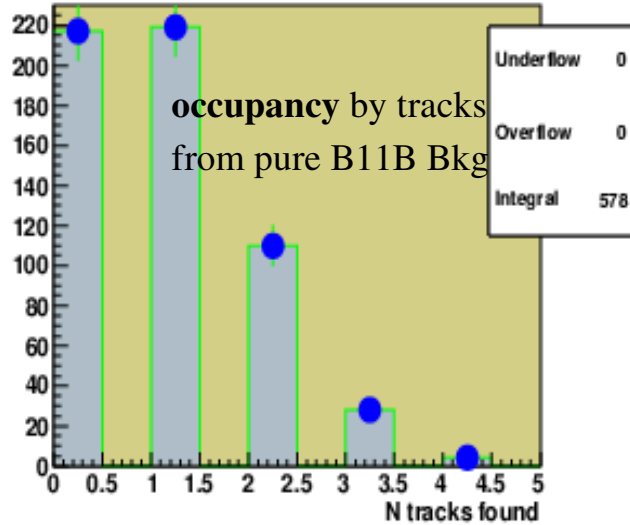
occupancy by tracks from pure B11B Bkg

Underflow	0
Overflow	0
Integral	578

Underflow	0
Overflow	0
Integral	539

Underflow	0
Overflow	0
Integral	357

Underflow	97
Overflow	113
Integral	147

~63% of events with well reconstructed tracks within χ2<2

~38% of events with one track occupancy

~24.7% of events with occupancy >=2 tracks

- 25.4%(147/578) of events are within P': 6.8 – 7.0 TeV
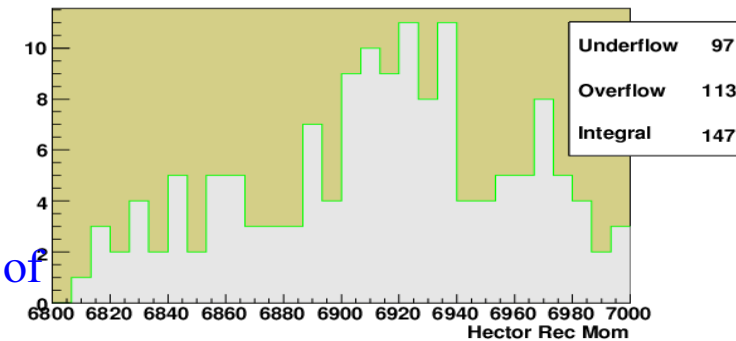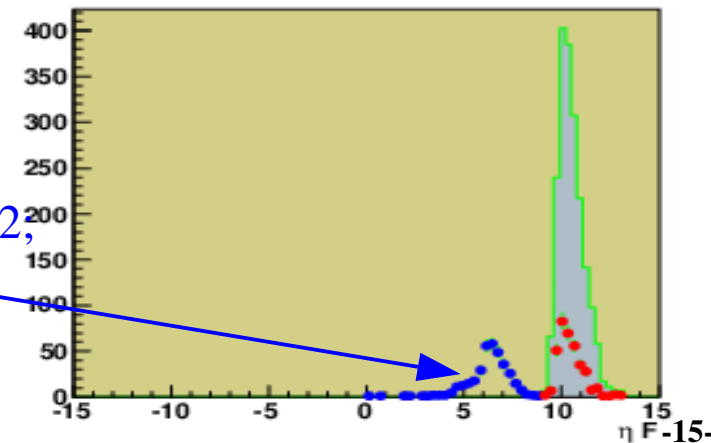
reminder:

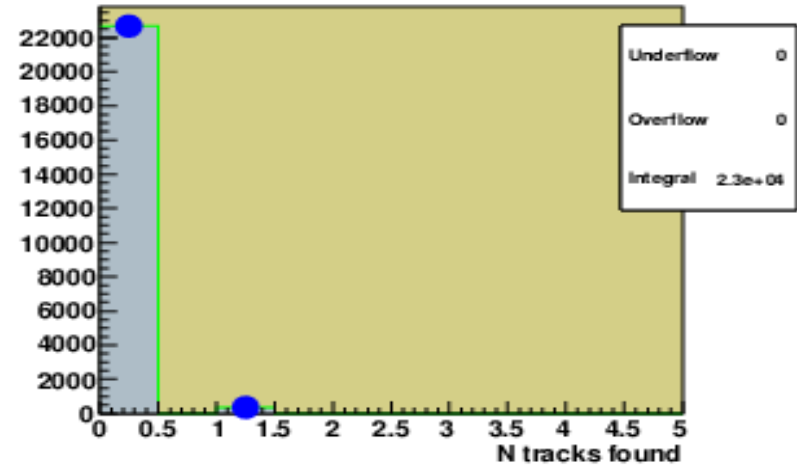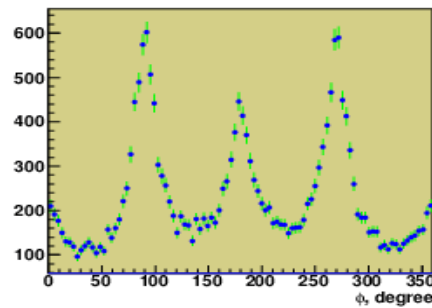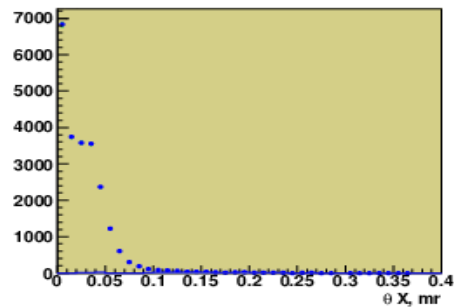*select highest momentum track for events with #tracks > 1*
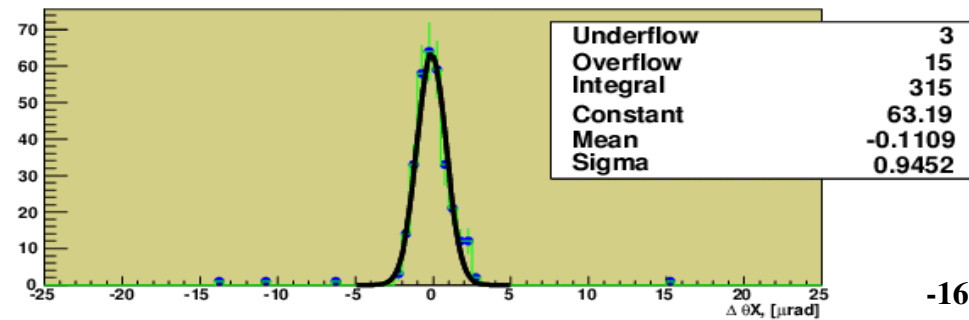
- no events with Q2 < 1 GeV2;
- for all events η ~< 10;

F-15-

eff. for BGas Bkg particles to be detected is ~1.5%

(333/23K)

detected

cluster's occupancy per station
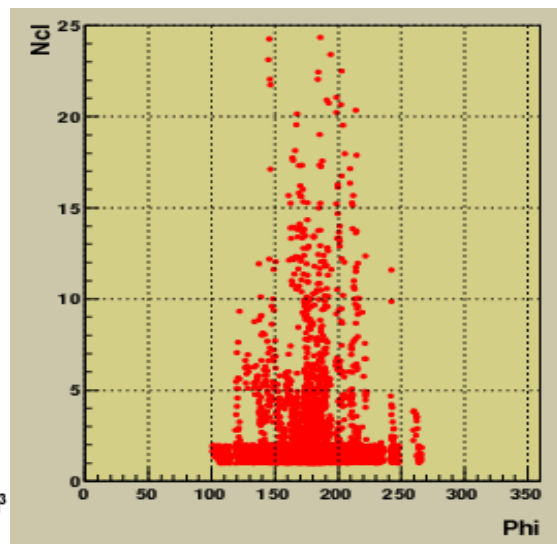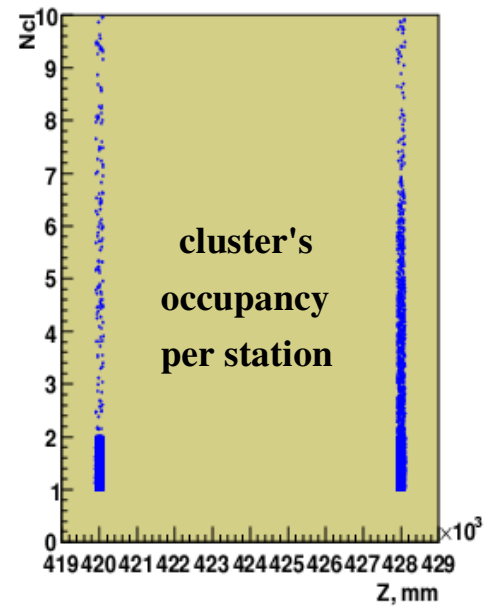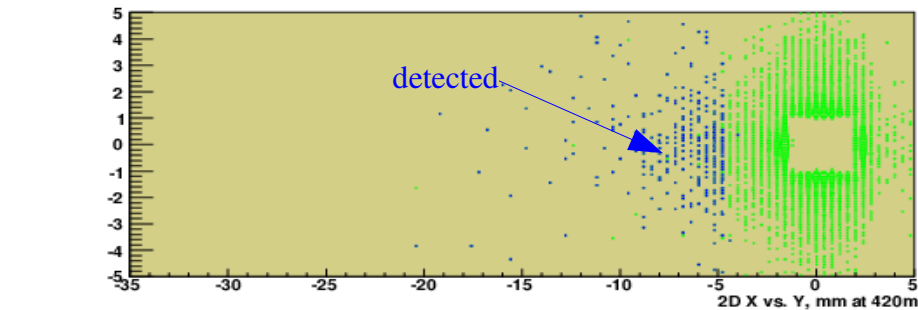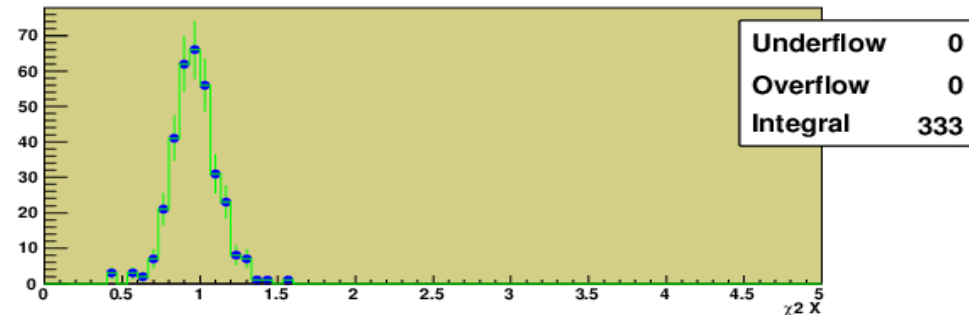
(Signal) & (Signal(in detector acceptance)+BGas(rate=1.))

Signal

track's occupancy

Under flow	0
Over flow	0
Integral	759

57 + 702 -> losses:57/759=7.5%

Underflow	0
Overflow	0
Integral	702

Underflow	7
Overflow	8
Integral	687
Constant	142.5
Mean	-0.02061
Sigma	0.9175

Both

a bit more clusters reconstructed in 2nd station wrt pure Signal

Under flow	0
Over flow	0
Integral	759

55 +693 + 11

~91.3% of events with one track occupancy
~1.5% of events with occupancy of 2 tracks

Underflow	0
Overflow	0
Integral	716
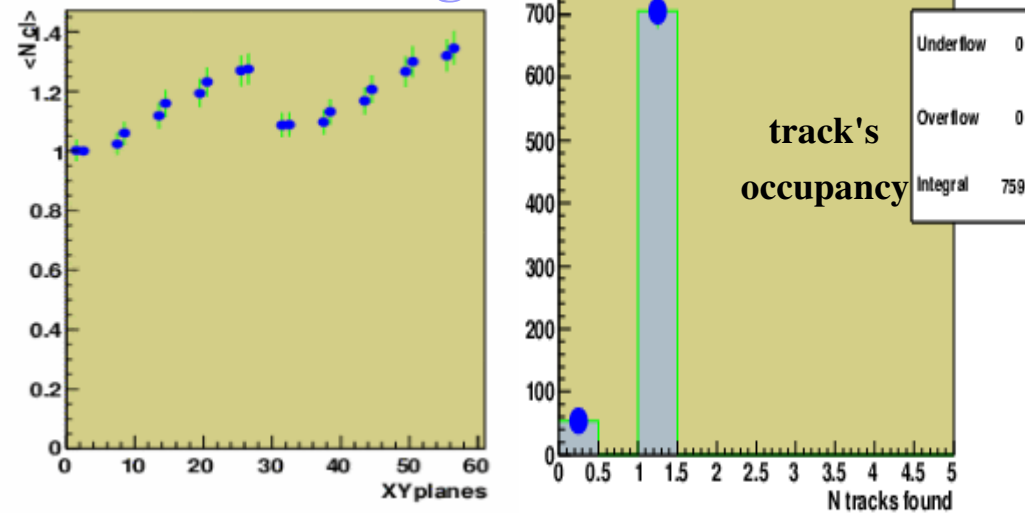
687-686=1
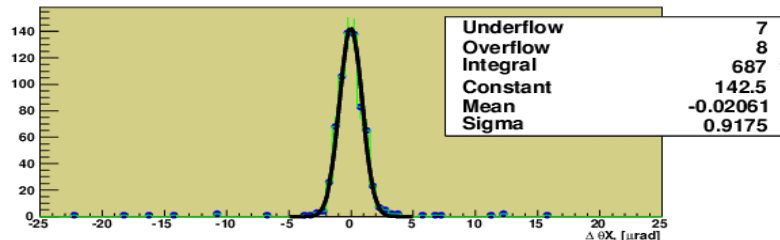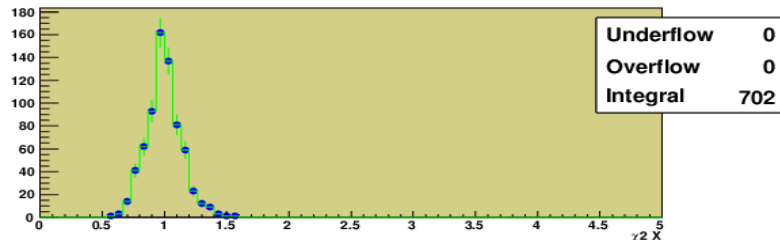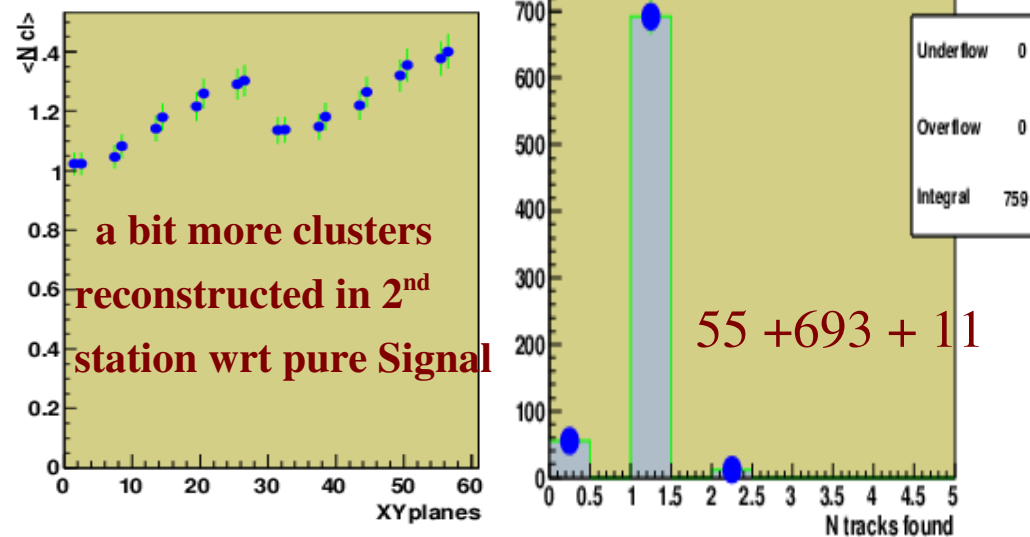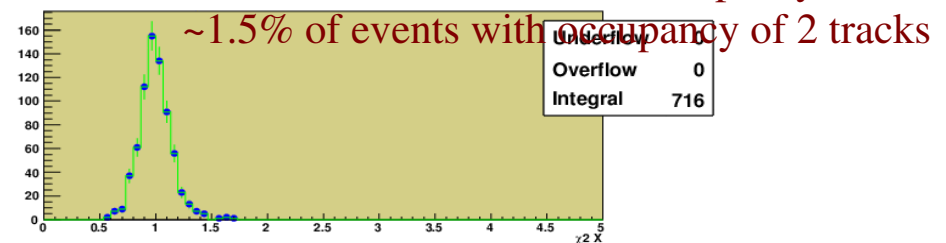
Underflow	14
Overflow	16
Integral	686
Constant	143.9
Mean	-0.0204
Sigma	0.9131
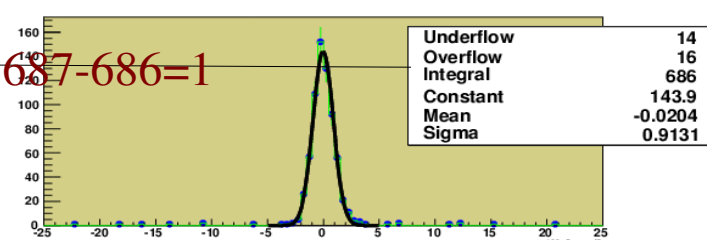
signal proton losses are negligible wrt pure Signal case:1/687=0.2%
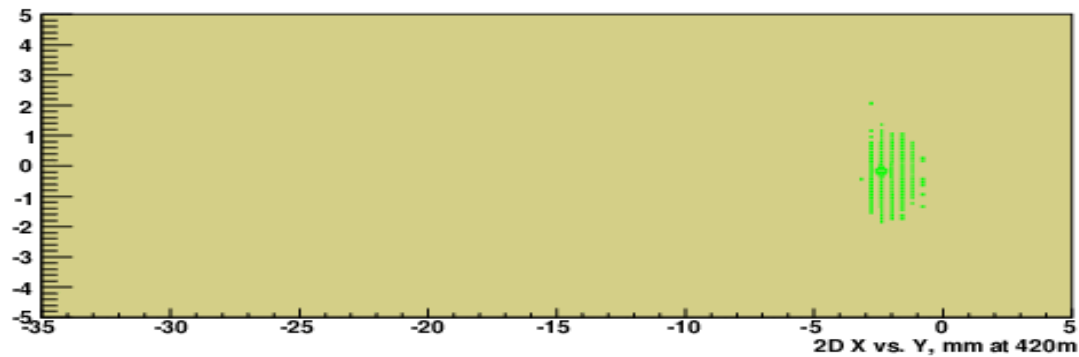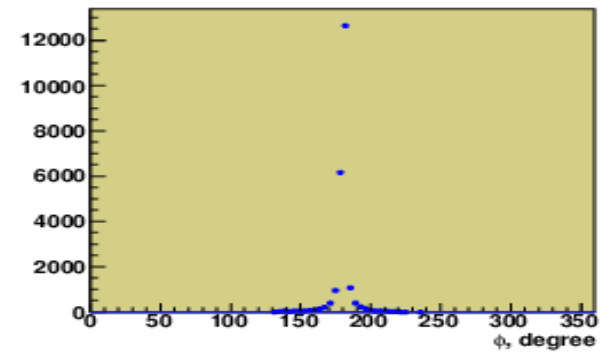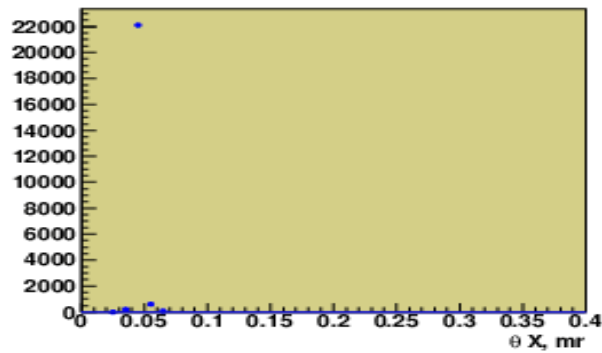
no any hit and hence rec. tracks
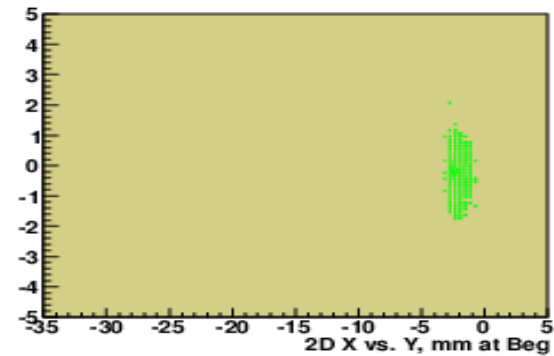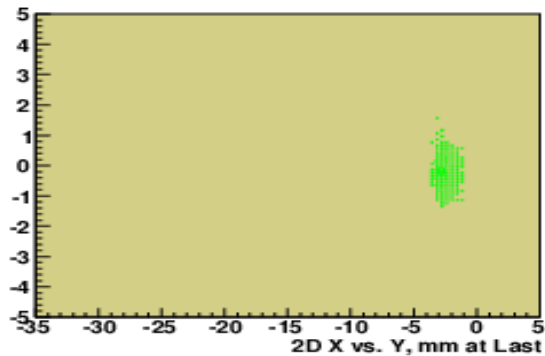
Conclusions

✔ **the loss of Signal protons accompanished by MB Bkg is in agreement w/ loss estimation based on MI and is about 15%** **that is 2 time higher than losses w/o MBPU;**

(MBPU was added to Signal with a real rate corresponding to L=10^34 sm-2 c-1)

(this rate is ~ 0.3/bx with mainly one Bkg track occupancy)

✔ **all tracks are reconstructed with χ2<2. in the events w/ MBPU;**

with simple criterion of selection of highest momentum track there are 20% losses of signal track for P': 6.8-7 TeV/c and *33% - for Q2>2.5 GeV2 (10.5% w/o MBPU)*

(a dedicated criteria to select Signal proton in a more one track sample of events can reduce fake track contamination);

✔ **in Hbb Signal *sample with transported proton* the contamination of fake events from MB Bkg is order of 12% for Q2 range < 1 GeV2**

✔ **with efficiency ~ 1.5%** **the tracks in FP420 detector are reconstructed with χ2<2. from particles of BeamGas Bkg ;**

for Signal events accompanished by BGas Bkg of rate 0.005 there are 91.3% of events with occupancy of one track, 1.5% - of 2 tracks , and signal track losses order of 0.2%;

Conclusions (cont.)

✔ **no hits and tracks in FP420 detector reconstructed from any single particle of MomentumCleaning Bkg**

✔ **for single particles of B11B Bkg there are**
no tracks reconstructed in the detector at |y| > 2mm & x > 18mm,
no tracks reconstructed from neutrons,
~0.05% of reconstructed tracks from photon impack on the detector

✔ **the loss of events because of B11B Bkg PU is negligible (~0.27%) if even Signal proton is not reconstructed at all for all such events, but nevertheless, the estimation with real particle multiplicity (m=29) of event losses is just 0.07%**
(~38% of events with one track detector occupancy for PU events)
(~36% of events with detector occupancy by >=2 tracks for PU events)

✔ **for case of pure B11B Bkg w/ m=29(no Signal track in detector acceptance) there are:**
~63% of events with well reconstructed tracks within $\chi2<2$;
~38% of events with one track occupancy;
~24.7% of events with occupancy >=2 tracks;
(the detector at beam1 will be occupied by this kind of Bkg w/ rate ~0.00265)

Backup

PYTHIA MBE Processes

Processes:

Subprocess	Generated ev.	Sigma, (mb)
0 All included subprocesses	13220	1.014E+02
11 f + f' ⇒ f + f' (QCD)	916	1.251E+01
12 f + fbar ⇒ f' + fbar'	0	0.000E+00
13 f + fbar ⇒ g + g	3	2.302E-02
28 f + g ⇒ f + g	1398	1.073E+01
53 g + g ⇒ f + fbar	103	7.904E-01
68 g + g ⇒ g + g	4062	3.117E+01
91 Elastic scattering	2827	2.221E+01
92 Single diffractive (XB)	1000	7.151E+00
93 Single diffractive (AX)	923	7.151E+00
94 Double diffractive	1274	9.687E+00
95 Low-pT scattering	0	0.000E+00

MBE Processes (continuation)

● **Rates:**

$L = 10^{34} cm^{-2} s^{-1}$, $\sigma_{MinBias} = 101.4 mb$, $bunch\ time\ width\ Tb = 25\ ns$,
$total\ number\ of\ LHC\ bunches\ Nb_{total\ LHC} = 3564$,
$number\ of\ filled\ bunches\ Nb_{filled} = 2808$, $Frequency = 40 MHz$

$\epsilon_{transported} = N_{420mTransported}/N_{tot} = 3560/13220 = 0.27$
$\epsilon_{fp420} = N_{fp420}/N_{tot} = 100/13220 = 0.0076$, (0.76%)

$N_{interactions}^{total} = L \cdot \sigma_{MinBias} \cdot Tb \cdot (Nb_{total\ LHC}/Nb_{filled}) =$
$\qquad 10^{34} \cdot 101.4 \cdot 10^{-3} \cdot 10^{-24} \cdot 25 \cdot 10^{-9} \cdot 3564/2808 = 32.2$
$N_{interactions}^{fp420} = N_{interactions}^{total} \cdot \epsilon_{fp420} = 0.25$
$Rate_{fp420} = N_{interactions}^{fp420} * Frequency = 0.25 \cdot 40 \cdot 10^6 = 1.00 \cdot 10^7 protons/sec$

εfp420 = 0.84% with higher statistics

MBE w/o ES (← CMSSW default)

● **Rates:**

$L = 10^{34} cm^{-2} s^{-1}$, $\sigma_{MinBias} = 79.24 mb$, $bunch\ time\ width\ Tb = 25\ ns$,
$total\ number\ of\ LHC\ bunches\ Nb_{total\ LHC} = 3564$,
$number\ of\ filled\ bunches\ Nb_{filled} = 2808$, $Frequency = 40 MHz$

$\epsilon_{acc} = N_{420mTransported}/N_{tot} = 400/6000 = 0.067$
$\epsilon_{fp420} = N_{fp420}/N_{tot} = 54/6000 = 0.009$

$N_{interactions}^{total} = L \cdot \sigma_{MinBias} \cdot Tb \cdot (Nb_{total\ LHC}/Nb_{filled}) =$
$\qquad 10^{34} \cdot 79.24 \cdot 10^{-3} \cdot 10^{-24} \cdot 25 \cdot 10^{-9} \cdot 3564/2808 = 25.1$
$N_{interactions}^{fp420} = N_{interactions}^{total} \cdot \epsilon_{fp420} = 0.23$
$Rate_{fp420} = N_{interactions}^{fp420} * Frequency = 0.23 \cdot 40 \cdot 10^6 = 0.92 \cdot 10^7 protons/sec$

$\implies \sigma_{MinBiasWithEL}\ increased\ by\ 20\%\ but\ Rate\ is\ not\ changing\ almost \impliedby$

● remark on use of official PU event samples which are produced w/o Elastic process (ES):

one should remember that if you want to estimate the PU contamination to your Signal one have to impose 25 interaction instead of 32 for $L = 10^{34}$ because of negligible contribution of ES to the rate, but 20% contribution to σ

● Realistic estimation was obtained with use of FastSimulation and ProtonTaggerFilter:
  - thanks to Patrick Janot and Florian Beaudette for providing the new PileUpProducer module and Dimitry Zaborov for the timely changes of ProtonTaggerFilter

  - with use of acceptance tables of ProtonTaggerFilter in FastSimulation:
  $\epsilon_{fp420} = N_{fp420}/N_{tot} = 106/10000 = 0.0106$, (1.06%), which is differ from 0.76% obtained in use of full sumulation $\implies$ coming because of difference in detector position: it was taken into account in evaluation of bkg particle numbers

  - simulation with 32 pile up interaction in the same event lead to the result:
  $p_1'' = 0.204$, $p_2'' = 0.042$, $p_3'' = 0.004$, $p_4'' = 0.0005$

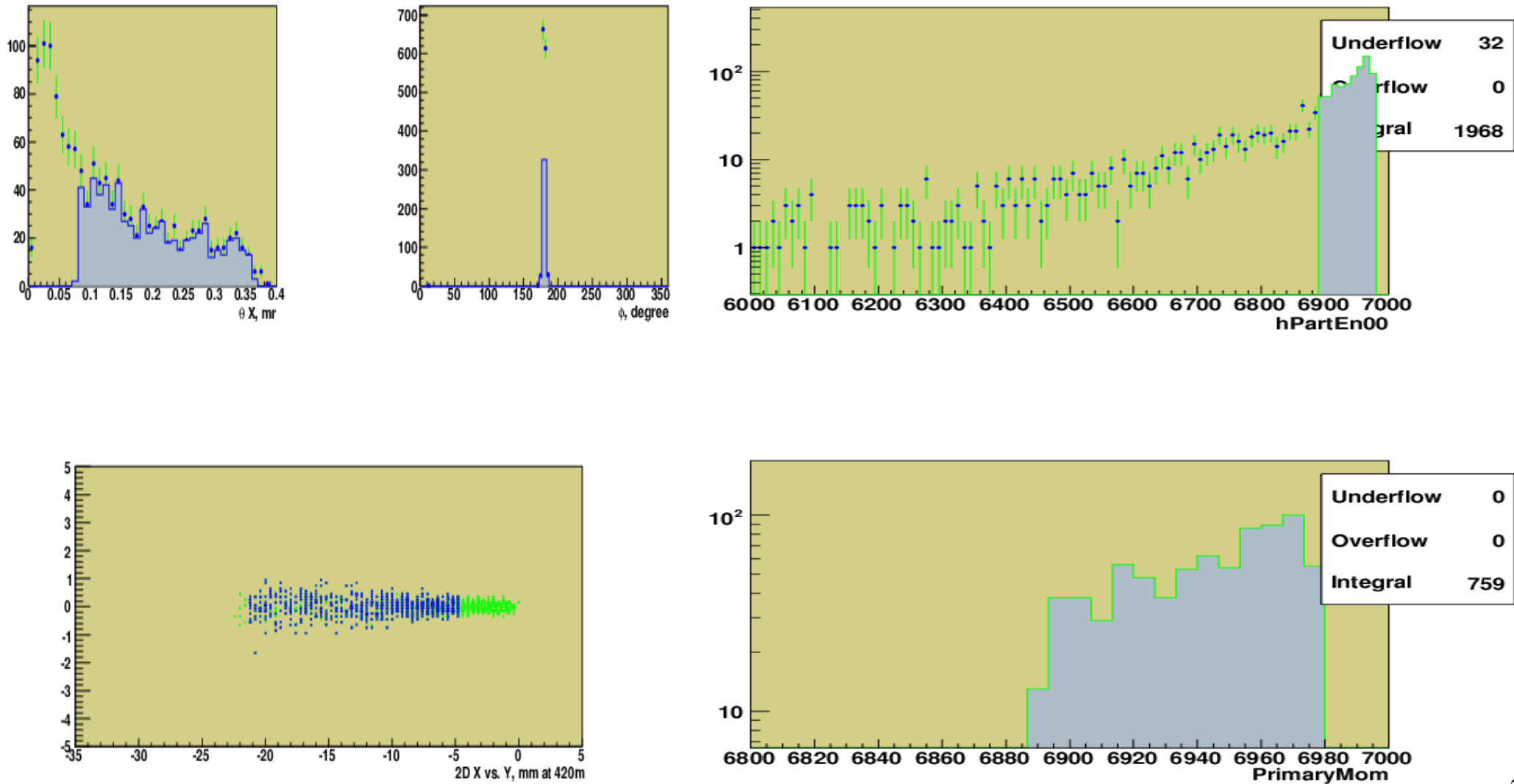 in use of 0.84% instead 0.76% the row with numbers is the following:

  P1=22.5, P2=4.6, P3=0.44, P4=0.06, ...

2000 events of ExHuMe: gg->H(120)->bbar are generated

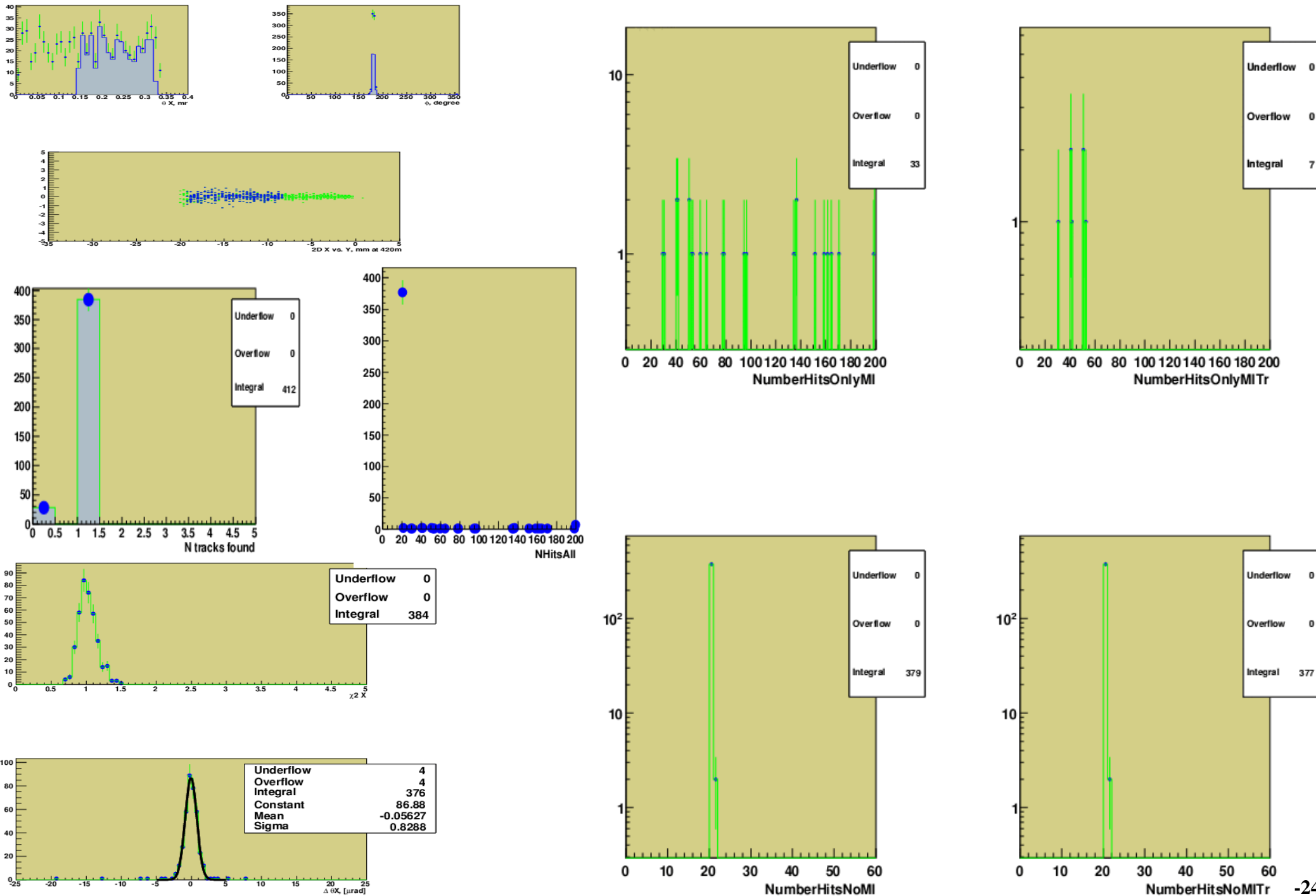## only for 759 events the proton fly in +FP420 detector acceptance
{losses are because of detector geometry position and dimensions
and proton transport(see plot for momentum)}

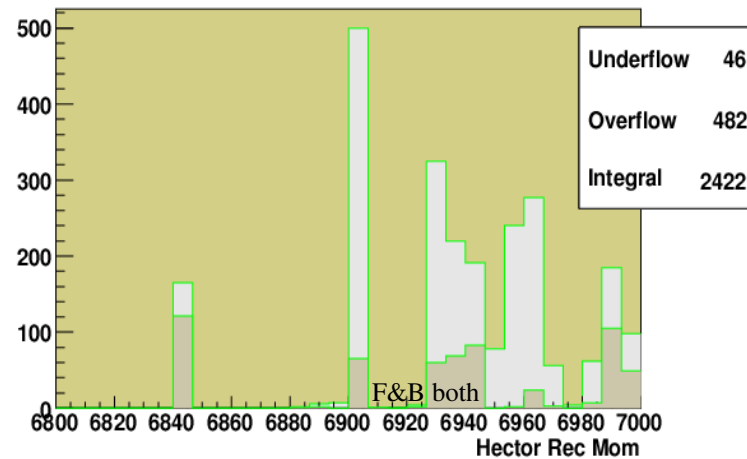# MI rate cross check with inline IP 7TeV protons Hector transported

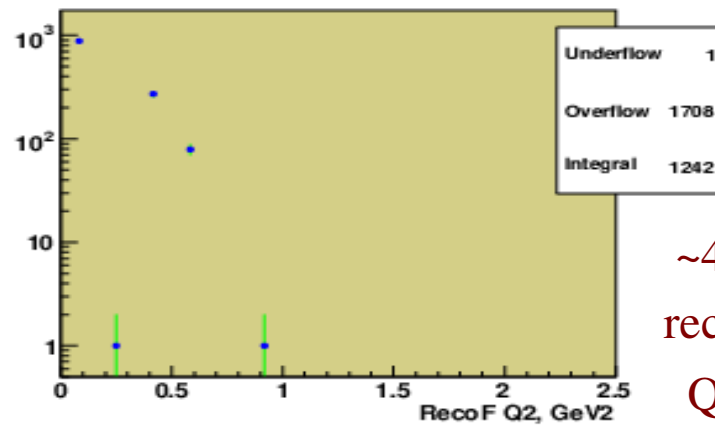MI:33/412-> 8%; Eff.of tr.rec.: 384/412-> 93.2%

for L=10^{34} sm-2 s-1 with <u>25 interactions/bx</u>

~83%(2422/2930) of rec. MB events
are in physical range of Signal
P': 6.8 – 7.0 TeV

~42%(1242/2930) of
rec. MB events are in
Q2 range < 1 GeV2