Position sensitive neutron detector for MPD

Konstantin Mikhailov
for Ndet group

ITEP, Moscow

Outline

- Introduction
- Tests of prototype (in ITEP)
- Efficiency of Ndet (Geant3 in MPD ROOT)
- Feasibility of Σ^+ and Σ^- identification (MPD ROOT)
- Conclusion & Next steps

Introduction

NDET list of authors (participants) from ITEP:
O. Denisovskaya, G. Dzyubenko, K. Mikhailov, P. Polozov,
M. Prokudin, G. Sharkov, A. Stavinsky,
V. Stolin, R. Tolochek, S. Tolstoukhov

Everyone is welcome !

Position sensitive neutron detector is for FLINT experiment
and
Also for MPD?

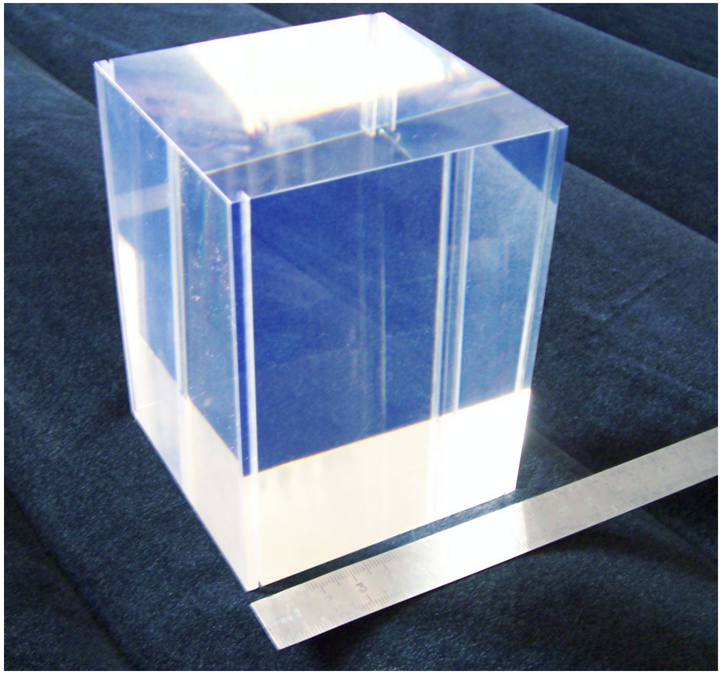
Motivation for NICA

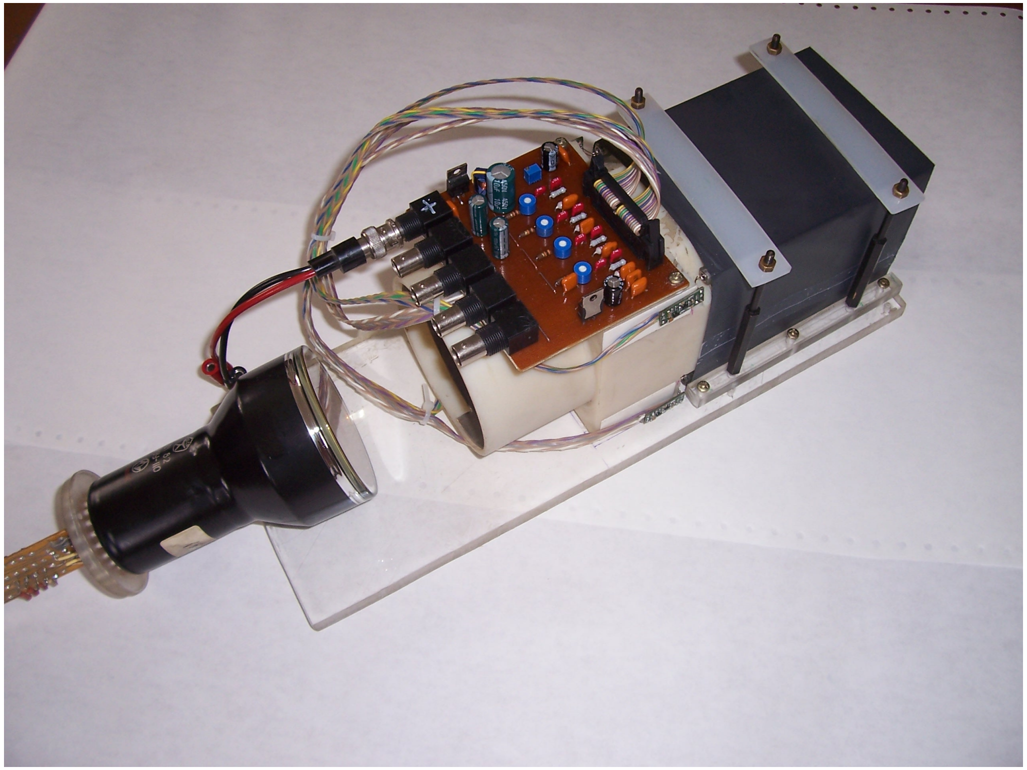
1. Increase a list of measurable baryons with NDET (+):

n	p	$\Lambda \to p\pi^-$	$\Sigma^+ \to n\pi^+$	$\Sigma^- \to n\pi^-$	$\Sigma^0 \to \Lambda\gamma$	$\Xi^- \to \Lambda\pi^-$	$\Xi^0 \to \Lambda\pi^0$	$\Omega \to \Lambda K^-$
+	+	+	+	+		+		+

2. AntiNeutron, antiΣ+, antiΣ^- with Ndet
   (and possible help for other antibaryons)
3. New ratios: n/p, Σ/p, ...
4. 3-dimension phase diagram (add axis Nn-Np)
5. Femtoscopy nn, np, pp, Σp, Σn, ...
   Unknown low energy scattering parameters for ΣN
6. Study of Dense Cold Matter (our proposal for NICA MPD):
   If we have not neutron detector, we will lose a half of information

The prototype of Ndet





Plastic Scintillator 96 * 96 * 128 mm^3

Fiber: KYRARAY,Y-11,d =1mm,

wavelength shift

MRS APD & Amplifier - CPTA(Golovin)

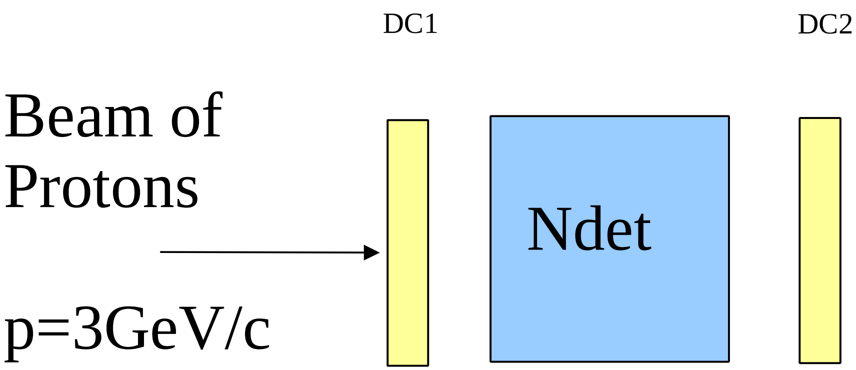
PMT for test EMI 9839A

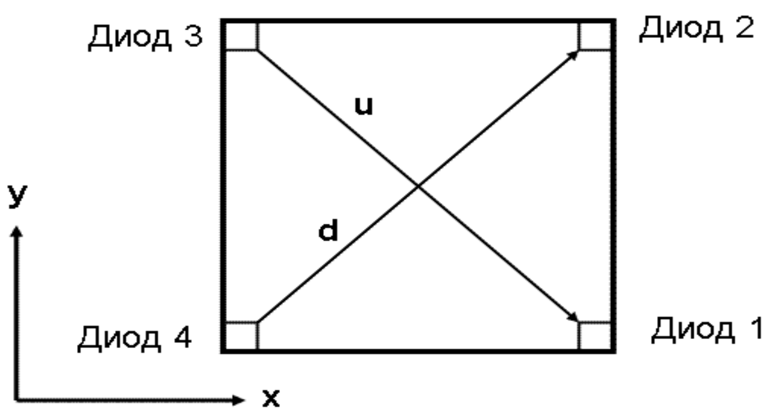
Efficiency (estimate) 15%

Matrix for FLINT 6x6=36

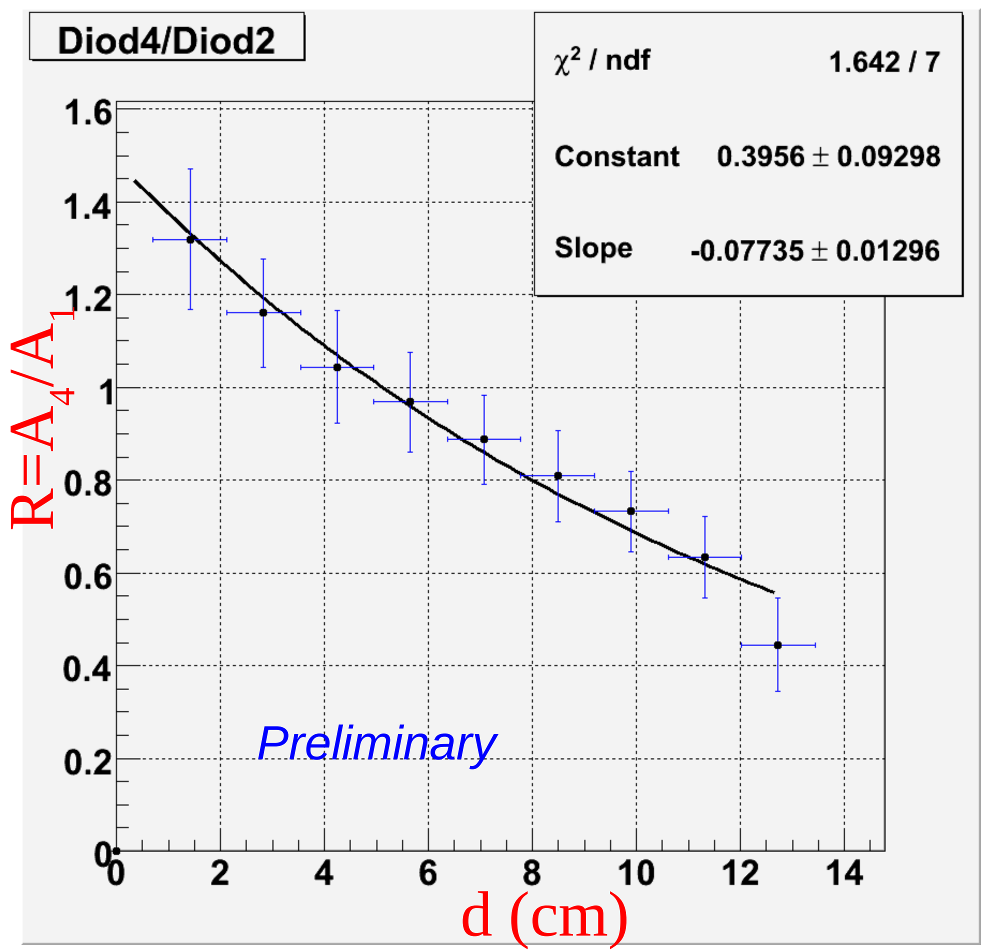
Matrix for NICA(ring with r=155cm) about 3000 neutron detectors

Beam tests of prototype

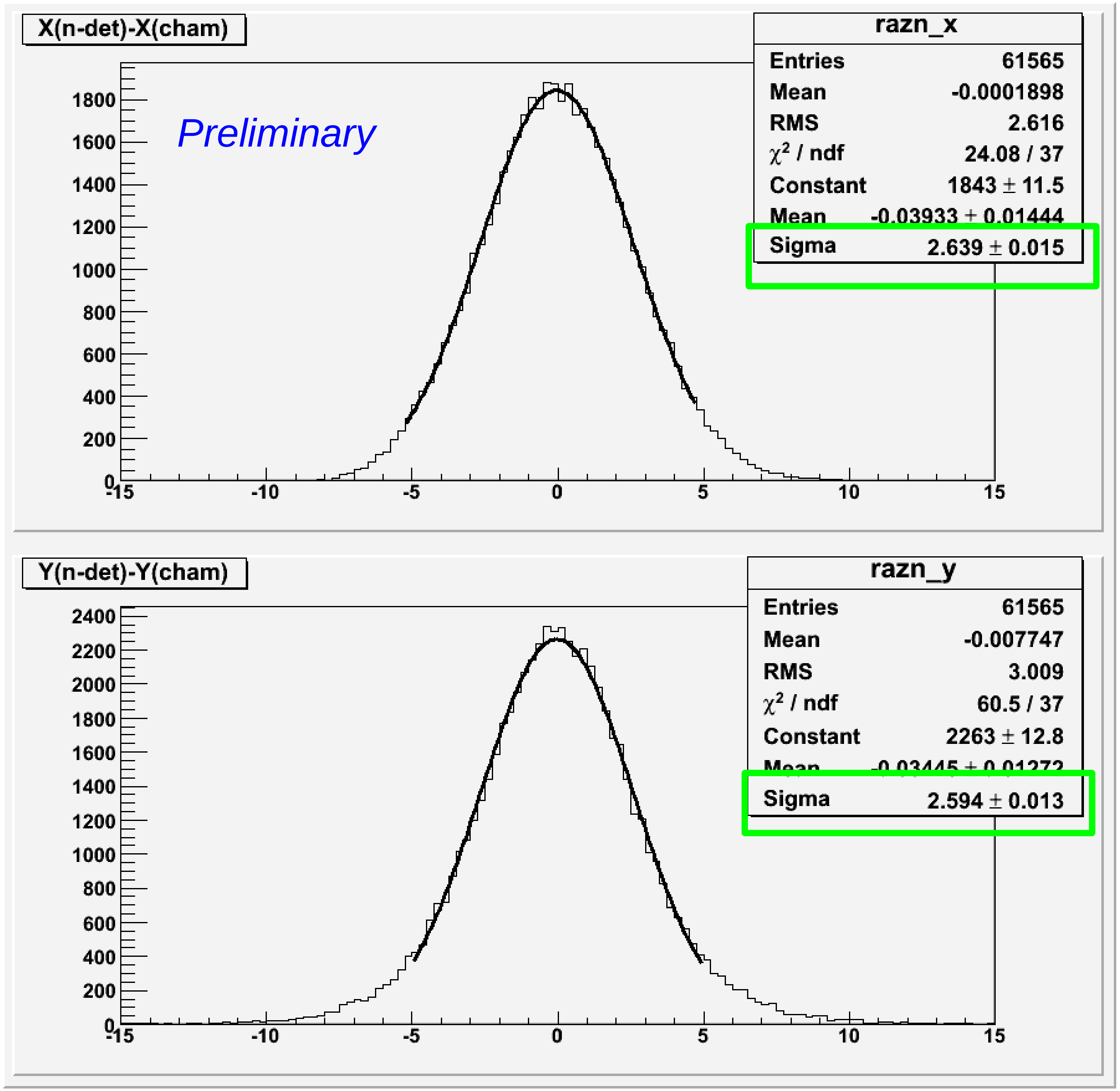




Ratio ($R=A_4/A_1$) of amplitude as exp(-R/d)



Beam test: Ndet space resolution



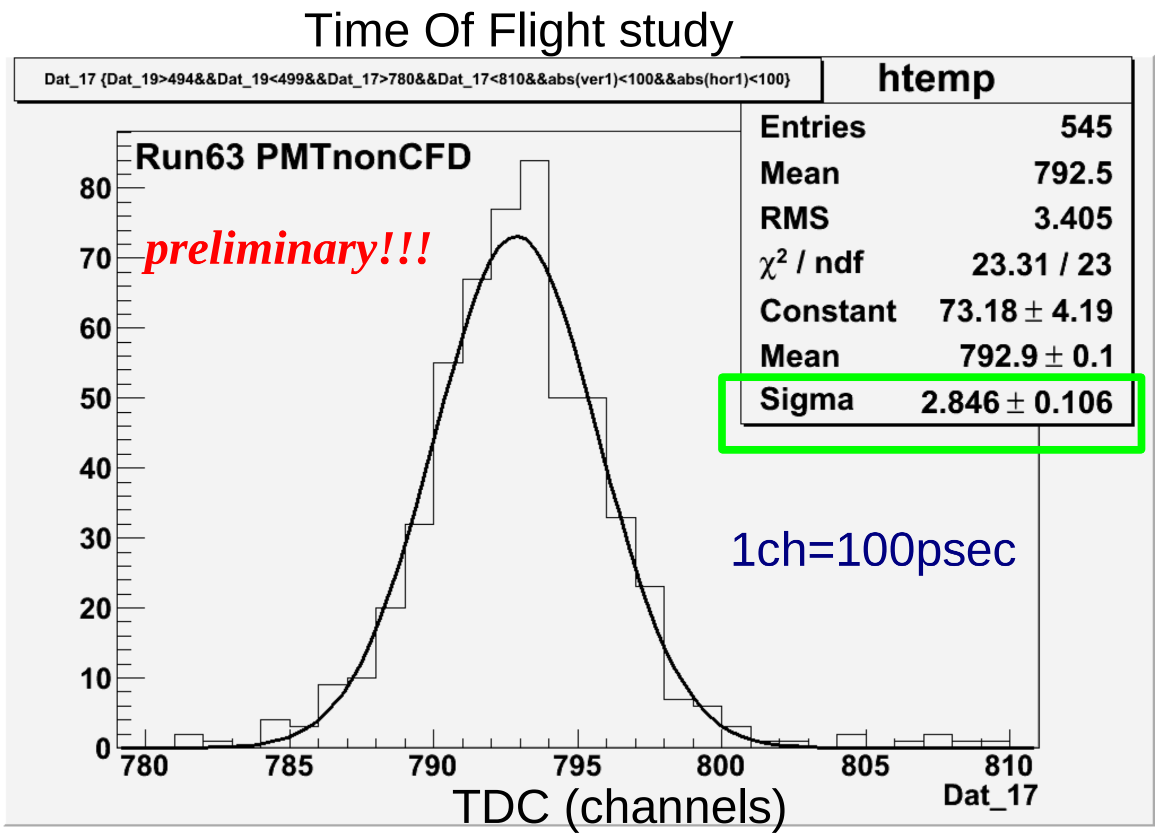
Preliminary resolution of neutron detector

$\sigma_x \approx \sigma_y \approx 2.6$ cm

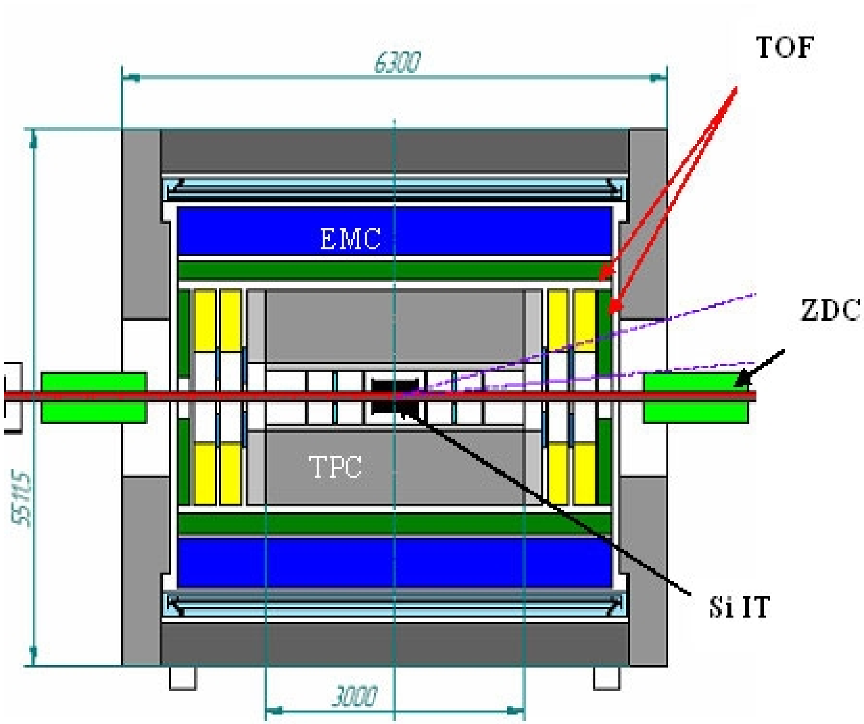
Beam test: Ndet time resolution

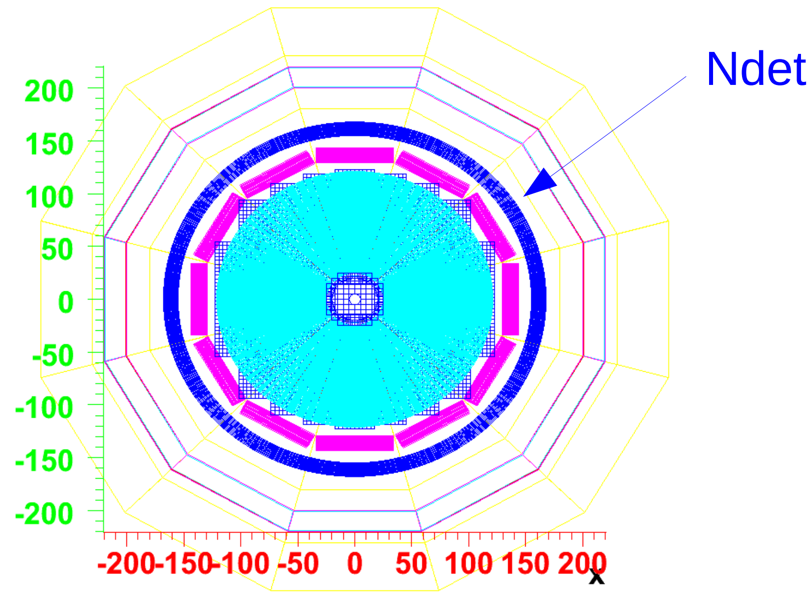
Very very preliminary!!!

Beam tests of time resolution of Ndet are in progress.
We have a run right now.
Very preliminary:
Time resolution with PMT ~ 0.3nsec



Ndet in MPD root





First version of Ndet is in MPDROOT trunk/ndet

(ring of plastic with r=155cm and width 12.8cm, box 9.6x9.6cm Zlength~3m

Matrix ~ 3000 detectors)

Test with MC central events AuAu at sqrt(s)3.8 GeV/c

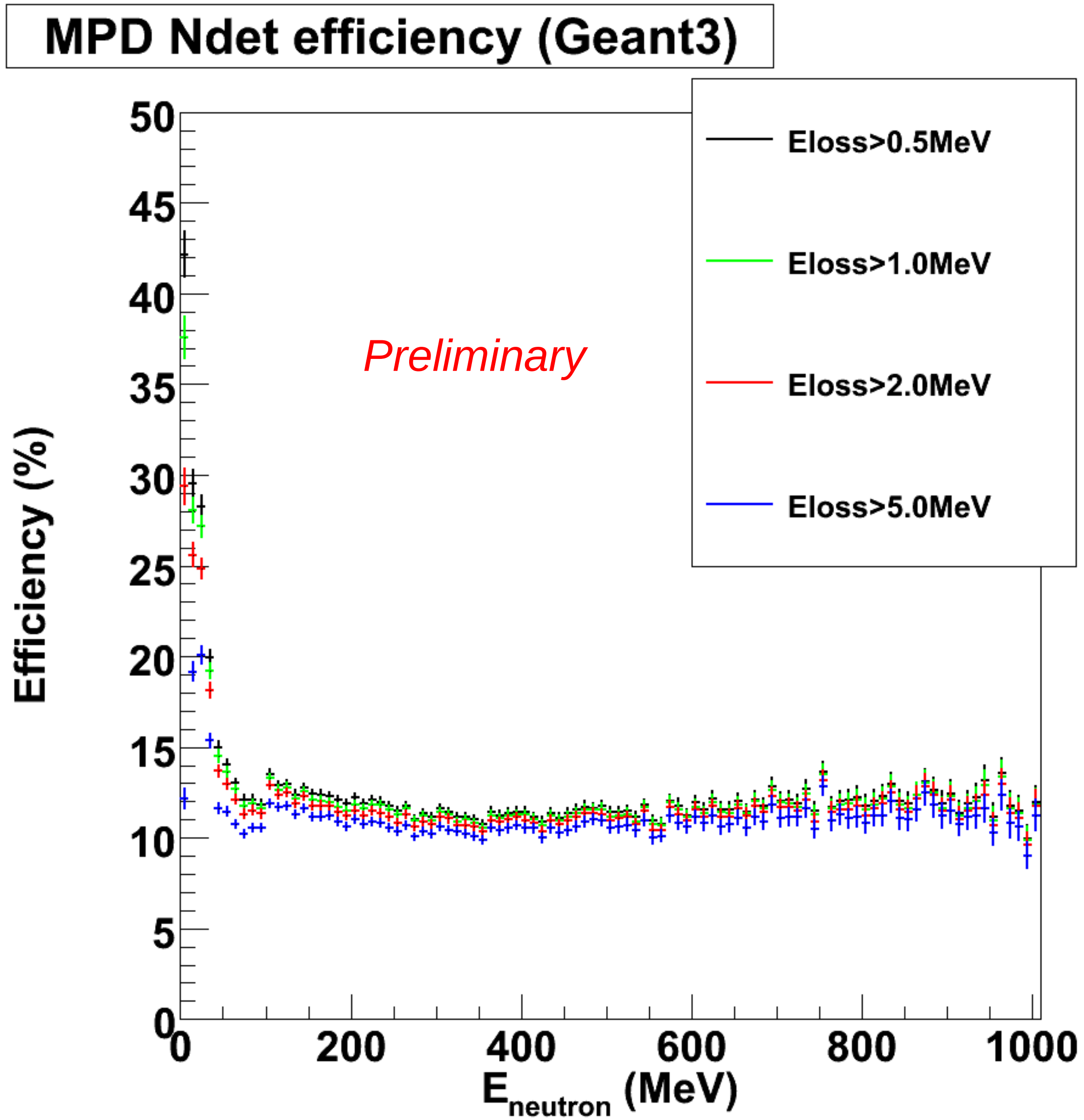
First step to the efficiency

- 10^4 UrQMD AuAu central events sqrt(S)=3.8GeV/nucleon
- MPD root with Geant3
- Preliminary Ndet efficiency with primary neutrons
- Comparison with DeMoN detector efficiency

Ndet efficiency

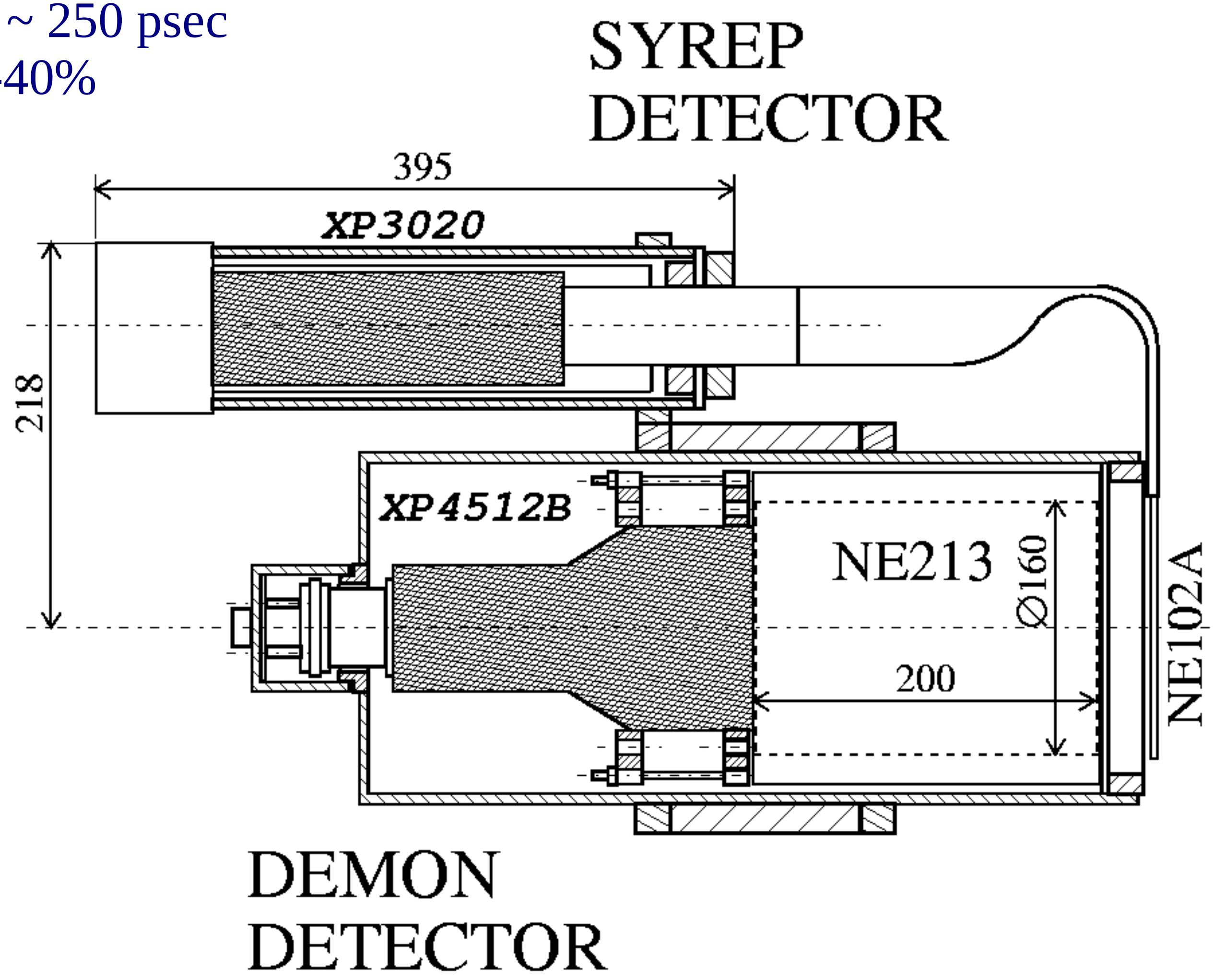
The efficiency of neutron registration is about 13% (length of Ndet is 128mm) at En>100 MeV

Proton momentum > 500 MeV/c
We have to know Ndet efficiency
Starting from En>50MeV

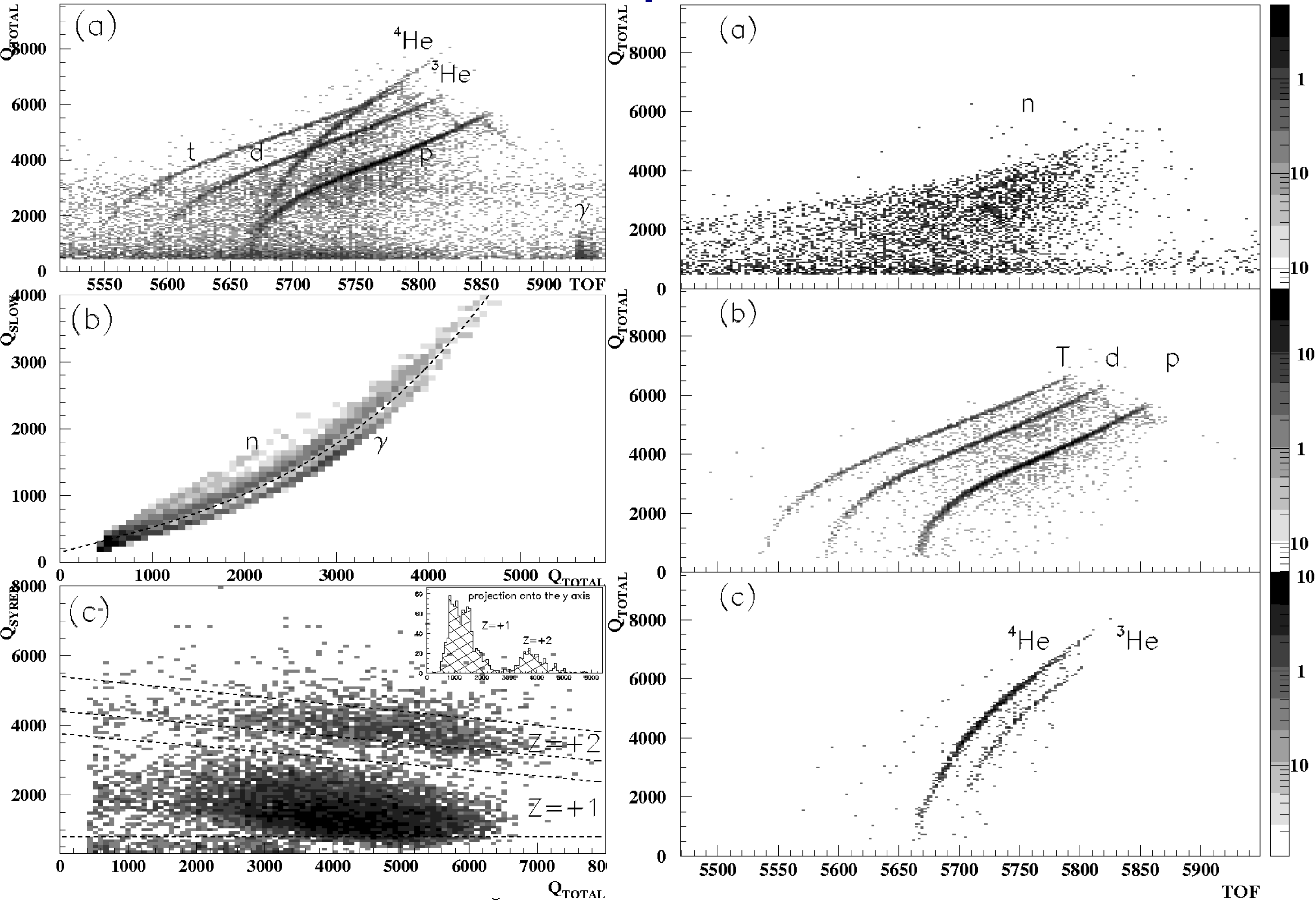


DeMoN detector

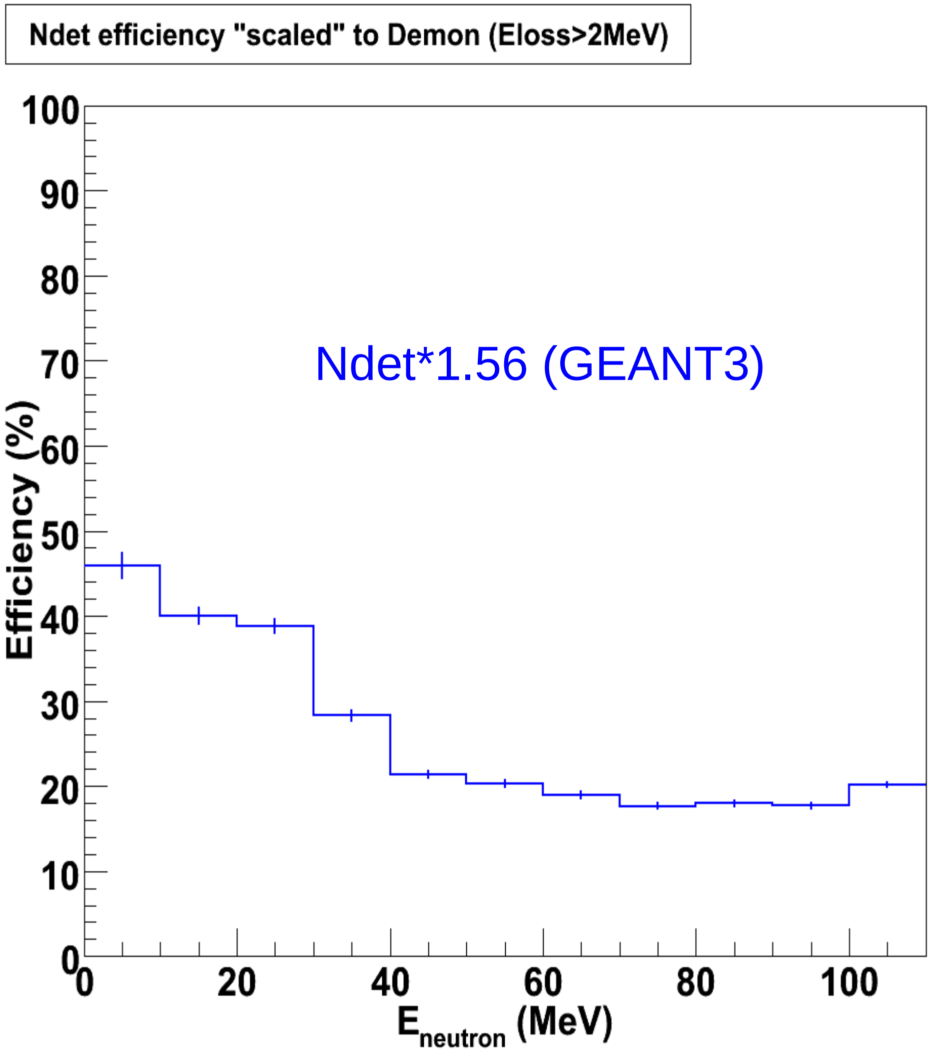
Time resolution ~ 250 psec
Efficiency ~ 30-40%

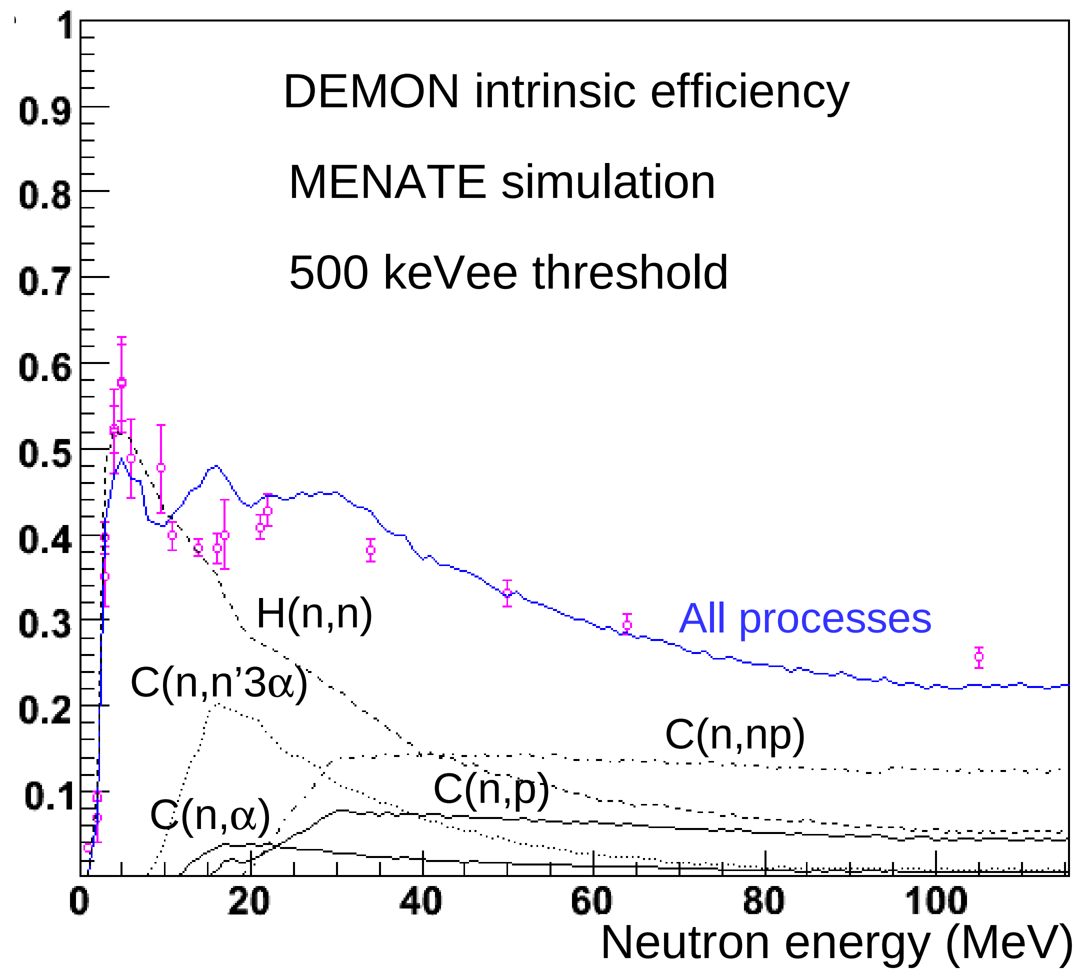


E286 experiment



Ndet and DeMoN





Present calculation roughly corresponds to DeMoN efficiency

P. Désesquelles et al, NIM A 307, 366 (1991)

Diaphony and Cross-Talk

In a modular detection system the same neutron can interact in several modules. If neutron is scattered in one module without being registered and later on is detected in another one then the ***diaphony*** take place.

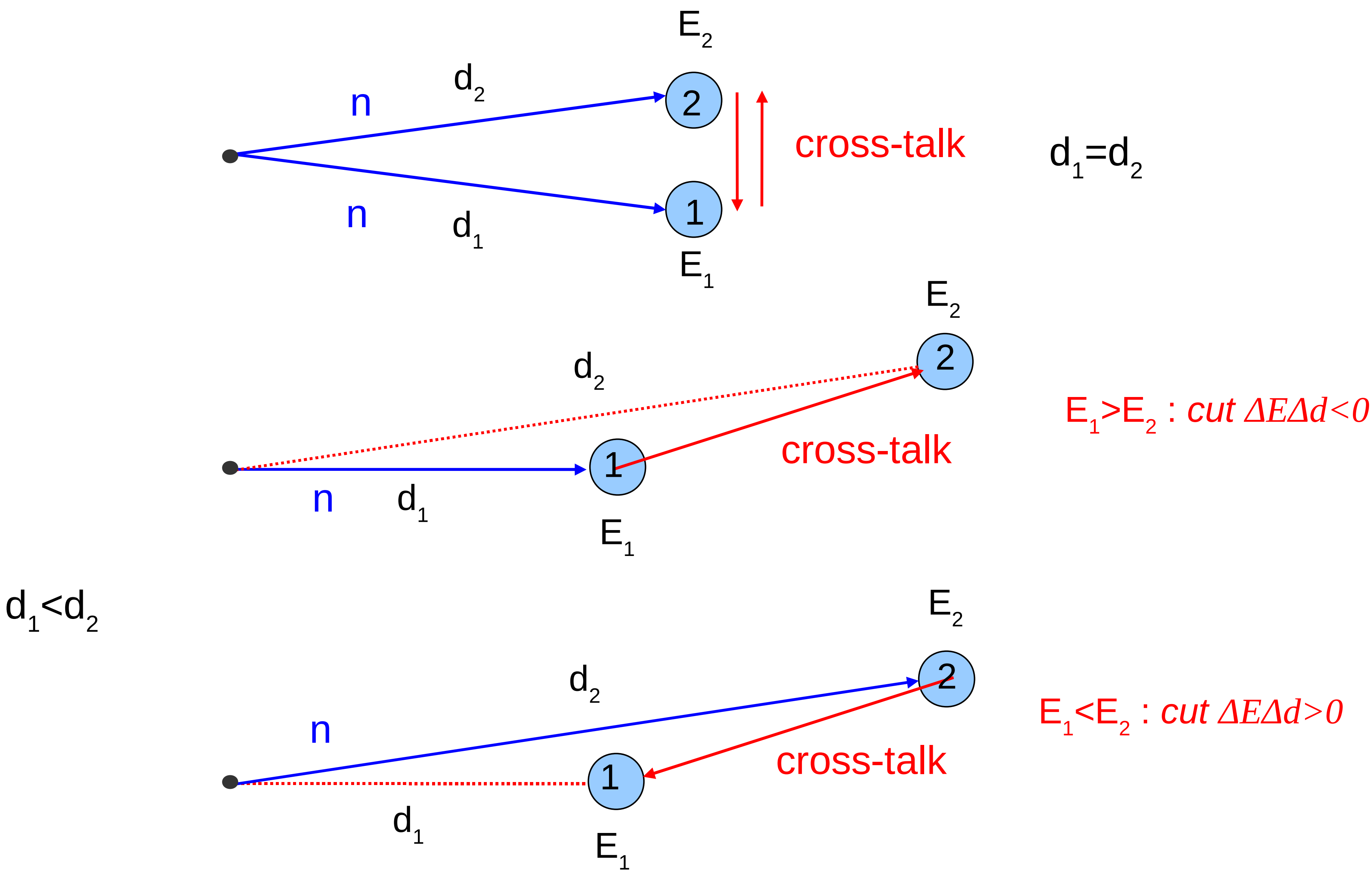
If the same neutron is registered in two or more detectors – the ***cross-talk*** effect occurs.

Diaphony: distortion of the emission angle and the energy

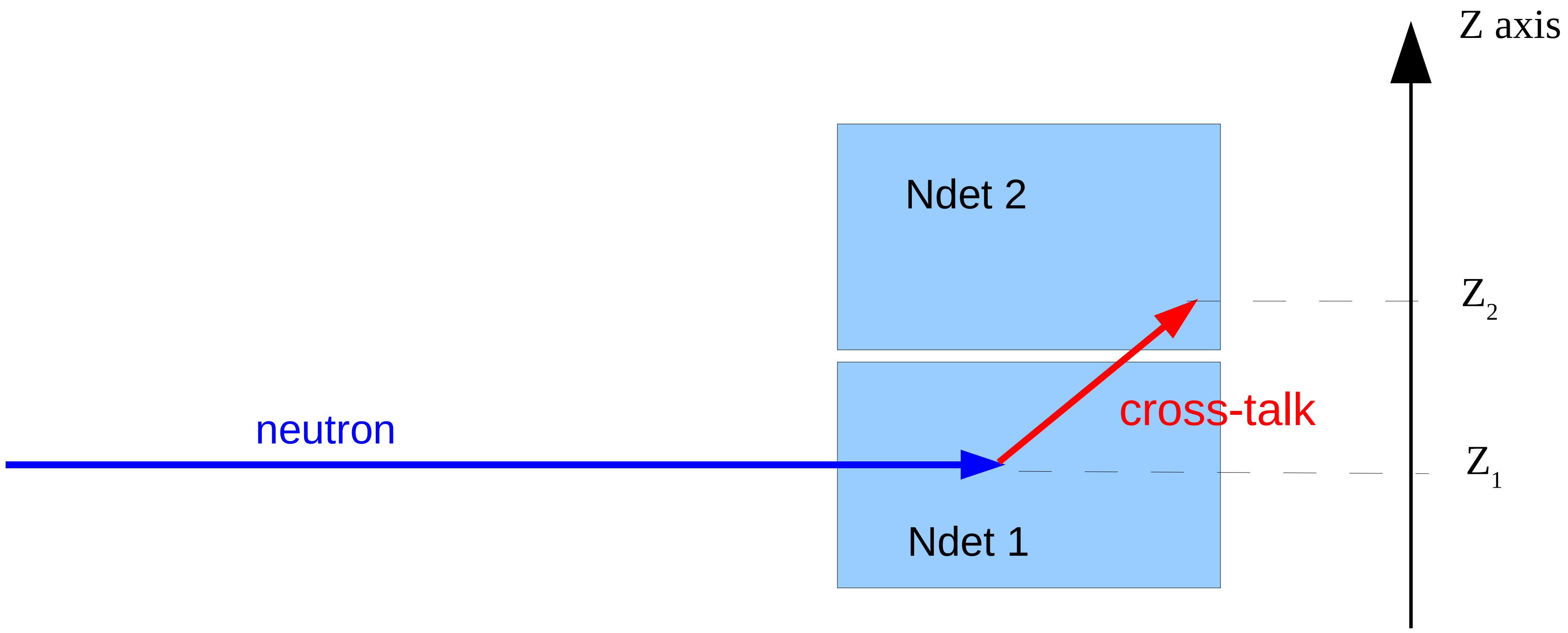
Cross-talk: simulates of two or more neutrons in coincidence leading to a strong spurious correlation. In case of one-particle distribution the cross-talk effects are usually small, but in femtoscopy measurements this effect is quite important and dangerous.

Cut Cross-Talks

J.Pluta et al. NIM A411(1998) 417



Ndet Cross-Talks



Position sensitive neutron detector could be help to reject cross-talk if we do the cut on coordinate?

Simple simulation of Σ

- Simulation in MPD ROOT with Ndet package
- Standard staistics AuAu sqrt(S) = 3.8 GeV (UrQMD 10^4 events)
- Smearing due to Ndet tof resolution 0.3 ns
- Smearing due to Ndet space resolution 0.3 cm
- Suppose (for now) 100% neutron efficiency
- Do not use tracking information for pions and
  do not smear pion momentum

Ndet momentum resolution

Momentum resolution of neutron detector is a combination of time resolution and space resolution

<u>Time resolution</u>

β = L/TOF, where L distance from collision point to Ndet

Suppose TOF smeared byGaus(TOF,σ_{TOF}) and one can expect $\sigma_{TOF} <$ 0.3ns (to be measured)

Smeared momentum due to time

$P_{smeared} = m\beta_{smeared}/(1-\beta_{smeared}^2)$

<u>Space resolution</u> depends on

Angle $\Phi_{smeared}$ =Gaus(Φ, σ_s/R)

and

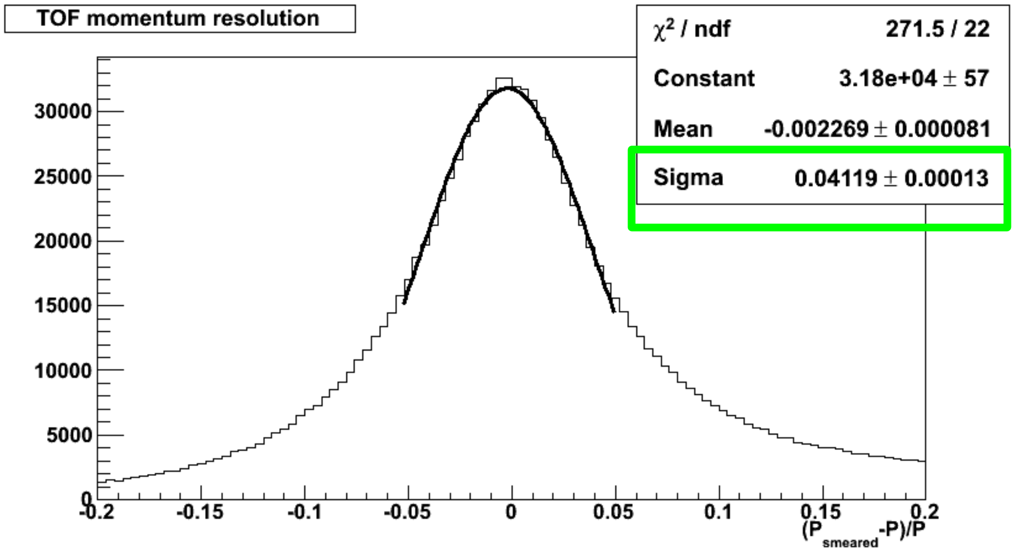
$Z_{smeared}$ = Gaus(Z, σ_s),

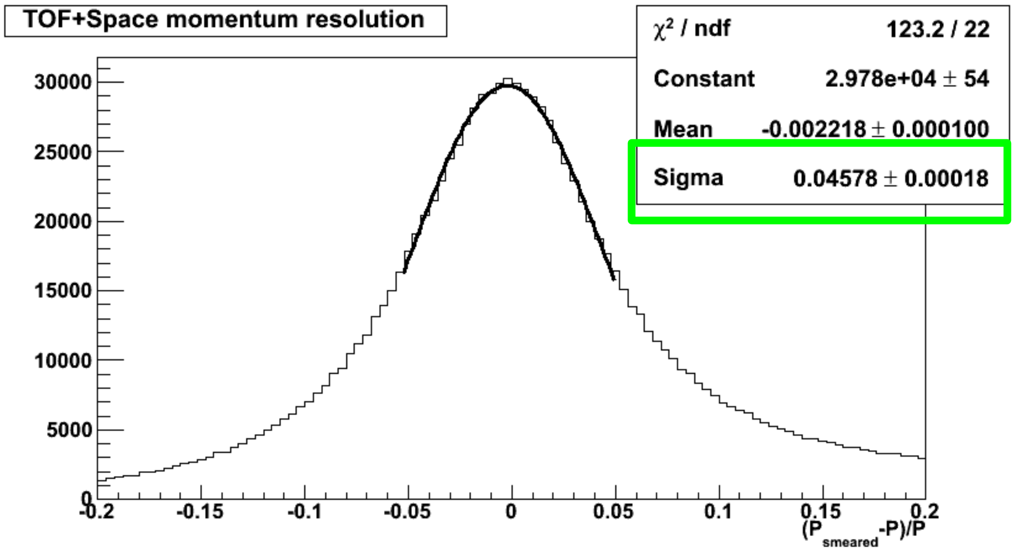
where σ_s = 3cm Ndet space resolution

R is radius of Ndet ring (155 cm)

$Y_{smeared} = \cos(\Phi_{smeared})$ R

$X_{smeared} = \sin(\Phi_{smeared})$ R





Sigma selection criteria

- Cut on neutron TOF: 20 ns (cut $\beta<0.3$ and reduce secondary neutrons from MPD detector components)
- Cut on pion vertex (distance from reaction vertex) > 0.1 cm to select decays

  $\Sigma^{+} \rightarrow n\pi+$(48%) $c\tau$ =2.404 cm

  $\Sigma^{-} \rightarrow n\pi-$ $c\tau$ =4.434 cm

  Background processes:

  $K^{0}_{S} \rightarrow \pi+\pi-$ $c\tau$ =2.68 cm

  $\Lambda^{0} \rightarrow p\pi-$ $c\tau$ =7.89cm

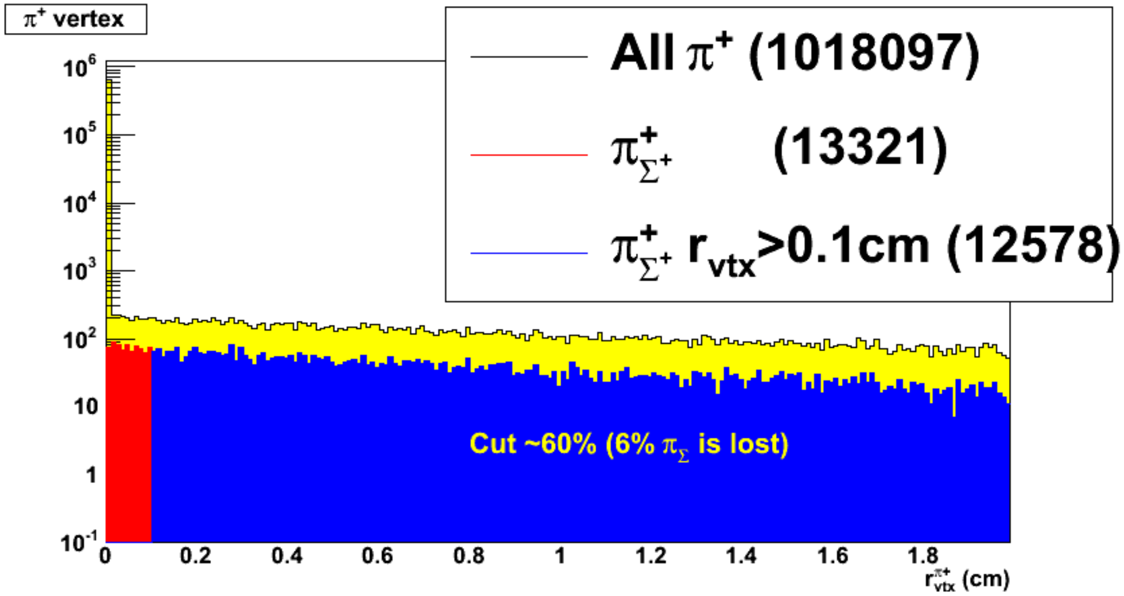
- Cut on vertex of reconstructed Σ, distance from collision point to Σ momentum line less than 0.1cm
- Cut on pion momentum > 0.15 GeV/c (reduce combinatorial BG)

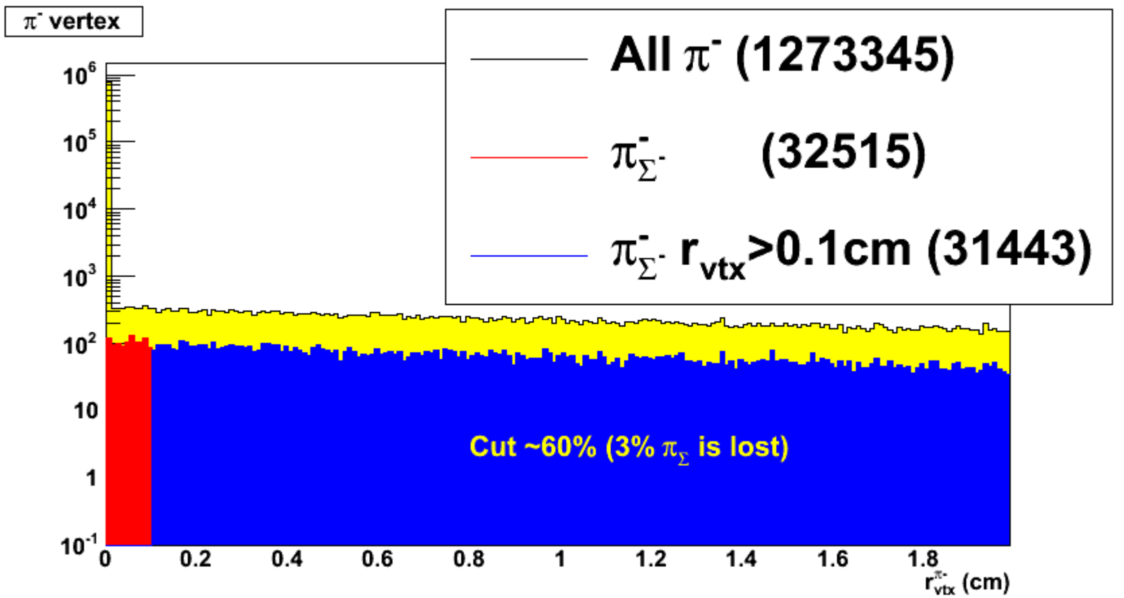
Pion Vertex cut

Most pions come from collision vertex

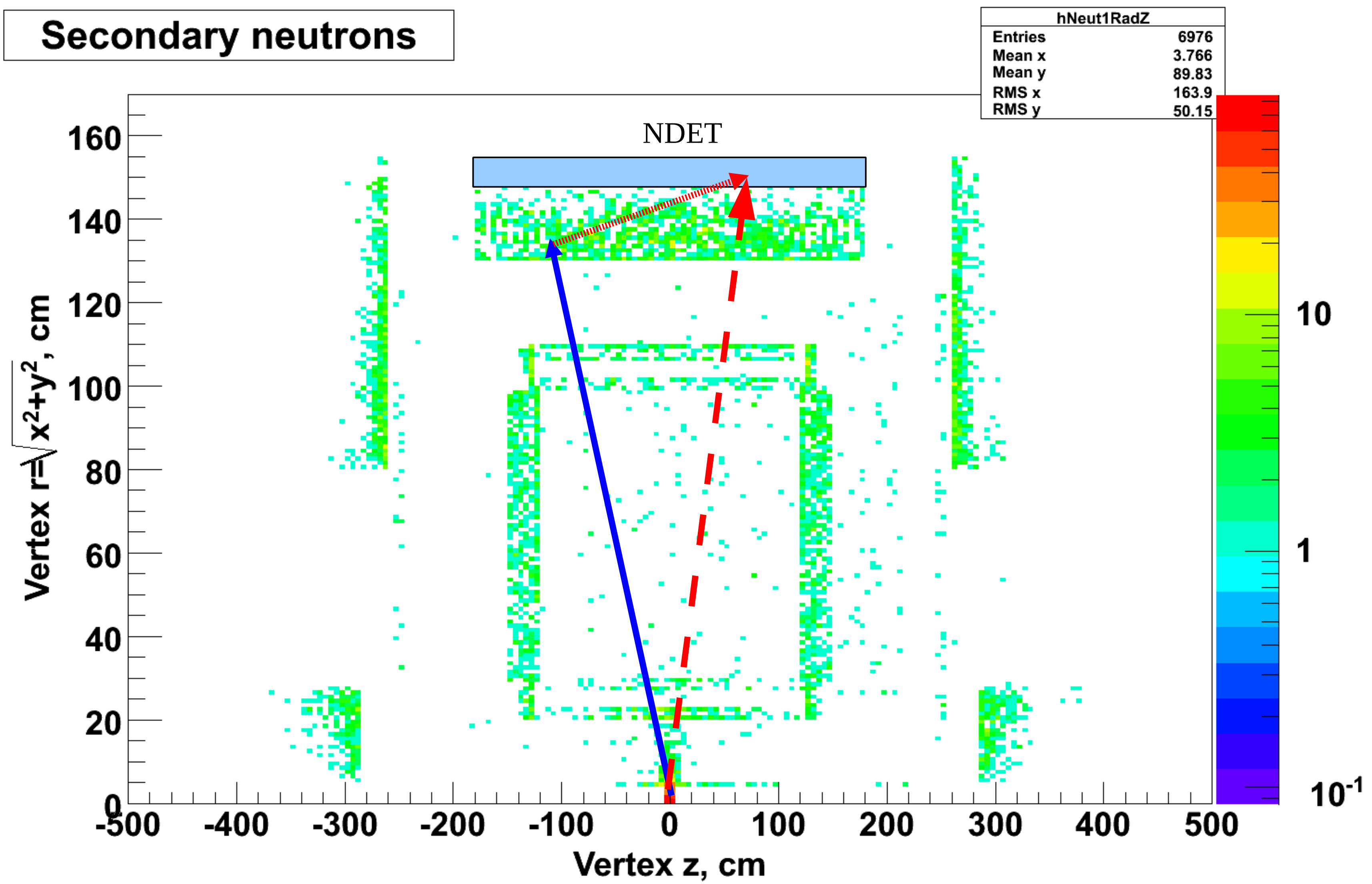
Cut on pion vertex > 0.1 cm

We cut about 60% of all pions and lost a few percents of pions from Sigma decay!



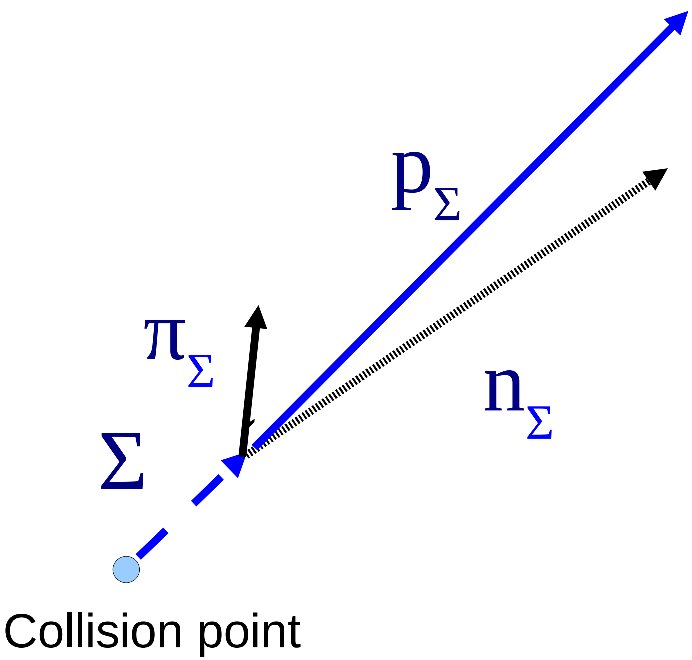


Fake neutrons

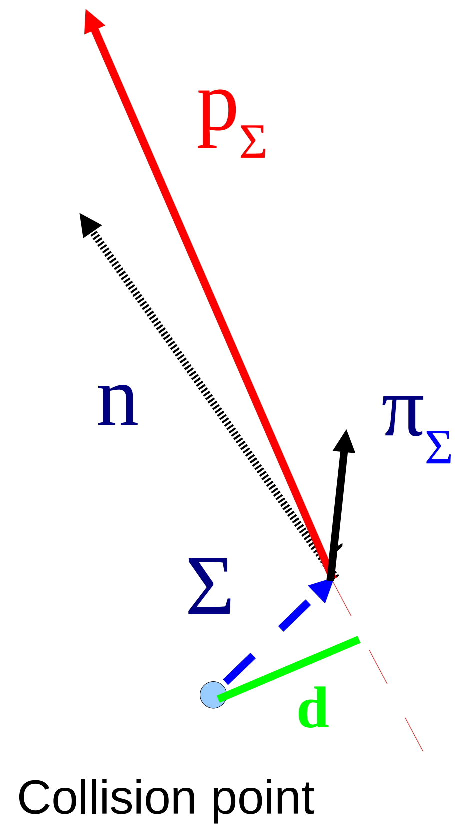


Vertex cut for Sigma

Real Σ comes from collision point (cp)

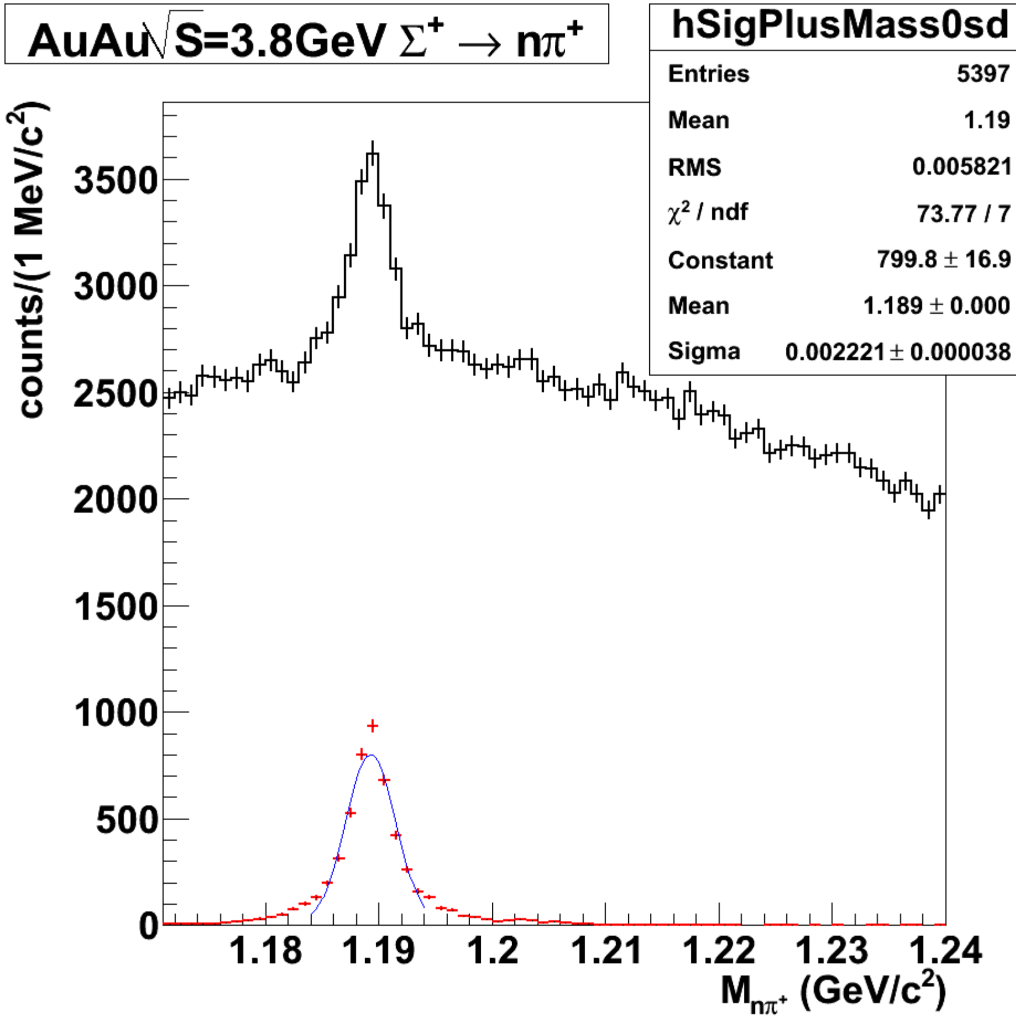


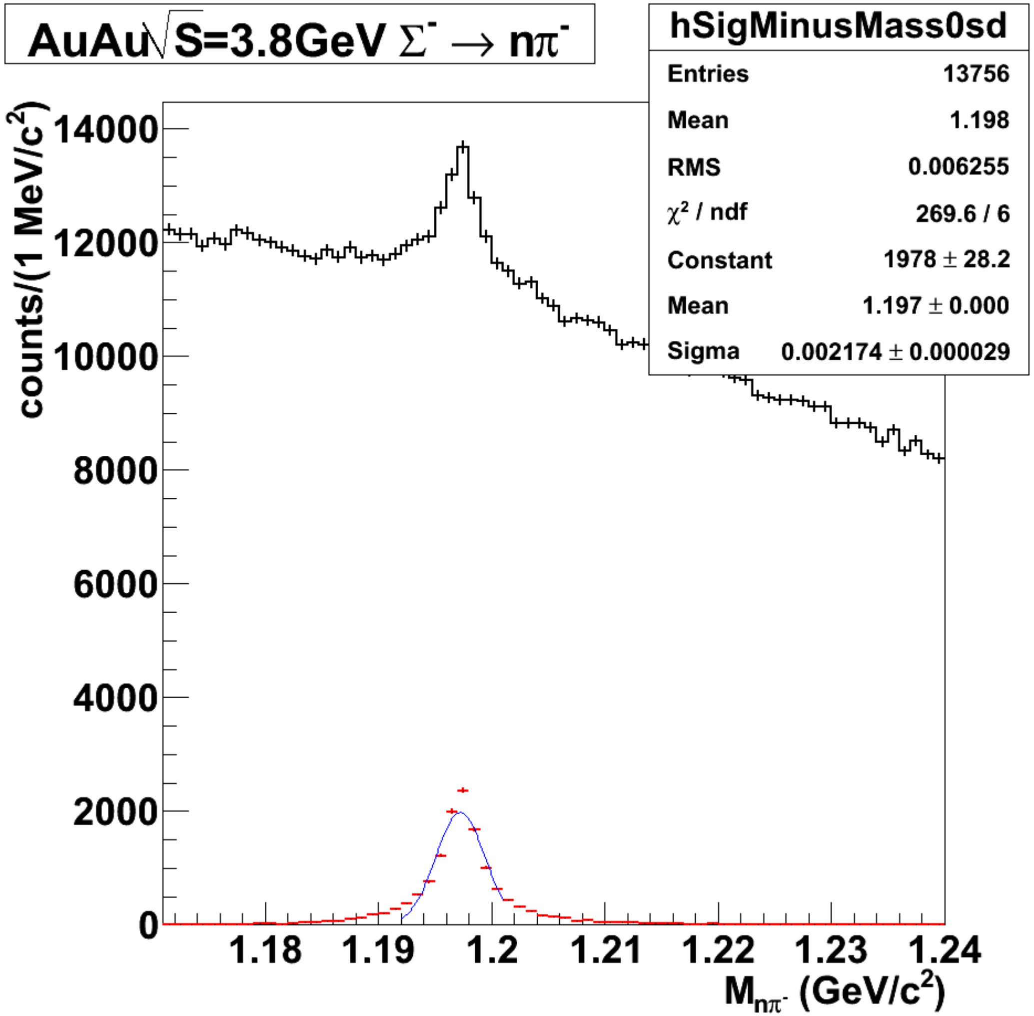
Fake Σ does NOT come from collision point (cp)
Cut on distance of closest approach (**d**)



Feasibility of Σ detection

10^4 AuAu central events at sqrt(S_{NN})=3.8 GeV





Conclusions

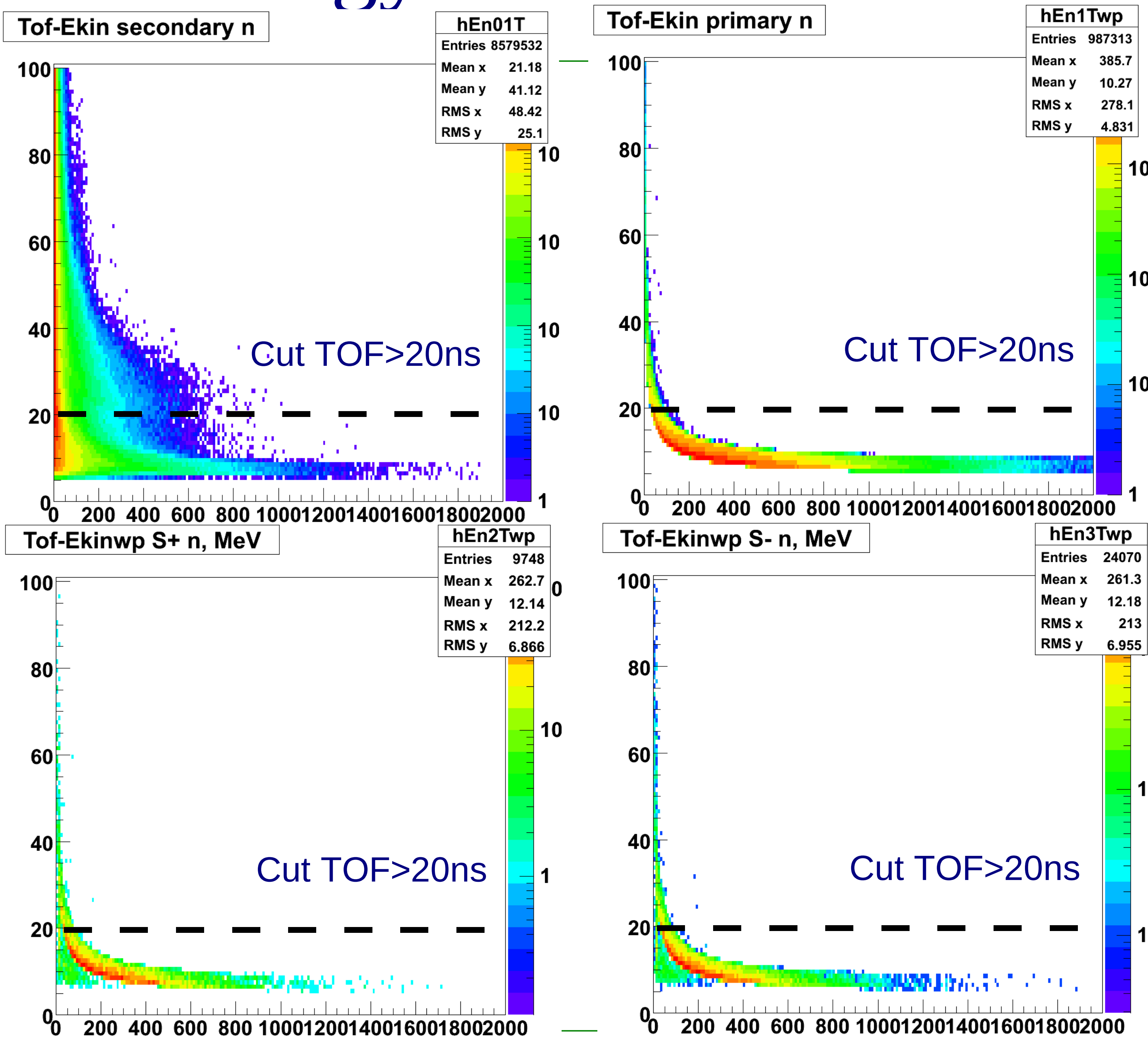
1. First beam tests of Ndet is started in ITEP
2. Space resolution is about 2.5 cm
3. Ndet is in MPD ROOT
4. Preliminary estimation of Ndet efficiency with GEANT3 is done
5. First study of Sigma (+ and -) response in MDP is done

Next Steps

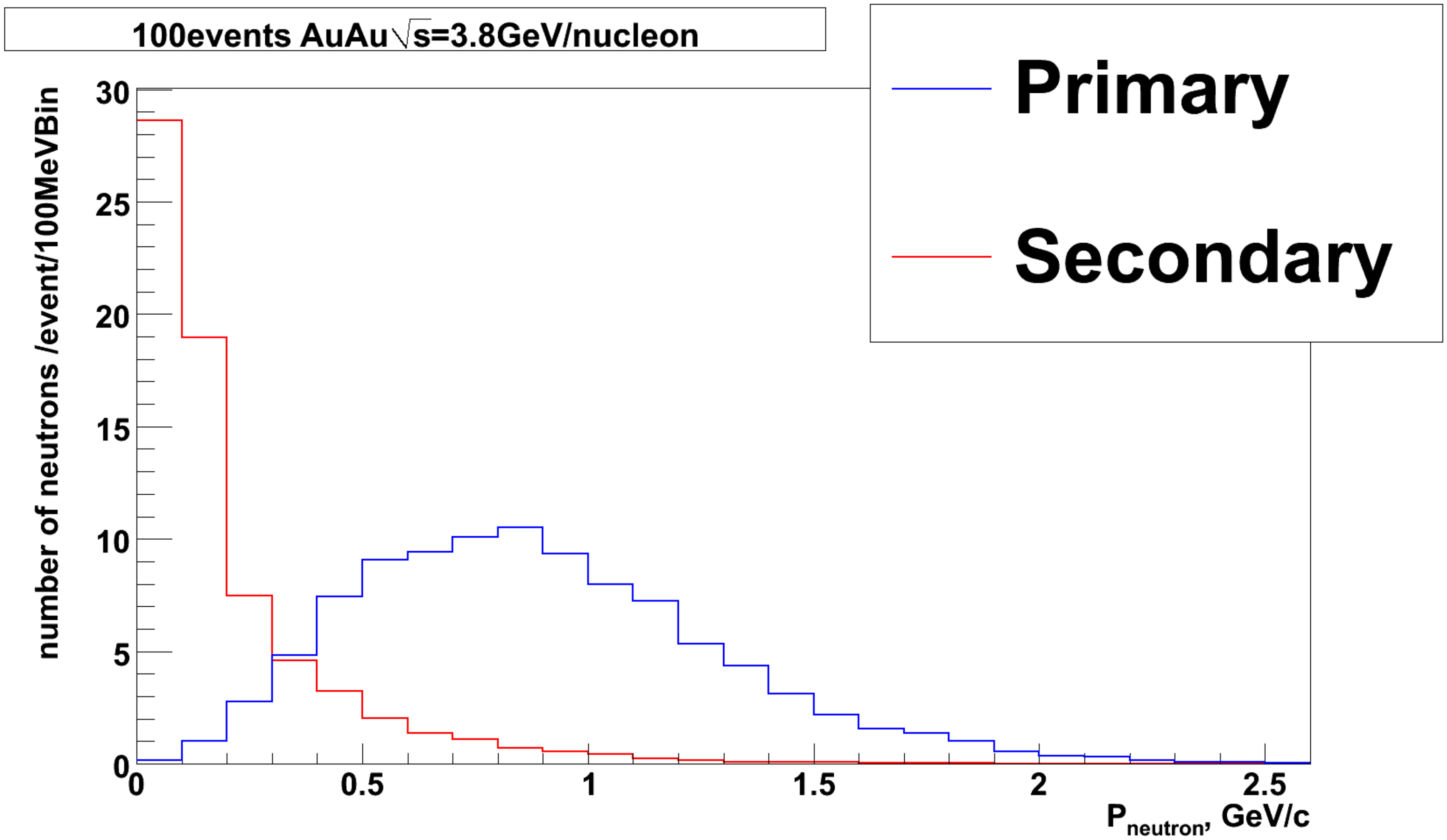
1. Continue study of prototype:
   a) Beam tests (we have a run right now)
   b) Study of time resolution of Ndet
   b) Configuration of prototype
2. Continue simulations of Ndet in framework of MPD root
   a) More realistic simulations of sigma signal with tracking of charge particles
   b) Cross-talk, diaphony study
   c) Study of antineutron reconstruction
   d) Efficiency simulation with Geant4

Extra

Energy-TOF neutrons



Primary and secondary momentum



$|\eta|<1$, $\Sigma \rightarrow n\pi$

<En> ~ 250 MeV (730MeV/c β~0.6)

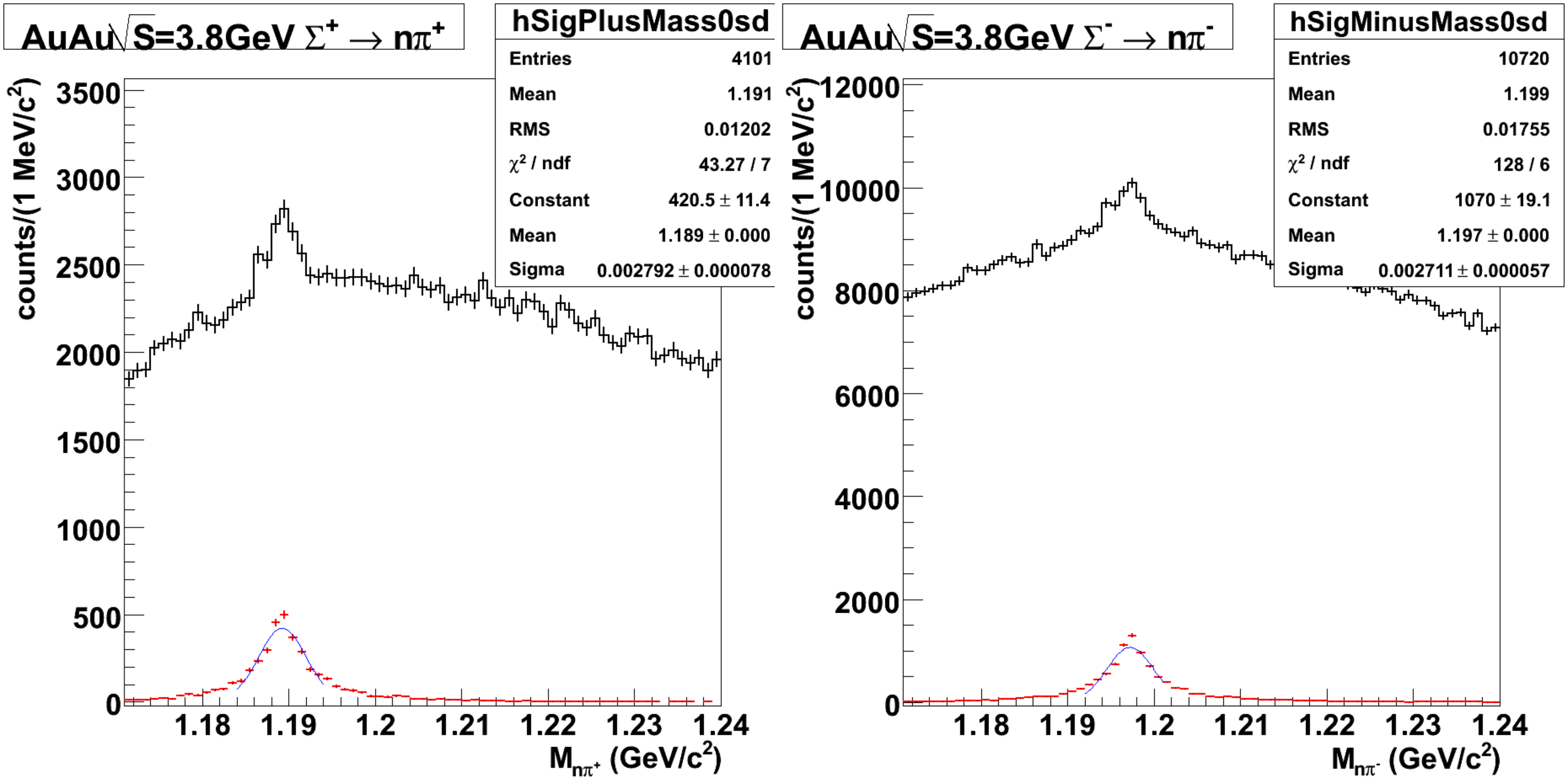
<Pπ> ~ 230 MeV/c

$<P_{\Sigma}>$ ~ 800 MeV/c

Σ detection (800 psec)

10^4 AuAu central events at sqrt(S_{NN})=3.8 GeV

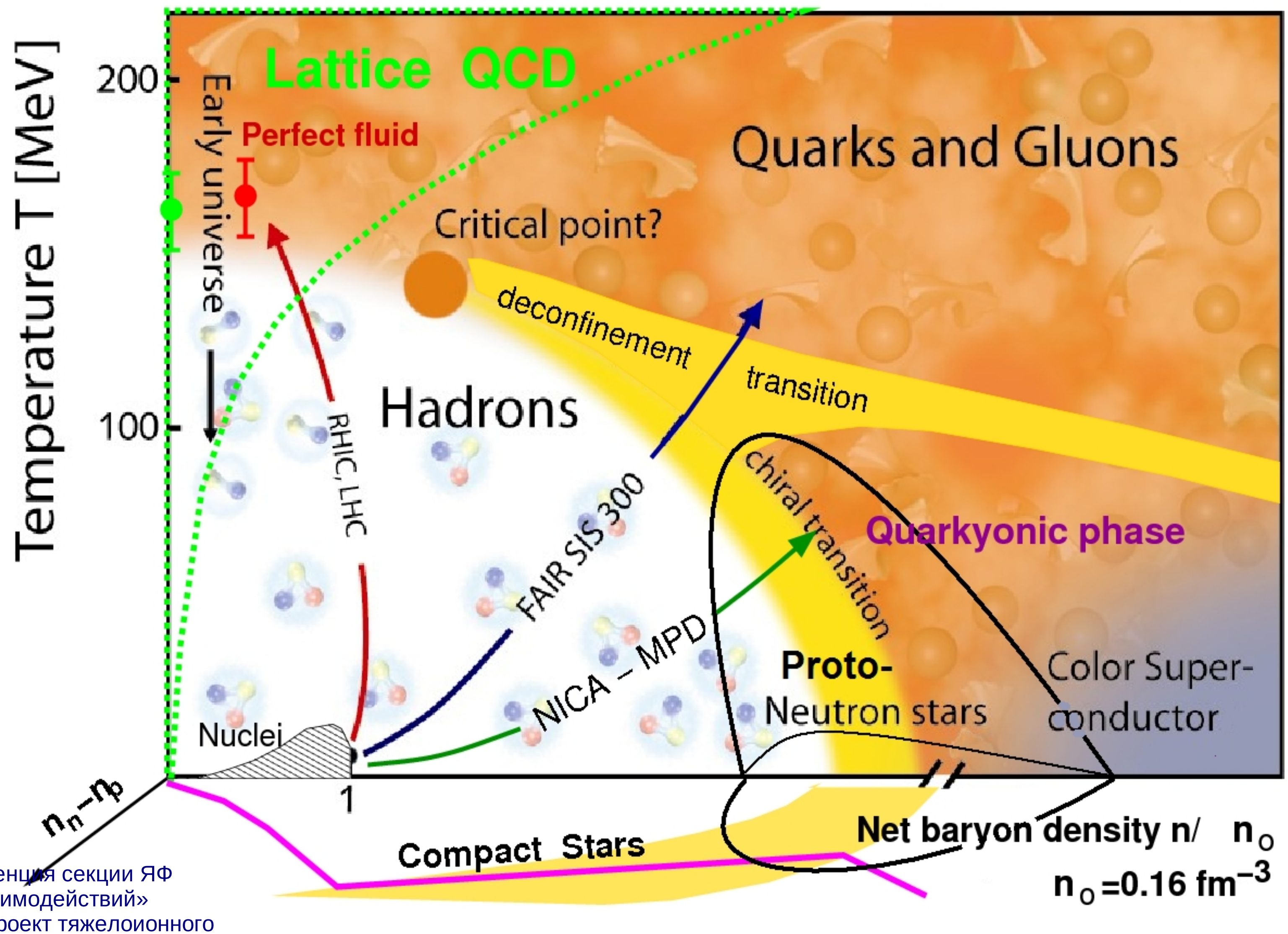
Time of flight resolution 800 psec



Средняя множественность для центральных Au+Au событий (прицельный параметр b < 3 фм) вычисленная по URQMD

Part.	4 GeV		7 GeV		11 GeV	
	4π	$\lvert\eta\rvert < 1$, $p > 100$ MeV/c	4π	$\lvert\eta\rvert < 1$, $p > 100$ MeV/c	4π	$\lvert\eta\rvert < 1$, $p > 100$ MeV/c
charged	430	250	870	430	1300	550
p	170	91	160	63	160	49
n	200	110	180	68	170	53
π^+	110	65	310	160	470	230
π^-	120	78	340	170	520	240
π^0	120	72	340	180	510	240
K^+	12	7.6	38	19	57	24
K^-	1.3	0.82	12	6.2	26	12
K^0	12	7.7	38	19	57	26
Λ	10	6.2	26	12	31	12
Σ^+	3.4	2.1	8.0	3.7	9.2	3.6
Σ^-	4.0	2.4	8.8	4.0	10	3.8
Σ^0	3.2	1.9	7.9	3.6	9.4	3.8
Ξ^-	0.16	0.11	0.87	0.42	1.7	0.66
Ξ^0	0.13	0.077	0.86	0.42	1.3	0.62
Ω^-	0.003	0.002	0.022	0.011	0.038	0.015

3d phase diagram



ИТЭФ, г. Москва, научная сессия-конференция секции ЯФ ОФН РАН «Физика фундаментальных взаимодействий»
А.Н.Сисакян (ОИЯИ) NICA - российский проект тяжелоионного коллайдера

Эксперимент E286

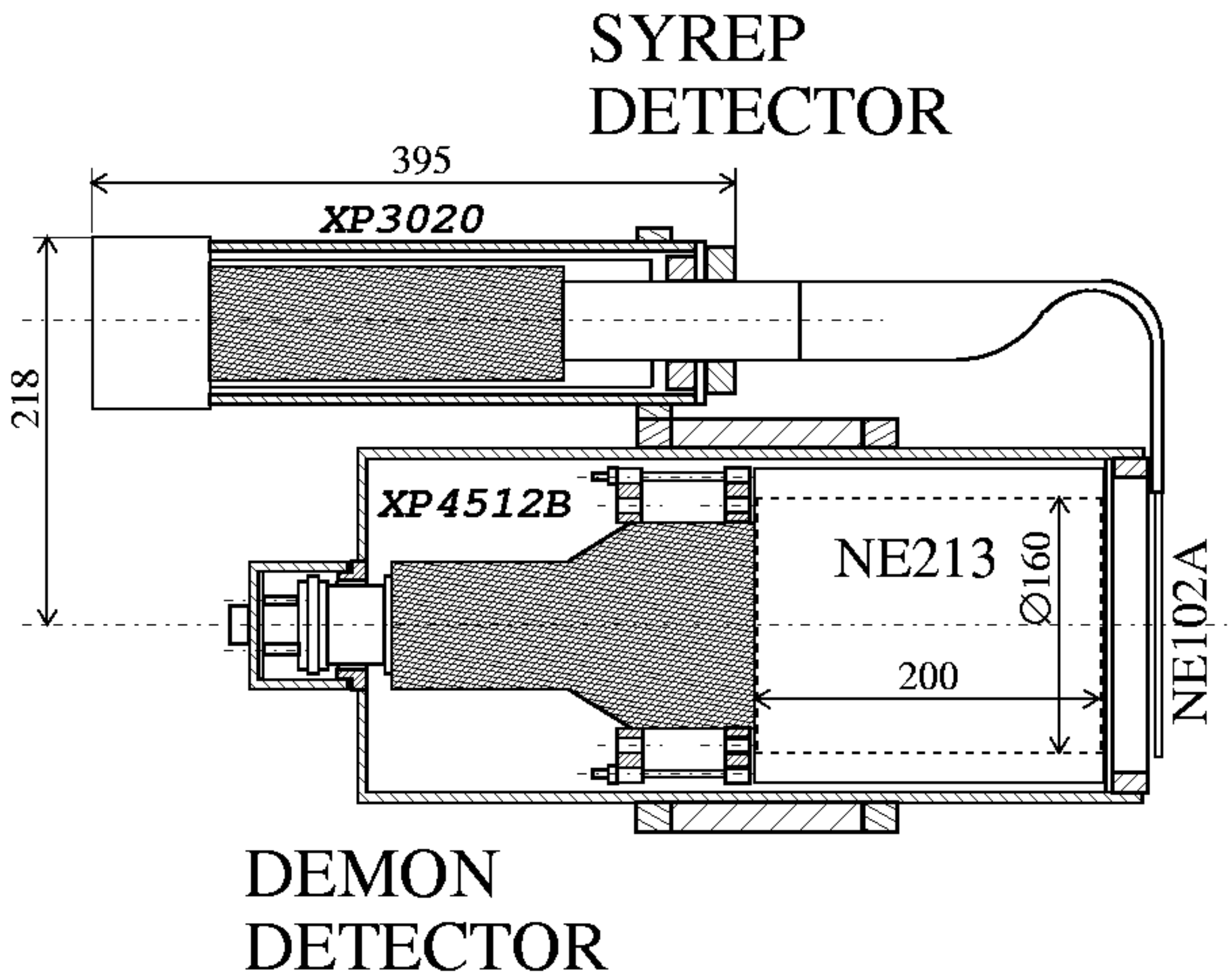
^{40}Ar (77 МэВ/нуклон) + $^{58}Ni \rightarrow$ n, p, d, T, ^{3}He, ^{4}He + X

“Data on light-fragment correlations in $^{40}Ar+^{58}Ni$ at 77MeV/nucleon”
Eur. Phys. J. A18 (2003) p.645-651. Коллаборация E286.

K.Mikhailov[1], A. Stavinskiy[1], J.C.Angelique[2], B.Benoit[3], E. de Goes Brennand[3], G.Bizard[2], J.Colin[2], G.Costa[4], P.Desesquelles[5], O.Dorvaux[4], D.Durand[2], B.Erazmus[6], Yu.Grishuk[1], F.Hanappe[3], A.Kieliszek[7], S.Kuleshov[1], C.Lebrun[6], R.Lednicky[8], G.Leksin[1], P.Leszczynski[7], M.Marques[2], Th.Materna[3], K.Miller[7], G.Papatheofanous[3], T.Pawlak[7], J.Pluta[7], M.Przewlocki[7], A.Staranowicz[7], L.Stuttge[4], B.Tamain[2], A.Vlasov[1], L.Vorobyev[1], K.Wosinska[7]

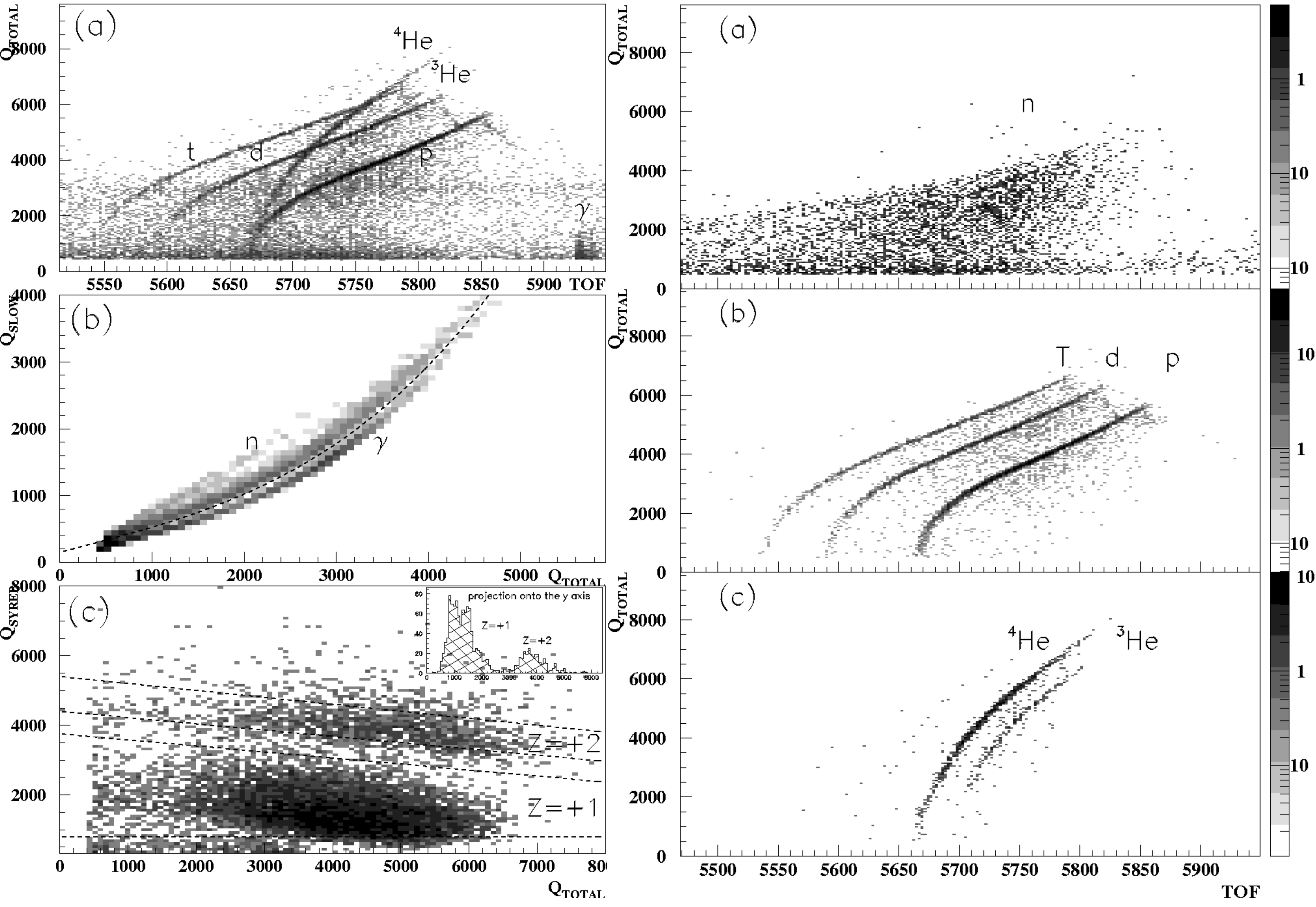
[1]Institute of Theoretical and Experimental Physics
[2]Laboratoire de Physique Corpusculaire,IN2P3,CNRS/ISMRA
[3]Universite Libre de Bruxelles,Belgium
[4]IRES,IN2P3-CNRS/Universite Louis Pasteur,France
[5]ISN,IN2P3/CNRS, et Univ.J.Fourier,France
[6]SUBATECH,UMR Univ.,EMN,IN2P3/CNRS, France
[7]Faculty of Physics,Warsaw University of Technology, Poland
[8]Institute of Physics ASCR, Czech Republic

Схема одного модуля установки DEMON (вид сбоку)

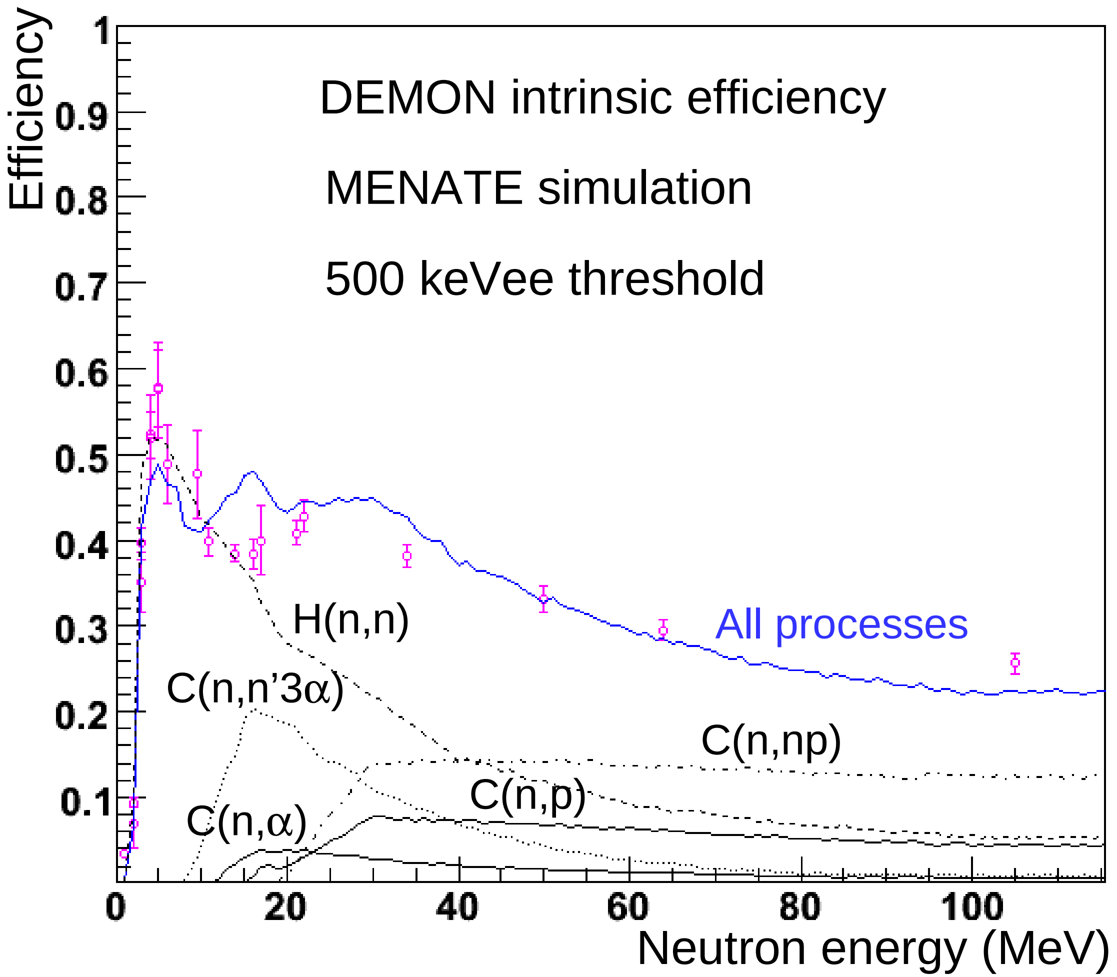


Детектор DEMON совместно с детектором SYPEP

E286 experiment: particle identification



DEMON efficiency with Menate



Reactions :
- H(n,n)
- 12C(n,n)
- 12C(n,n'γ)
- 12C(n,2n)
- 12C(n,α)
- 12C(n,n'3α)
- 12C(n,p)
- 12C(n,np)

Simple
Reasonably accurate
Only cylindrical detectors with NE213 scintillator

P. Désesquelles et al, NIM A 307, 366 (1991)

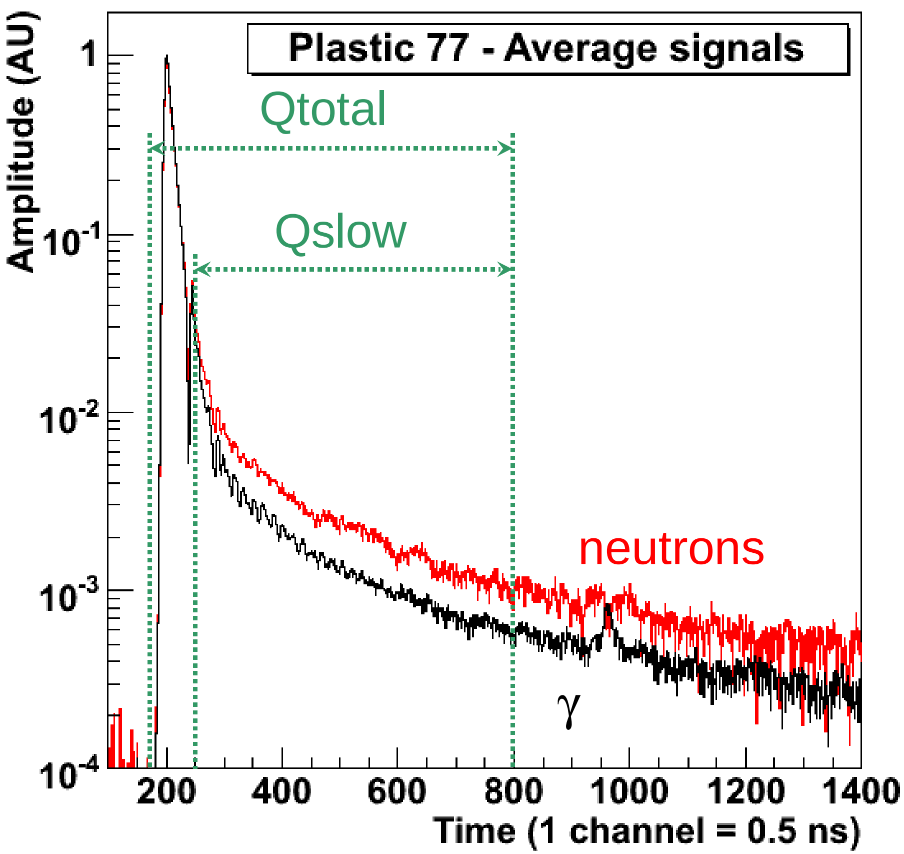
From presentation : « Neutron detector developments at LPC Caen »

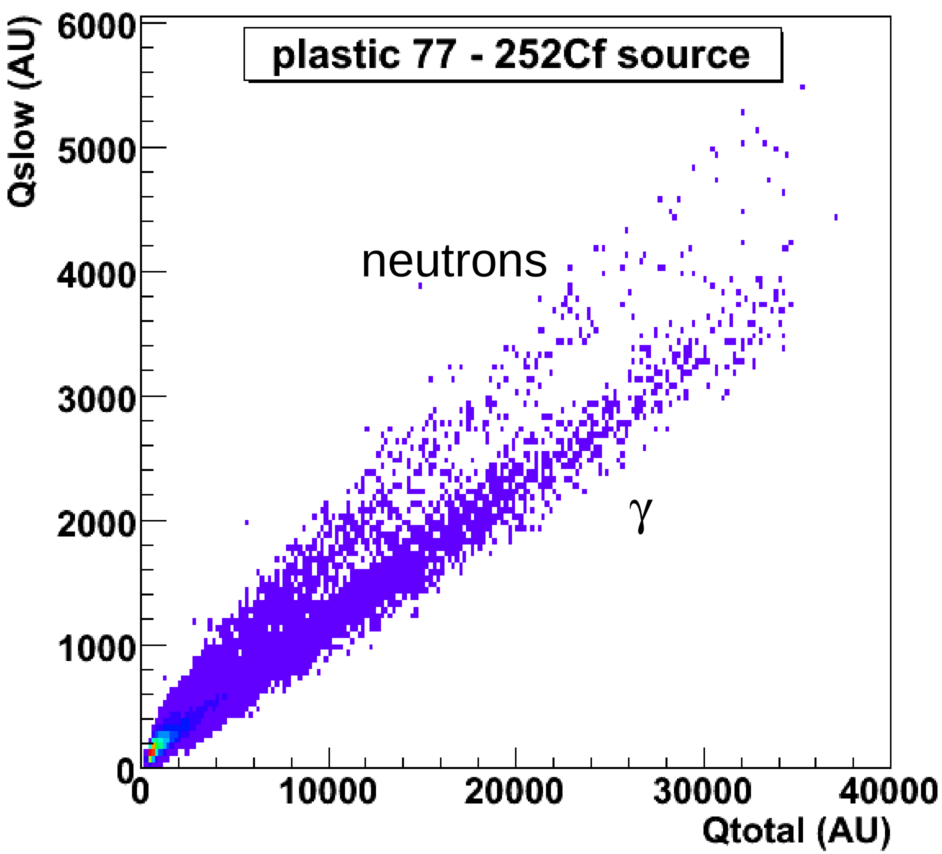
Discriminating plastic

« plastic 77 », Brooks et al, IRE Trans. Nucl. Sci., NS-7, 35 (1960)

No exotic compounds (similarities with NE213)
Light output ~ BC400
Clean synthesis process (CEA Saclay)

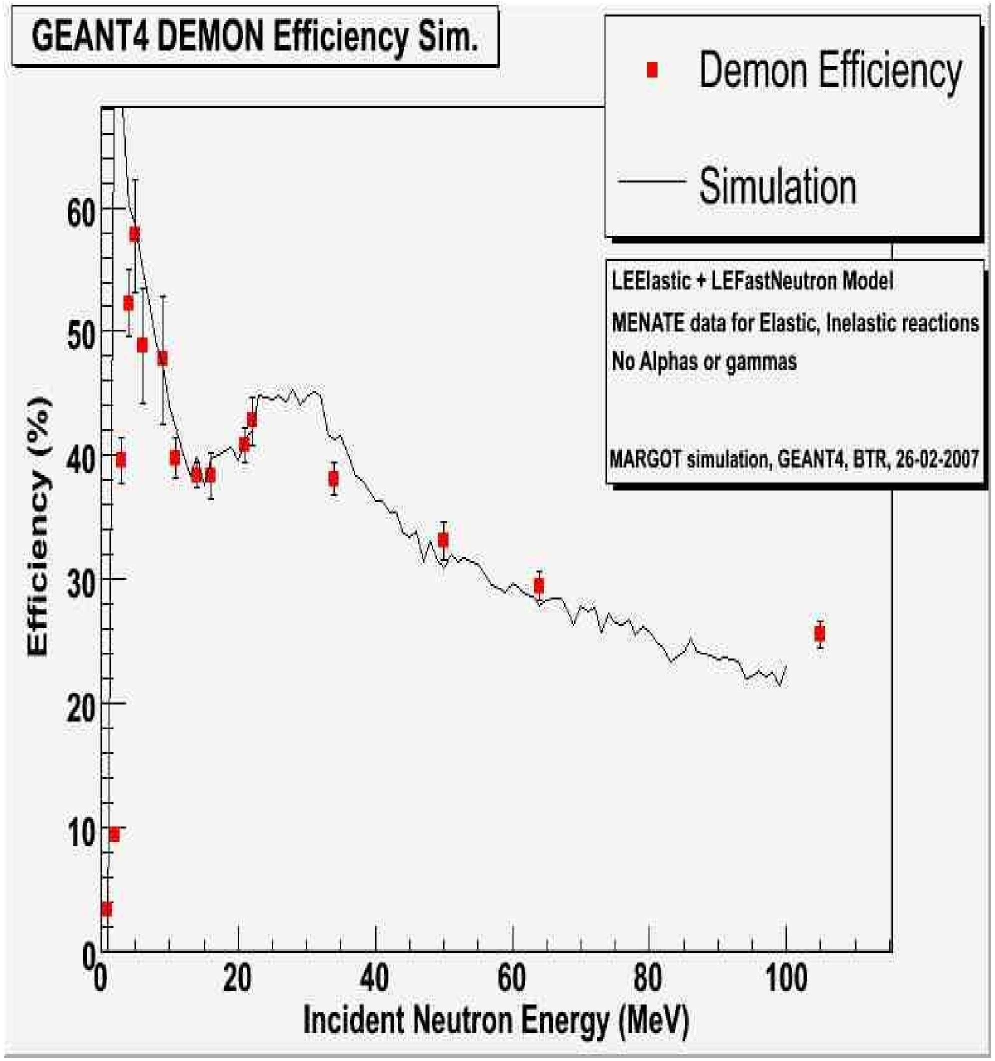
Test at LPC with digital ADC : 2 GHz, 12 bits, 2500 samples (1.25 μs), low rate

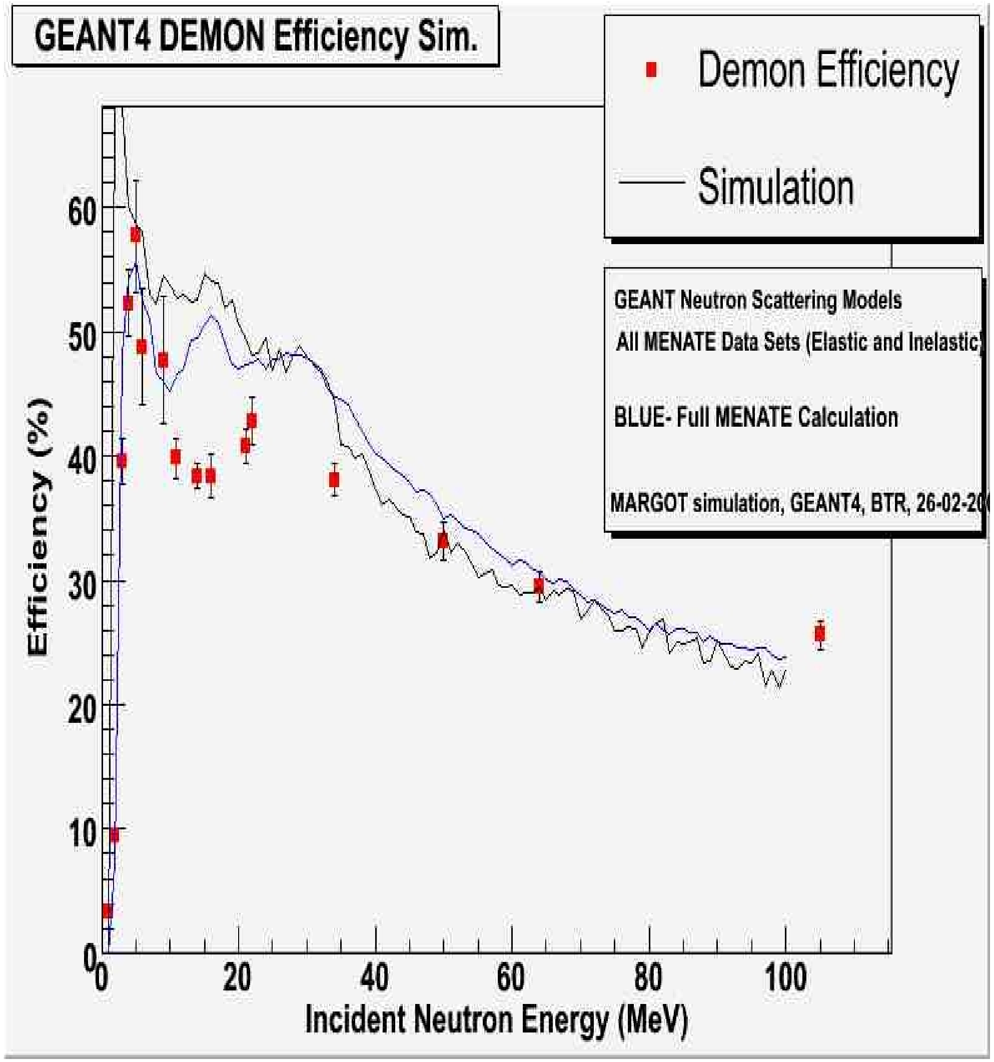




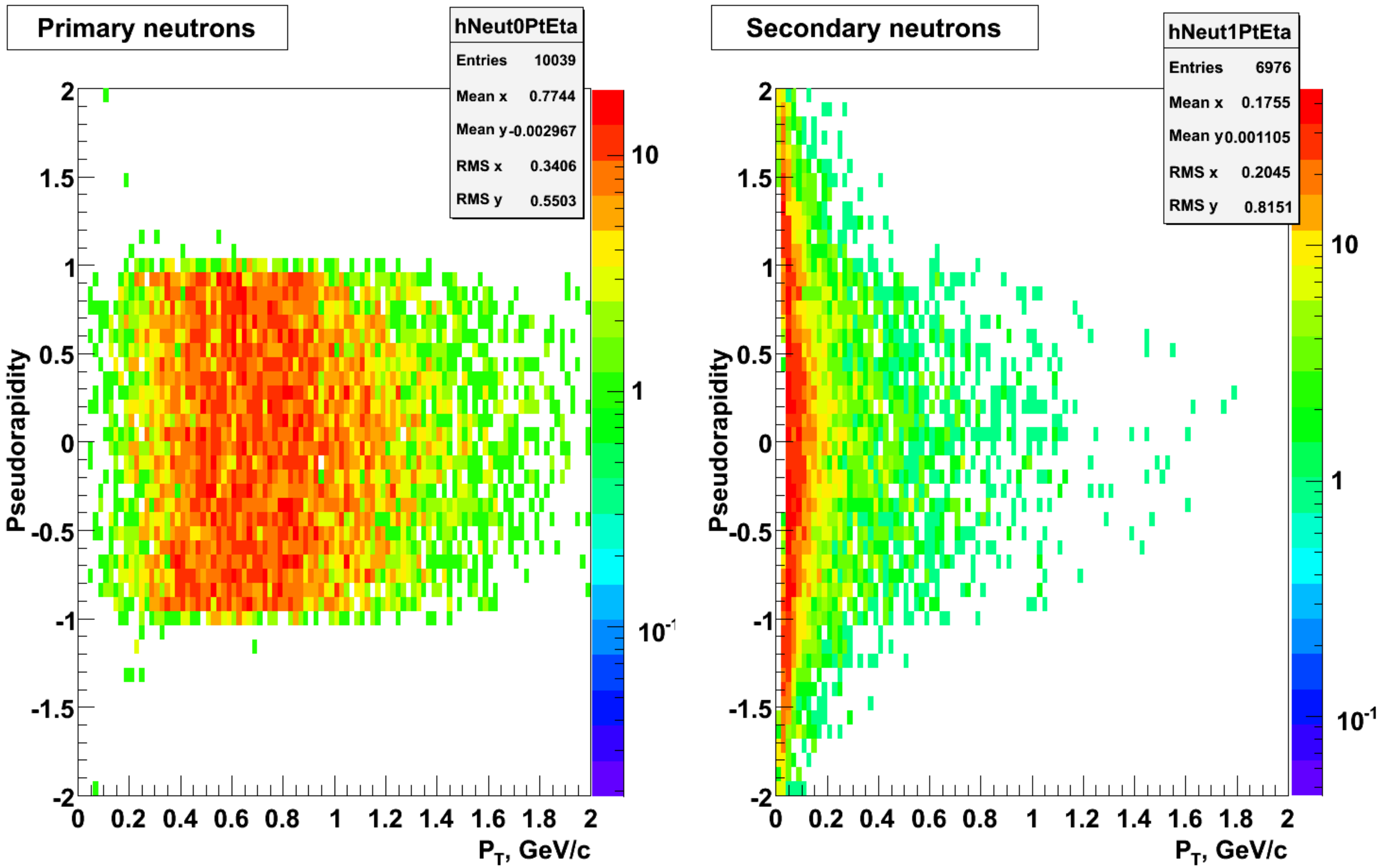
From presentation : « Neutron detector developments at LPC Caen »

Results of LEFastNeutron model

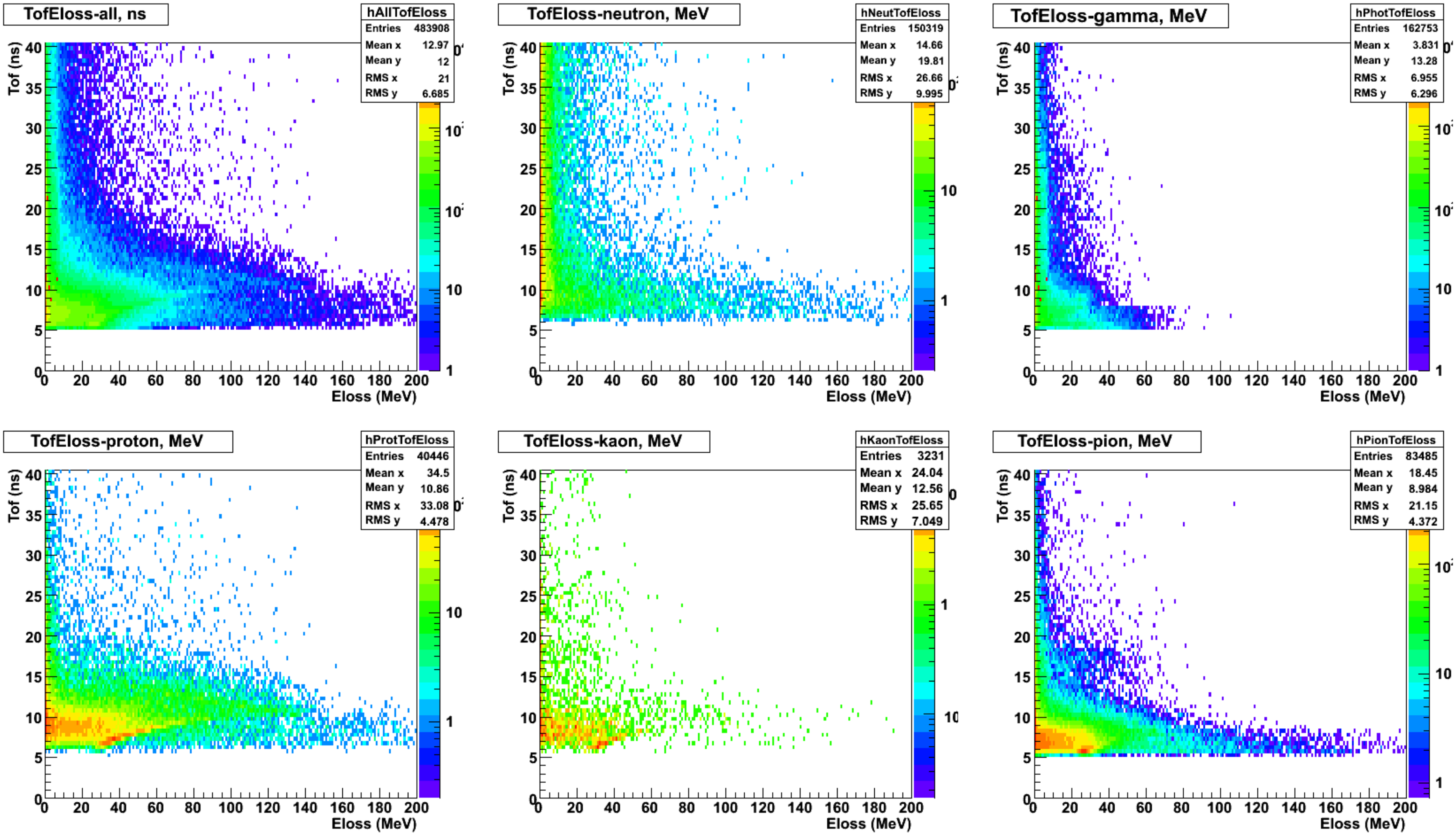




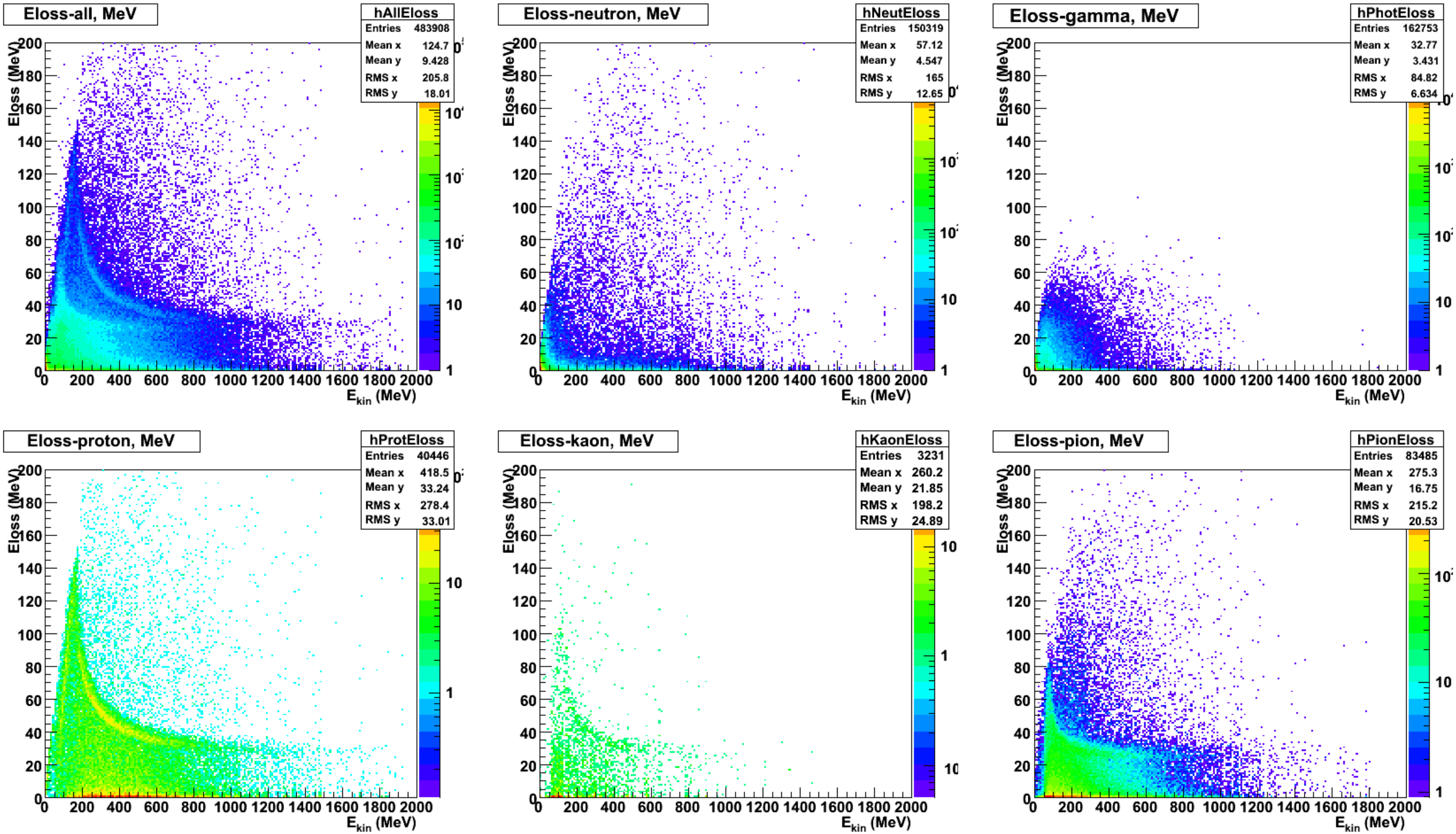
Neutron detector: eta-Pt



TOF-Eloss(prim&seco part.)



Energy Loss(prim&seco part.)



TOF(prim&seco part.)