Detector For Spin-Filtering Experiments.
Optimization and performance.

Gogi Macharashvili,
Ferrara, May 31, 2007

The goals of simulation:

Detector has to be optimized to detect scattered particles in the energy range $40 < T_p < 250$ MeV;

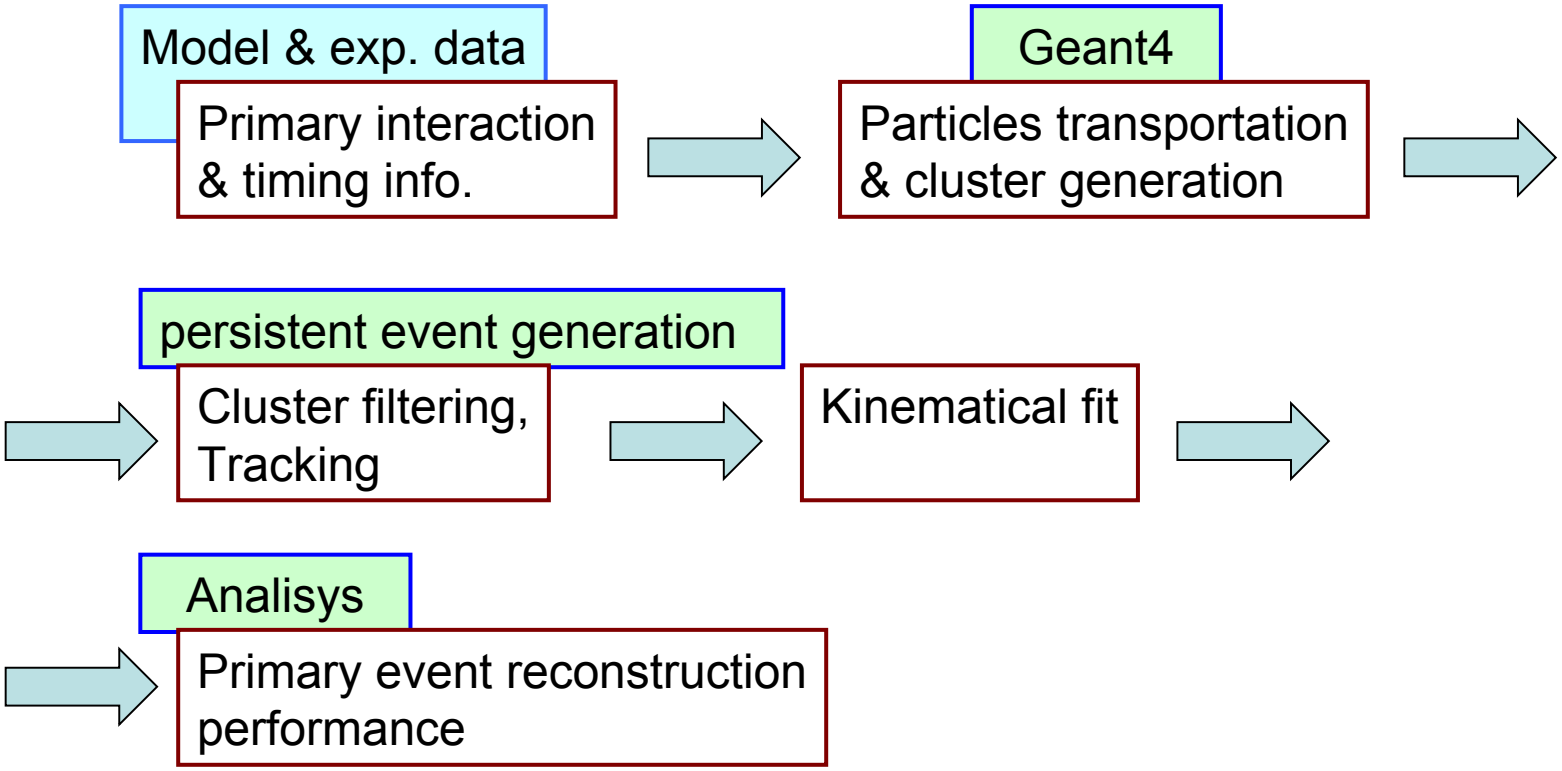
Acceptance and rate have to be estimated/maximized;

Parameters measurement uncertainties estimate;

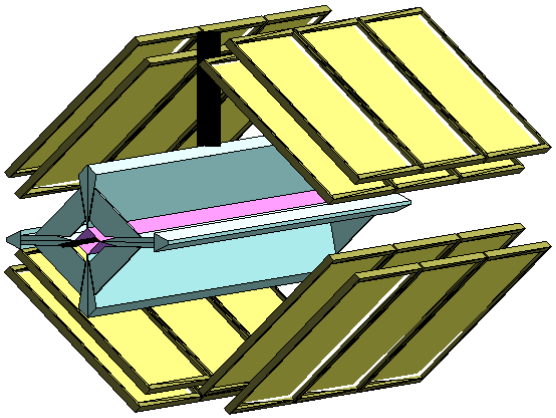
Reliable particle identification and suppression of background;

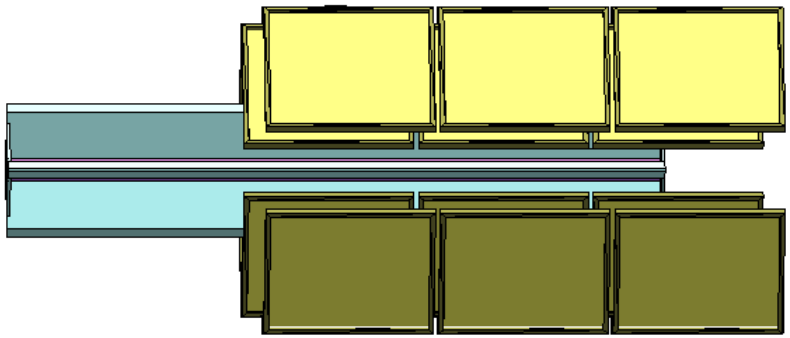
Raconstruction/analysis software development;

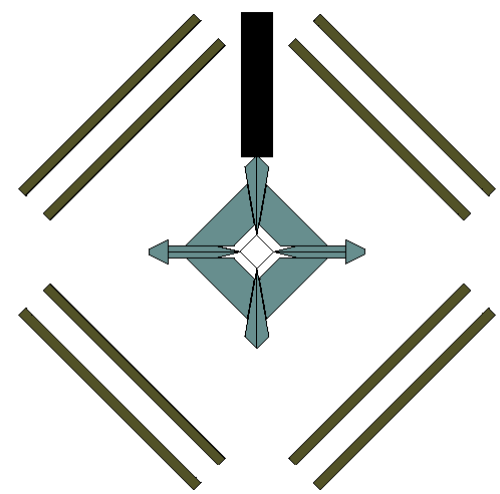
Simulation procedure



Detector. HERMES version

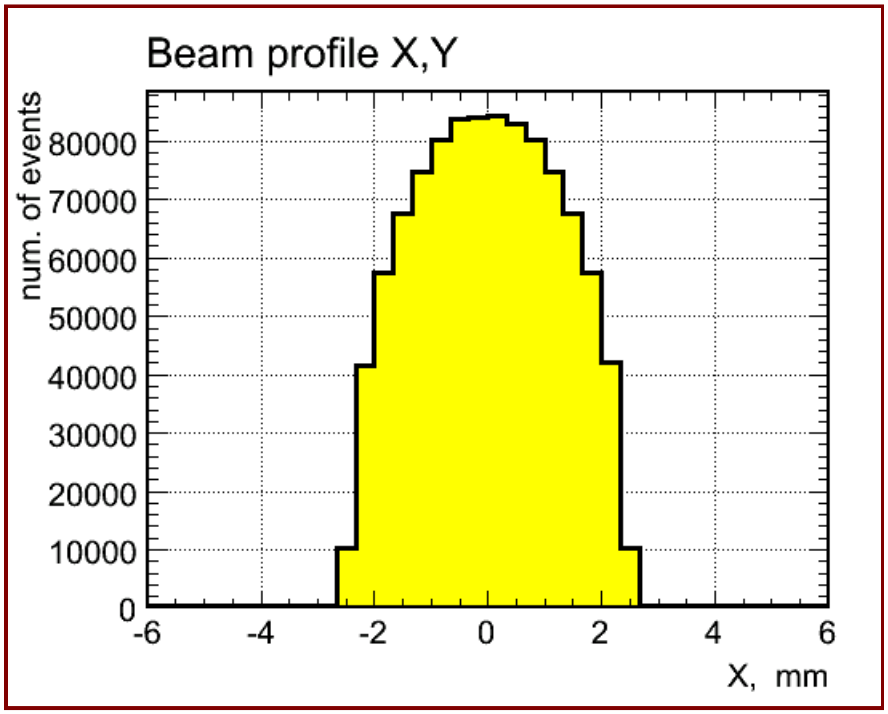


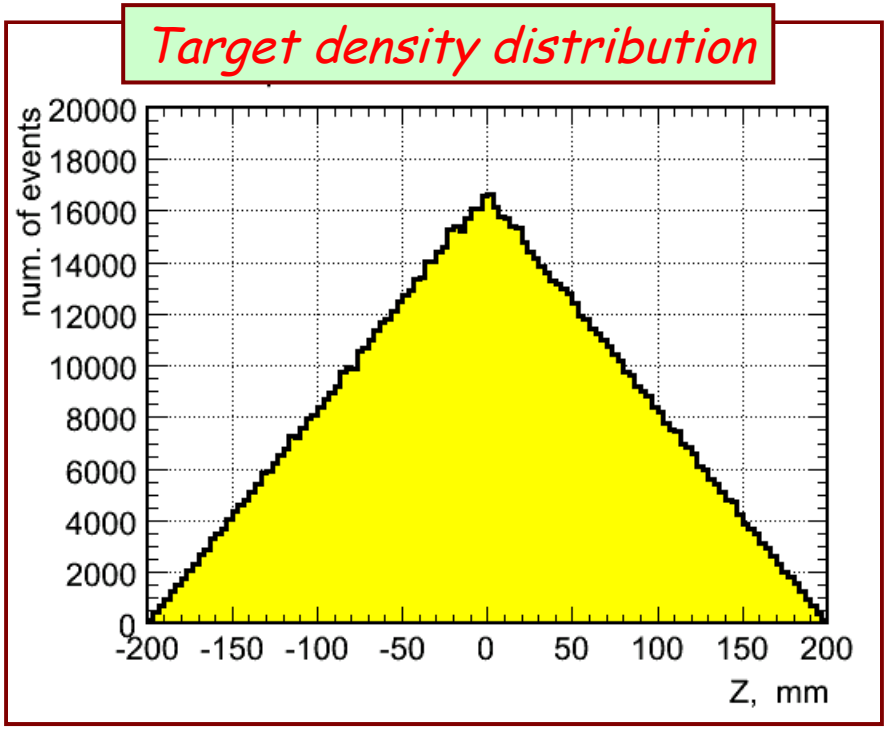




module active area:	97.3 x 97.3 mm^2
thickness:	300 μm
distance to beam axis	
layer 0:	72 mm
layer 1:	87 mm
strip pitch:	0.758x, 0.758y mm

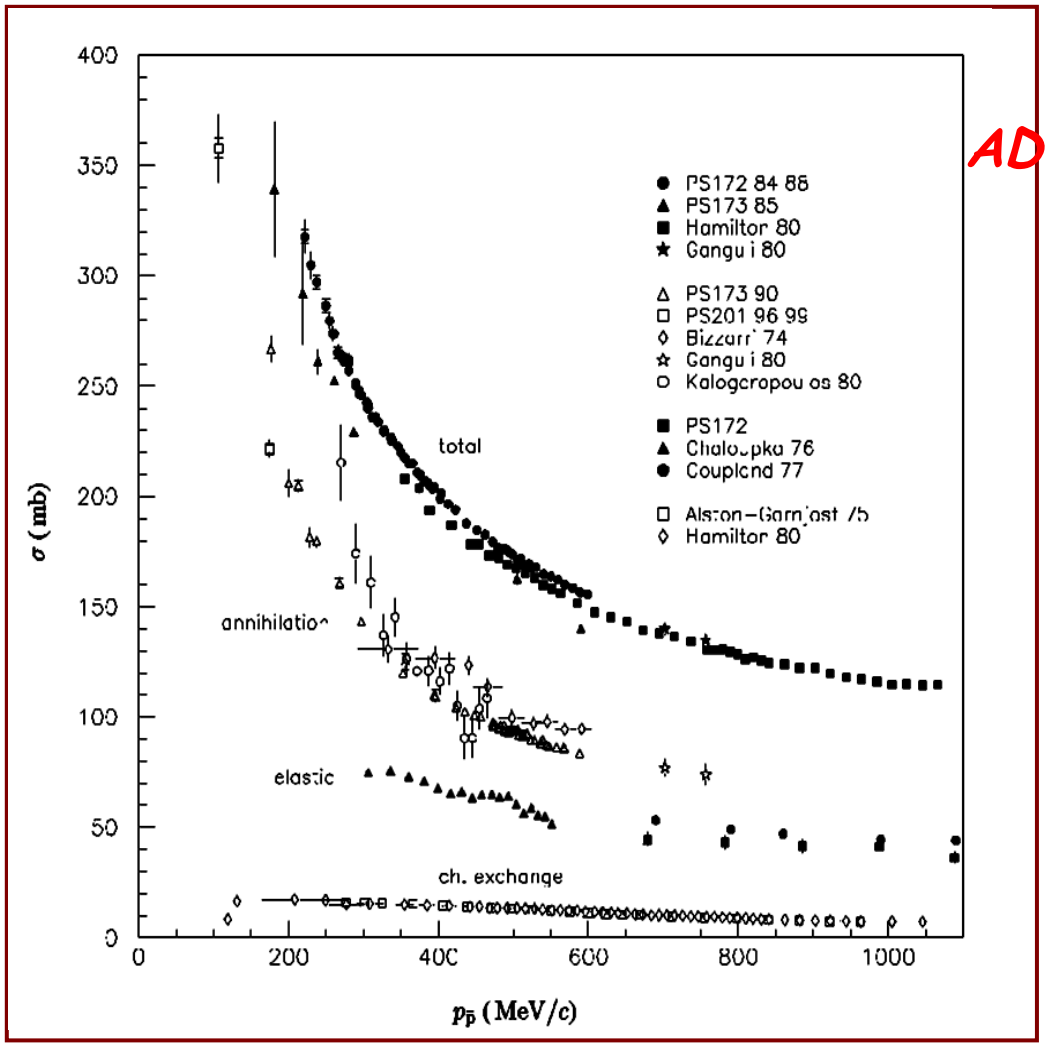
Vertex generation





Vertex distribution is the same for all energies

Total cross-section



AD luminosity: 10^{27} cm^{-2} sec-1

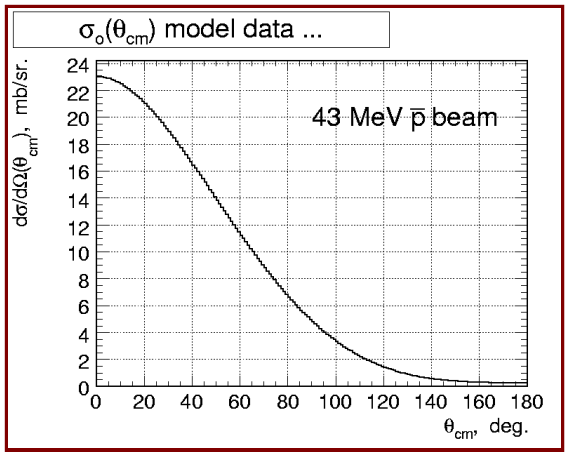
Klempt et al, Phys. Rep, 368, 119, 2002

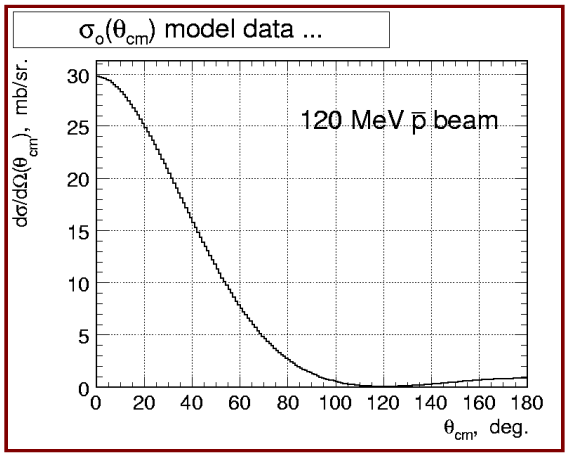
Total cross-section

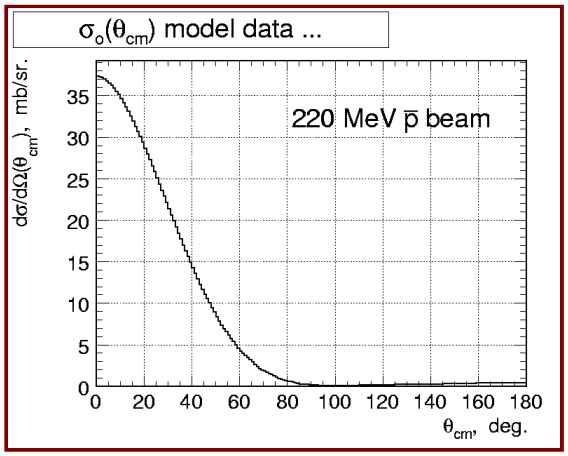
Primary antiproton-proton interaction profile

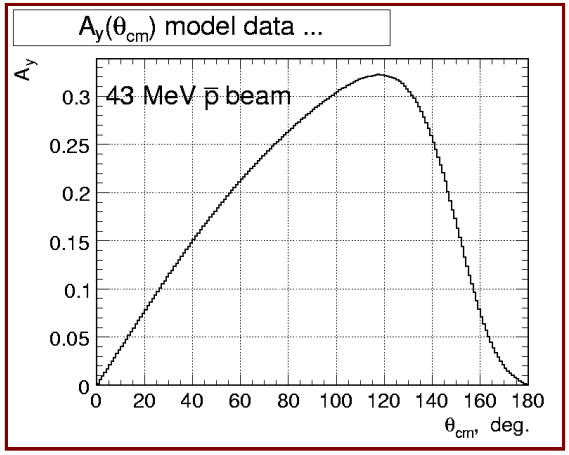
beam energy	MeV	43	120	220
momentum	MeV/c	286	491	679
σ_{tot}	mb	250	175	145
elastic	%	33	33	33
inelastic	%	60	60	60
charge-exchange	%	7	7	7

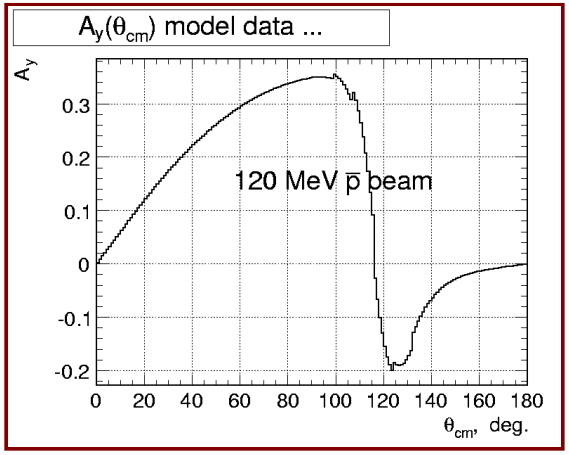
Antiproton-proton elastic cross-sections

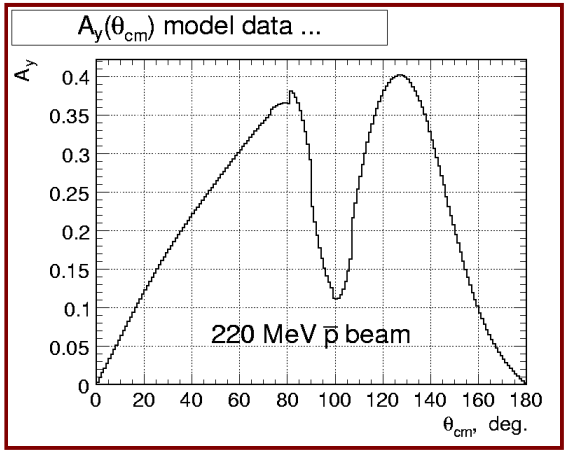






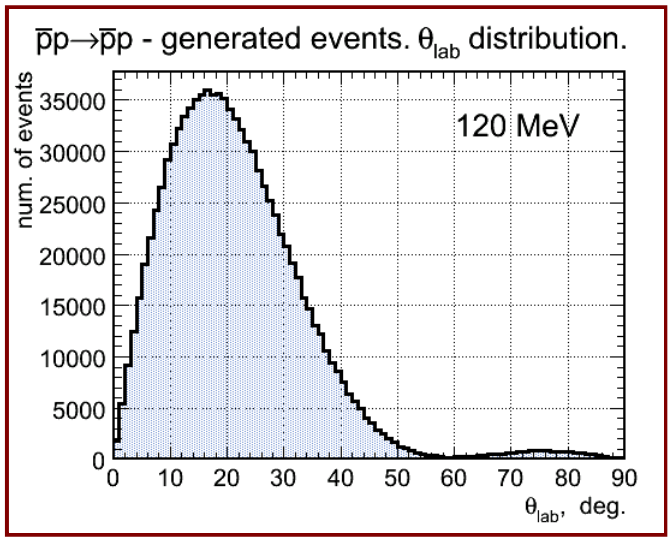


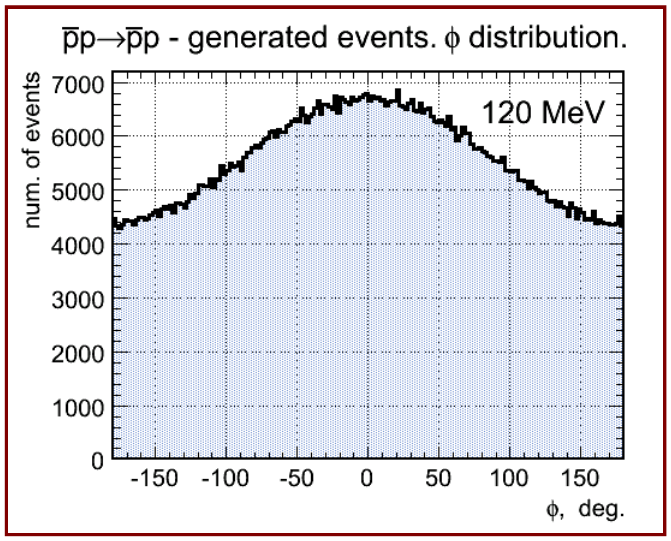




Model

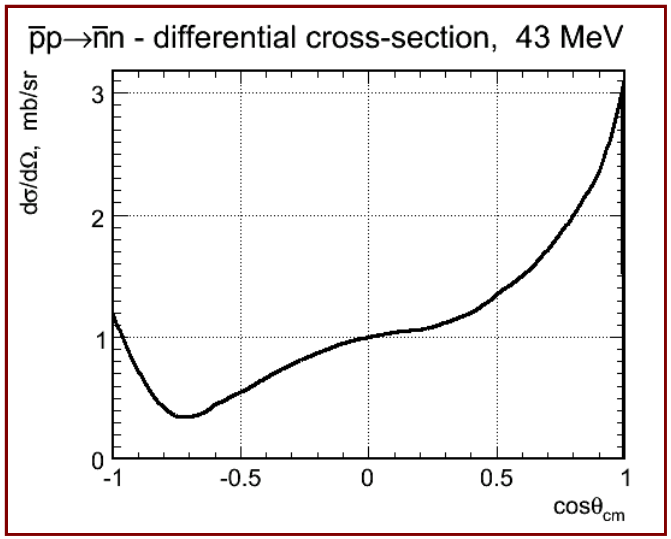
Antiproton-proton elastic cross-sections

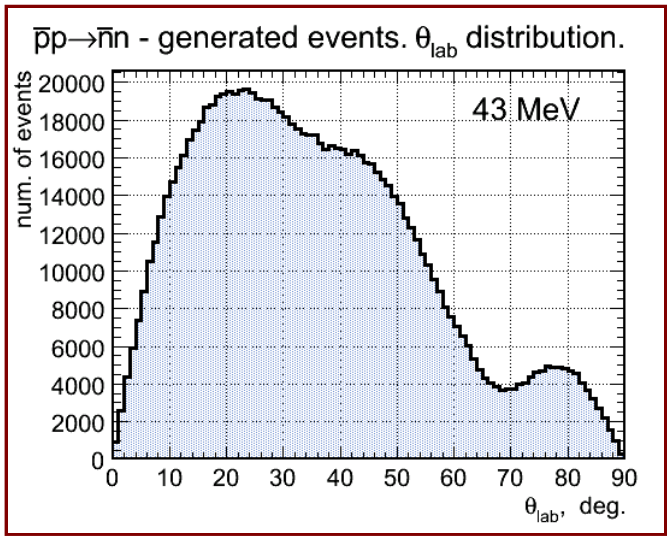




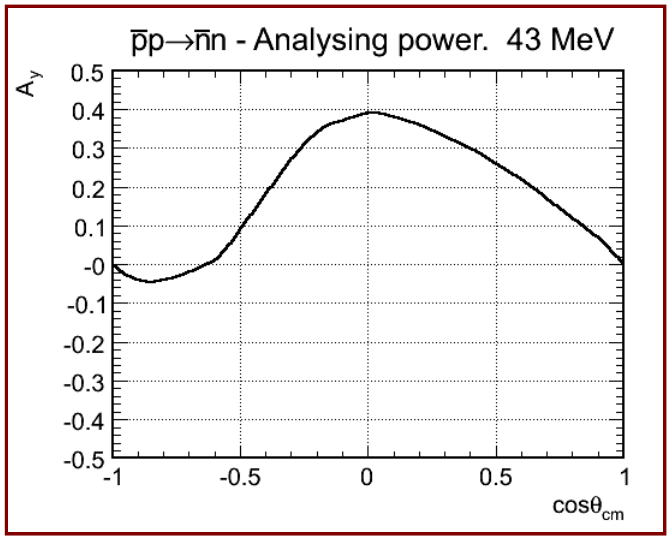
Model driven generated events . only 120 MeV is shown.

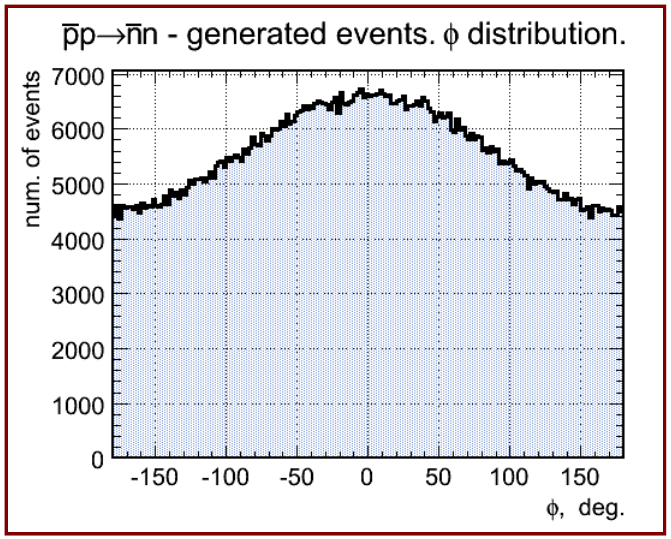
Antiproton-proton charge-exchange cross-section



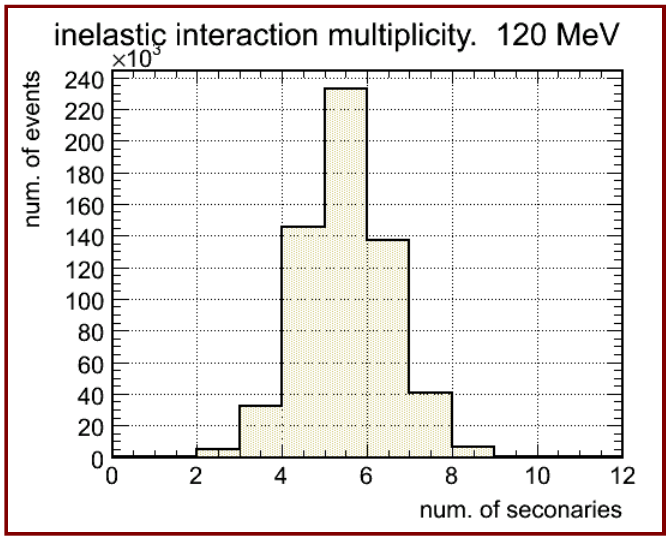


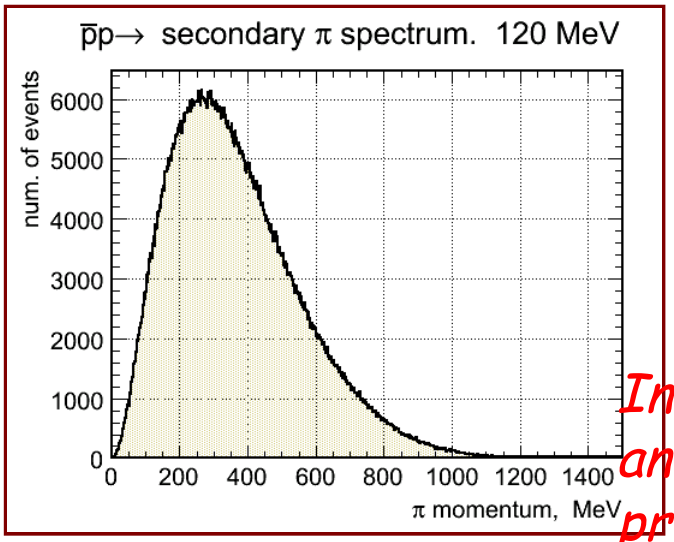
Data driven model

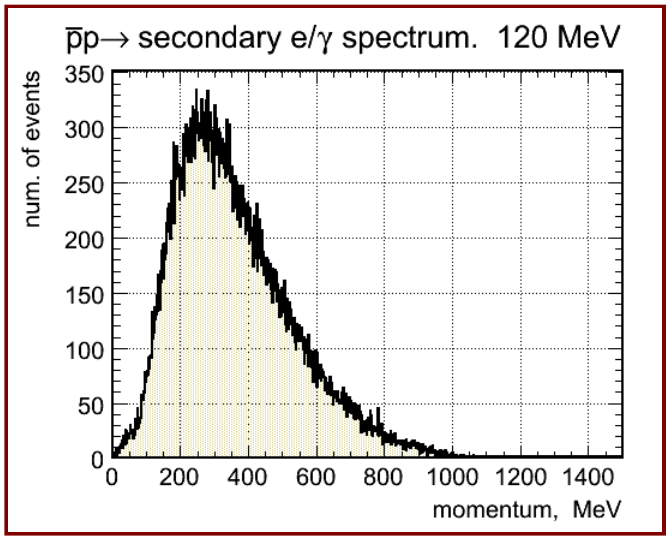


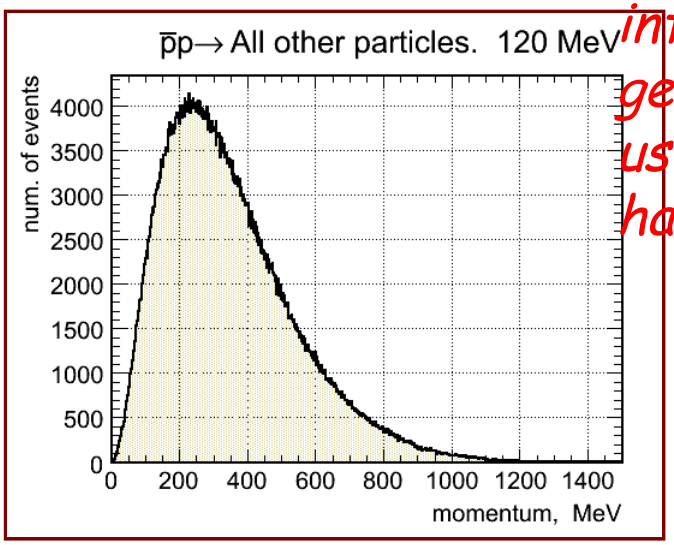


Antiproton-proton inelastic interaction events



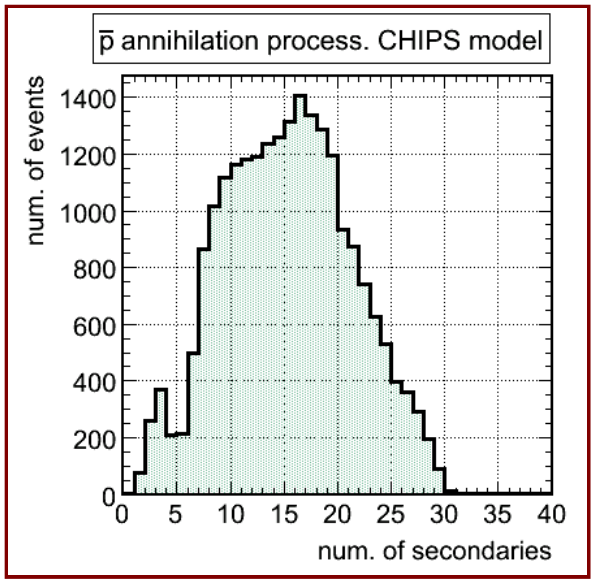


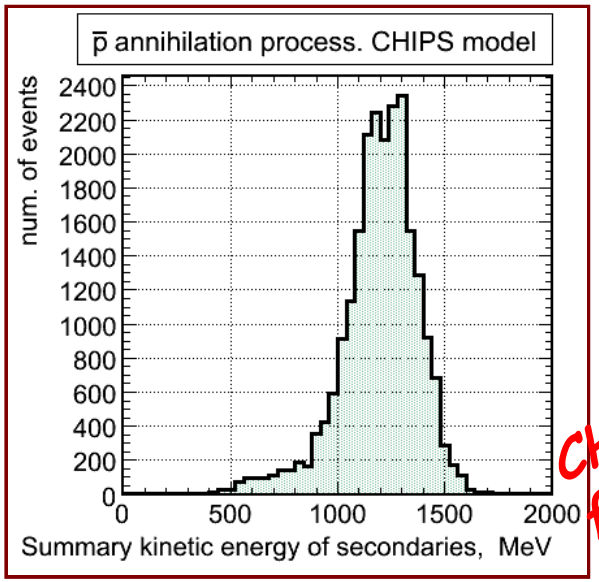




Inelastic antiproton-proton interaction is generated using CHIPS hadronic model

Antiproton annihilation in materials



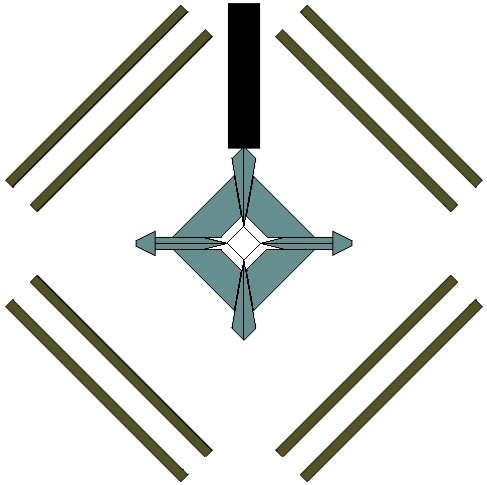


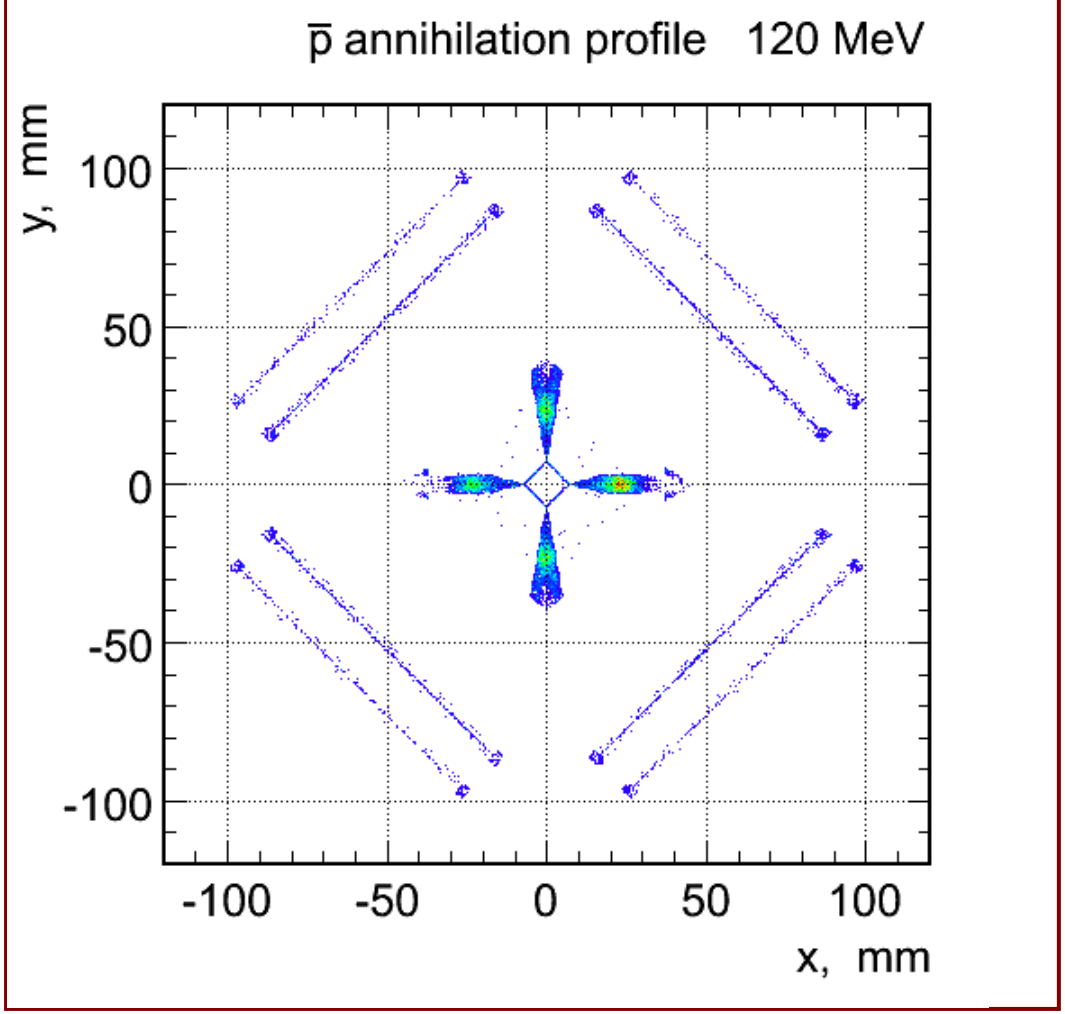
CHIPS model is used for antiproton annihilation generation

beam energy:	43	120	220	MeV
annihilation rate				
total:	16.4	6.7	0.70	%
layer 0:	0.74	0.40	0.15	%
layer 1:	0.72	0.15	0.06	%

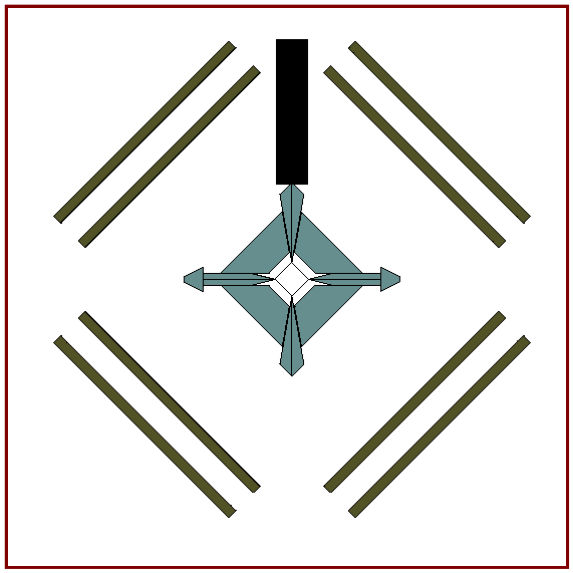
Current version of Geant4 is unable to simulate antiproton hadronic interaction with maretials (nuclei). Proton hadronic model is used.

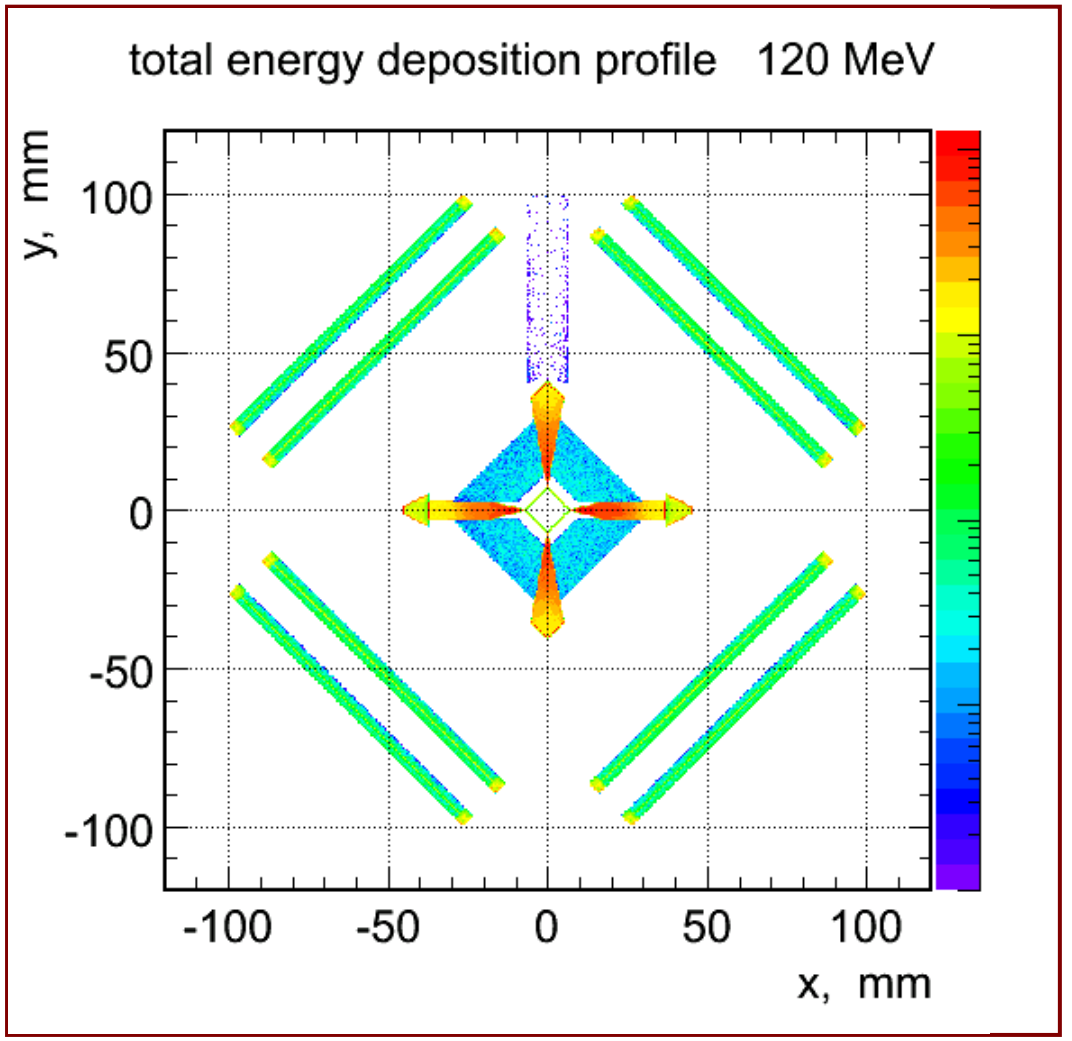
Antiproton annihilation in the set-up



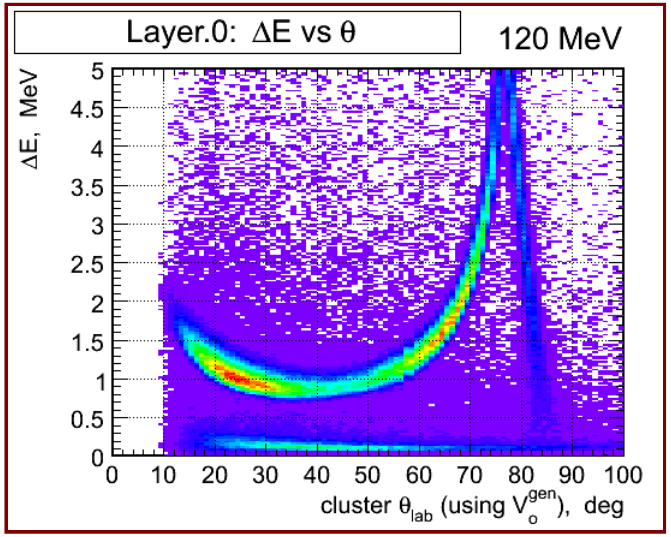


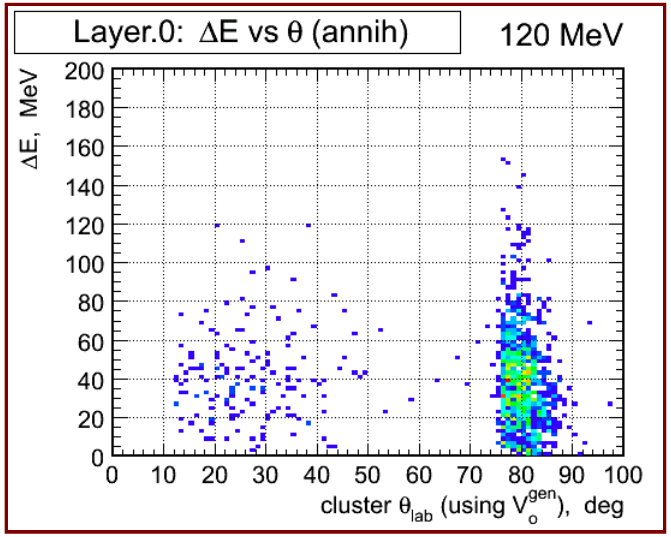
Total (summary) energy deposition in the set-up

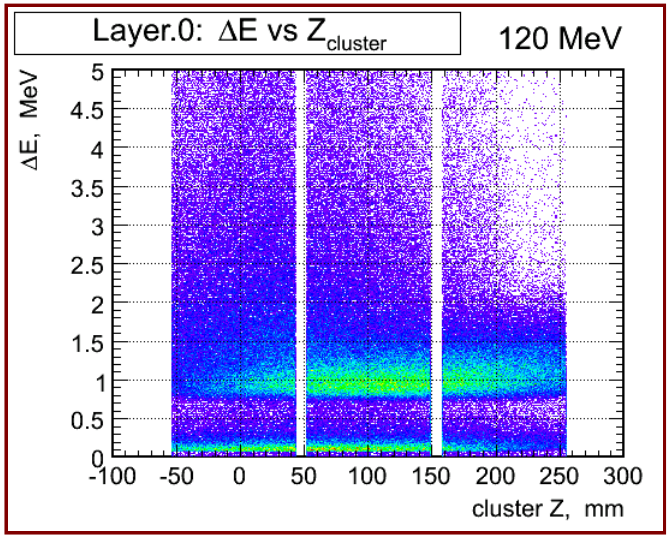


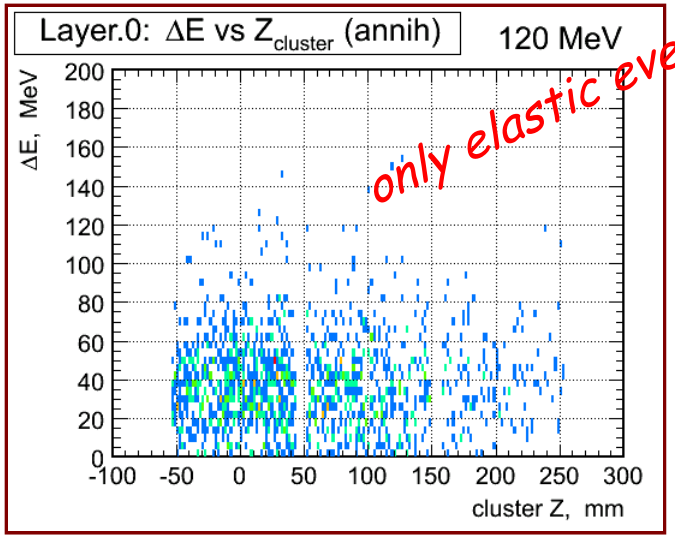


Energy deposition in layers



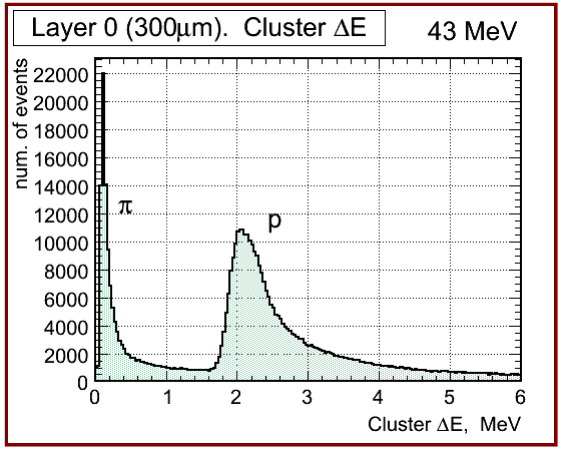


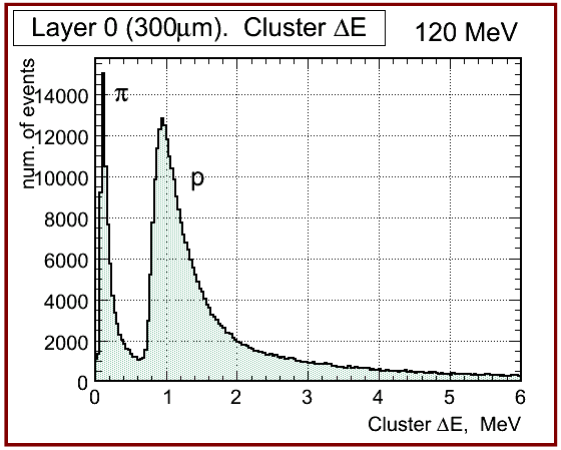


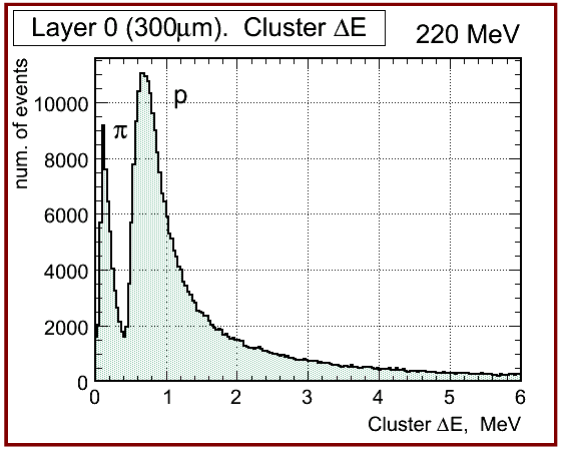


only elastic events are included

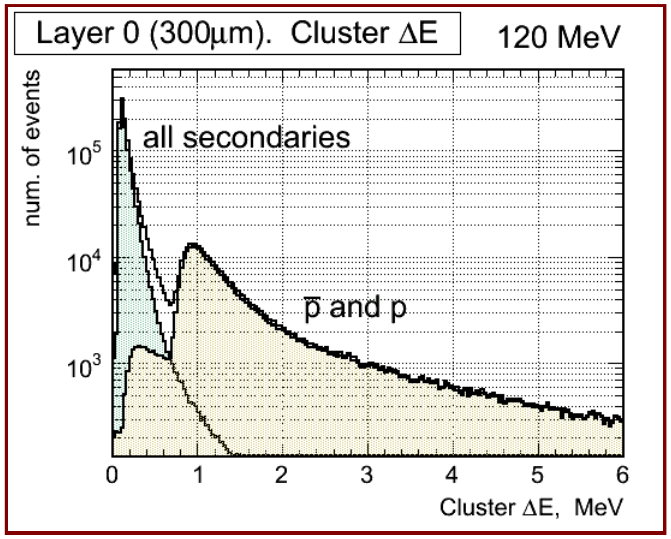
Energy deposition in layers

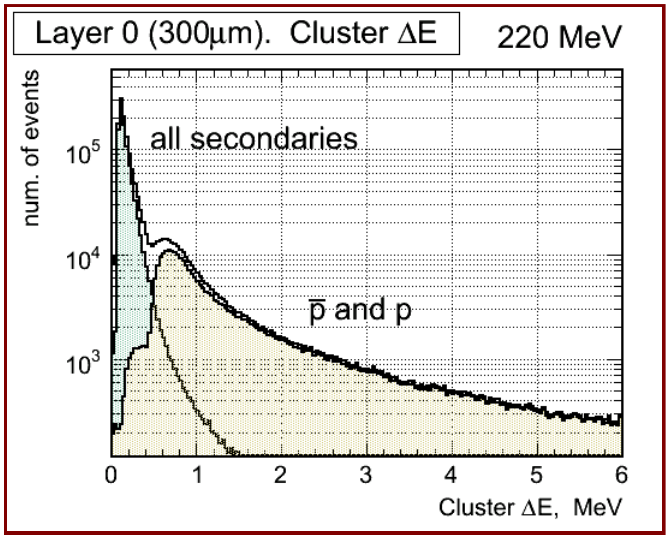






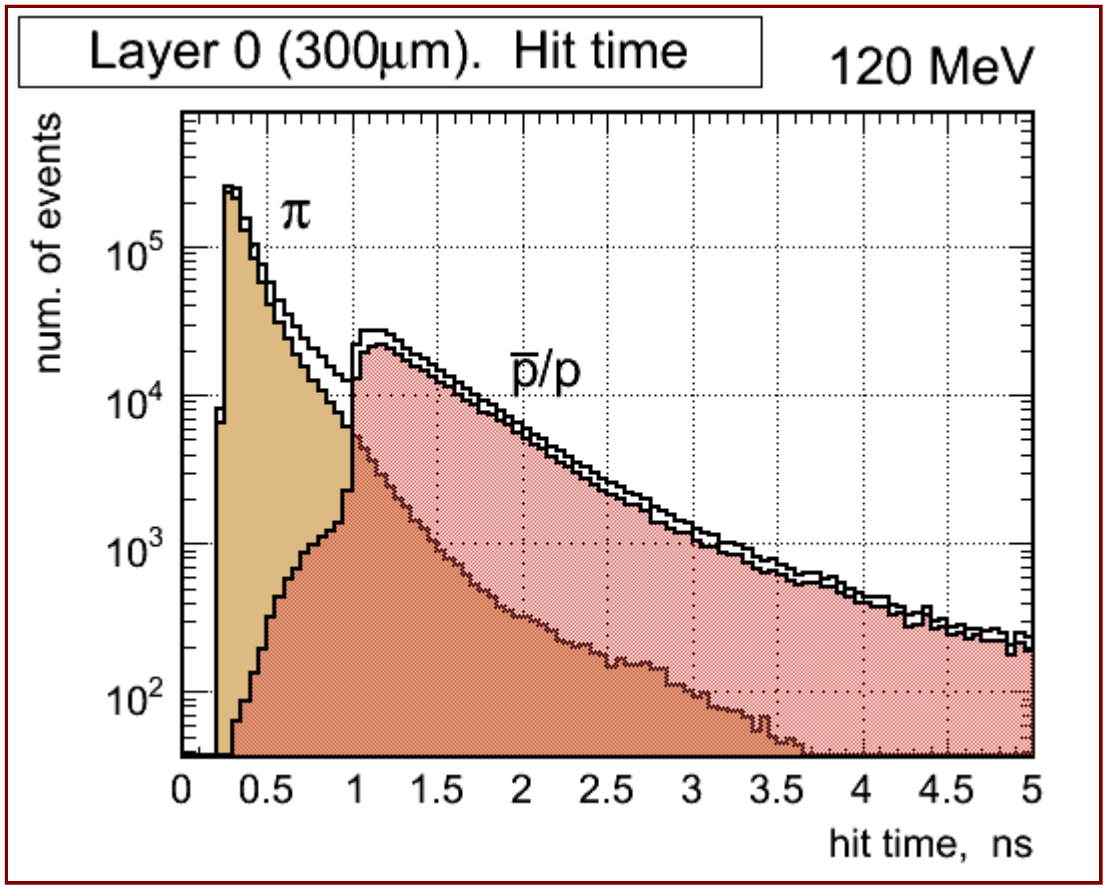
only elastic events are included





All events included

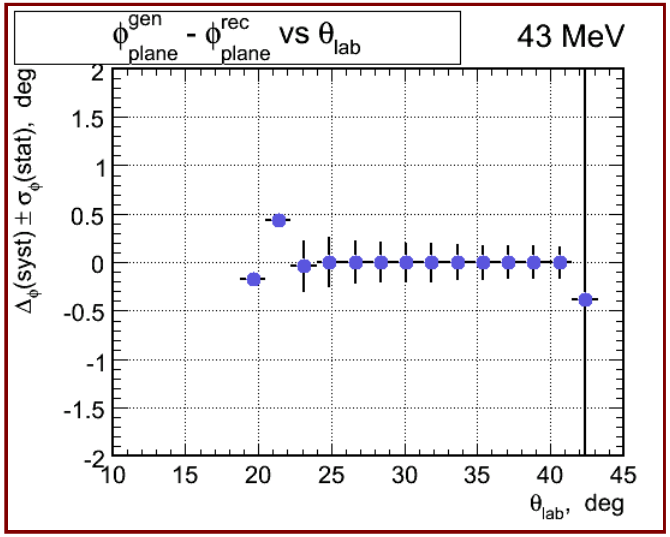
Timing information

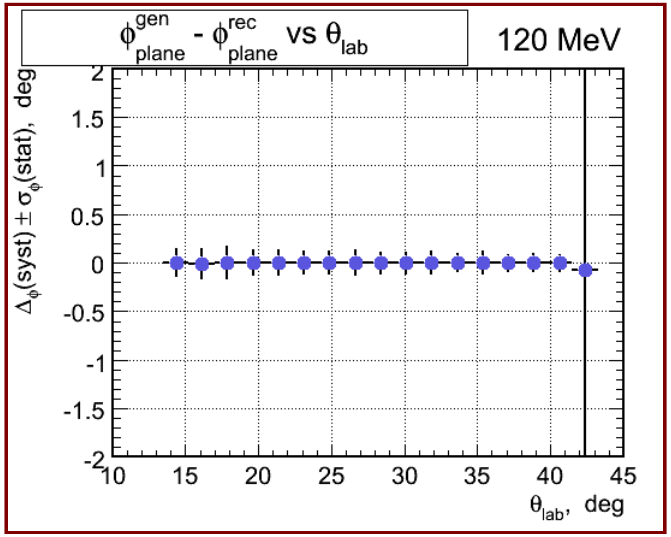


All events included

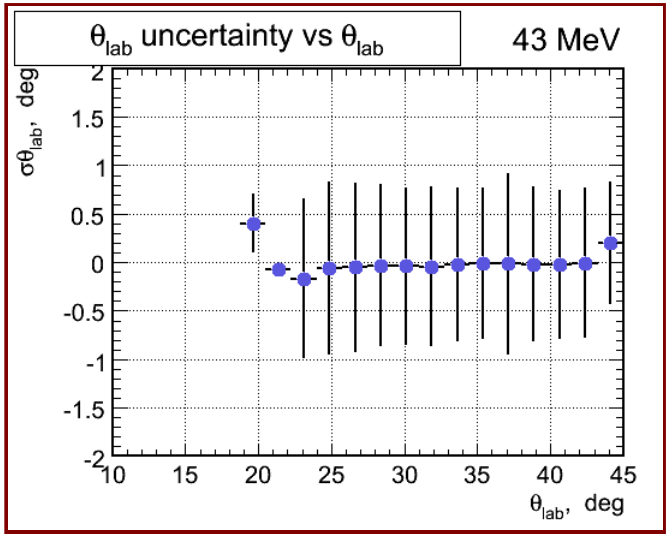
Not clear how to use for selection …

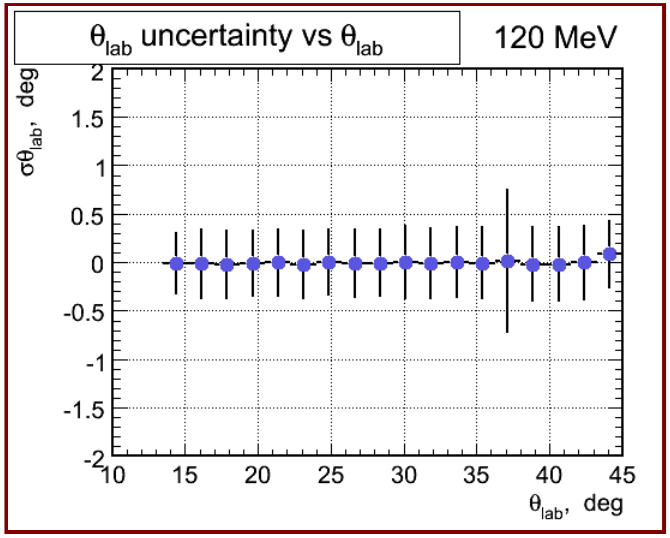
Parameter measurement uncertainties





ϕ_n





ϑ_{lab}

43 MeV

120 MeV

parameter reconstruction uncertainties

strip pitch	mm	$0.5\,mm$			$0.758\,mm$		
beam energy	MeV	43	120	220	43	120	220
$\sigma\vartheta_{lab}$	deg	0.77	0.35	0.25	0.81	0.42	0.32
$\sigma\phi$	deg	0.26	0.16	0.12	0.27	0.18	0.14
vertex $\sigma_x = \sigma_y$	mm	1.90	1.35	1.20	2.05	1.47	1.35
vertex σ_z	mm	0.34	0.19	0.14	0.35	0.21	0.17

Almost no difference between the two choices of strip pitch. Multiple scattering dominates.

Above $\vartheta \approx 45^\circ$ it is impossible to reliably define the reaction plane normal, because protons and antiprotons couldn't be distinguished.

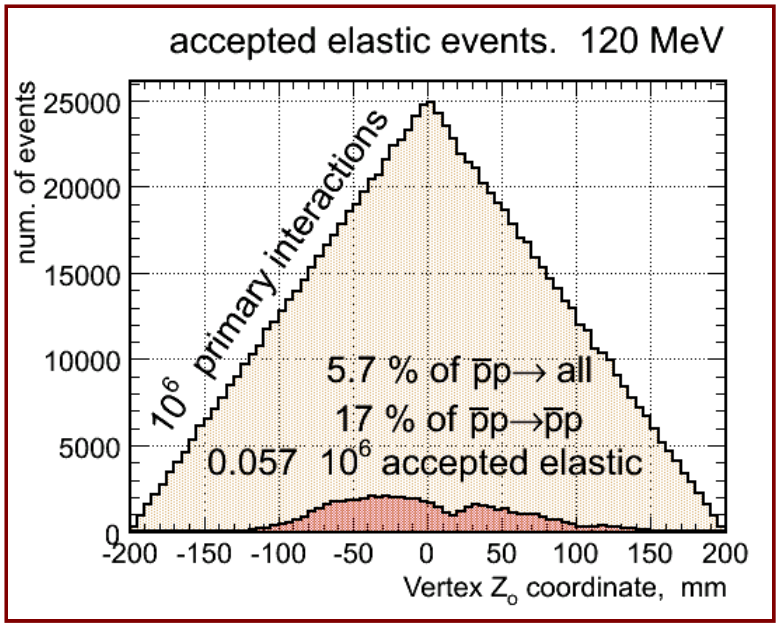
Integral acceptances and rates

beam energy:	43 MeV	120 MeV	220 MeV
total number of primary events:	1 M	1 M	1 M
Primary antiproton-proton elastic:	0.33 M	0.33 M	0.33 M
accepted: elastic	48 k	57 k	40 k
	14.5 %	17.0 %	12.0 %
total 'run' time:	4000 sec	5700 sec	6898 sec
good (reconstructed) event rate:	12 evt/sec	10 evt/sec	5.8 evt/sec

Accepted θ_{lab} range: 15^{o} – 45^{o}

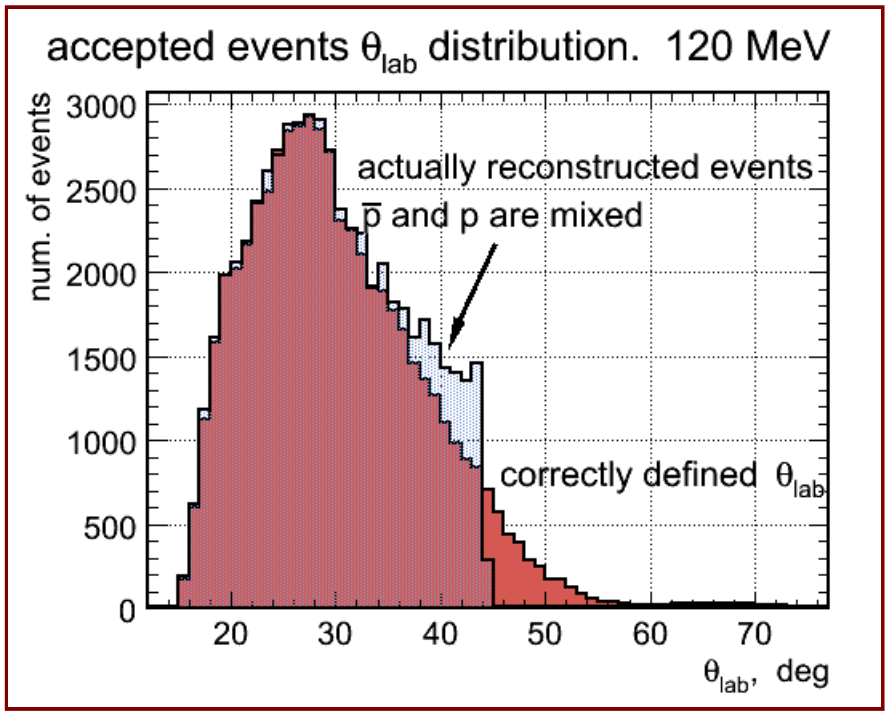
Using simple cluster selection criteria and reconstruction algorithm no background accepted as elastic (only few events).

Integral acceptances and rates

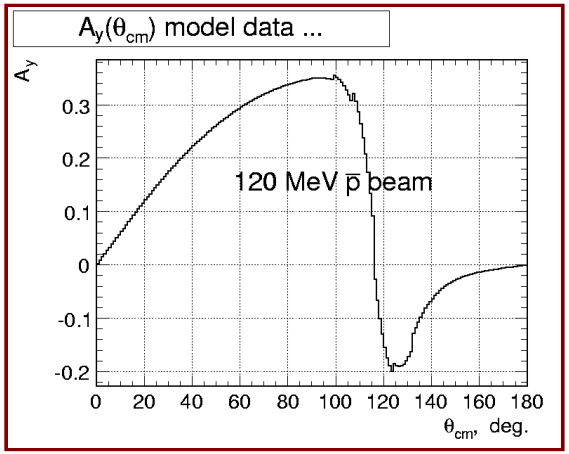


Vertex distribution along the target for accepted elastic events.

Scattering angle acceptance



Proton/antiproton mixing effect



Knowing existing data on the elastic scattering and the analysing power (see Klempt et al., 2002) the mixing effect can be accounted correctly.

Conclusions

- The same detector can be used for measurements at COSY and AD, perhaps with minor modifications;
- antiproton annihilation at the beam-target interaction or interacting with the detector materials, does not produce significant background. Annihilation rate in silicon does not exceed 0.7 %
- antiproton primary inelastic interaction background can be eliminated easily with proper selection cryteria,
- elastic scattering reconstruction in pp and app interaction does not differ. Annihilation events can be ignored,
- no principal difference in performance in case of strip pitch 0.5 mm and 0.76 mm (HERMES),
- The target cell mechanical parts does not produce significant background,
- preferable beam energy is around 120 MeV (good π/p separation by ΔE, cross-sect and A_y shape, less annihilation, less track spread due to MS);

Open questions

⇨ Impossibility to distinguish scattered and recoil particles makes problems in antiproton scattering measurement because the reaction plane normal can not be defined reliably above $\vartheta_{lab} = 40_o$. But scattered antiproton cross-section dominates to recoil one (above 120 MeV).

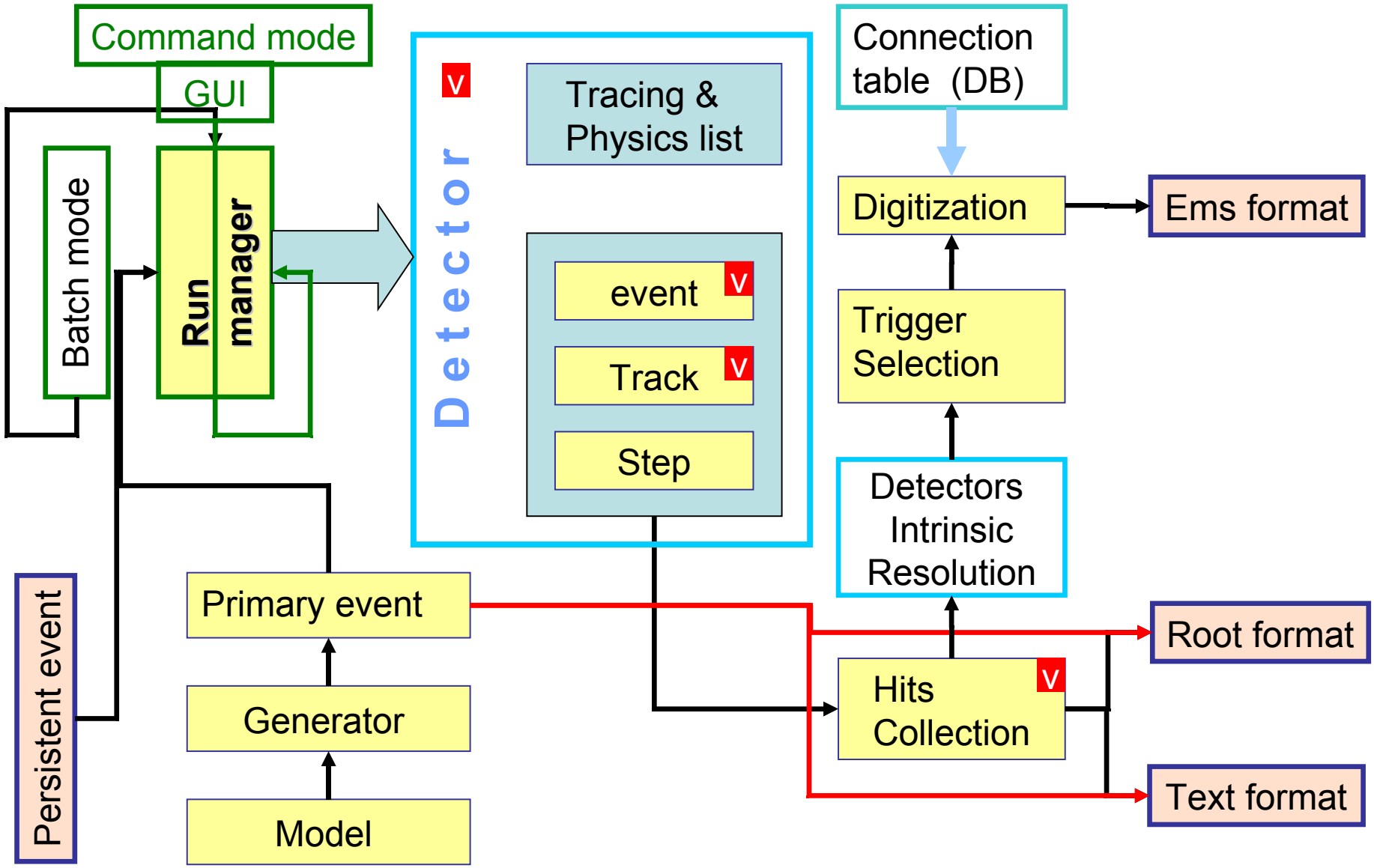
⇨ There are performance parameters that can only be checked and validated through actual testing with beam (e.g. intrinsic resolution, noise, etc). These parameters have to be accounted at the detector response (clusters) simulation.

⇨ Persistent event structure and access methods have to be developed.

⇨ Data base structures/interfaces has to be developed …

⇨ Trigger logic has to be added in simulation chain.

Analysis SW development. Simulation code diagram.



Antiproton-proton elastic cross-sections

Antiproton-proton elastic cross-sections

Antiproton-proton elastic cross-sections

Some header …