QM 2006 Xi'an Satellite Meeting

Nov22-25 Xi'an, China

Hadron Physics Programs at HIRFL-CSRm ——Status and plan

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- 1 HIRFL-CSR complex
- 2 **Hadron Physics LanzhoU Spectrometer (HPLUS)**
- 3 Sub-detectors R&D in progress
- 4 Summary

HIRFL-CSR complex

- **Physical Interests at CSR**

→**Hadron and nucleon Physics (Hplus)**

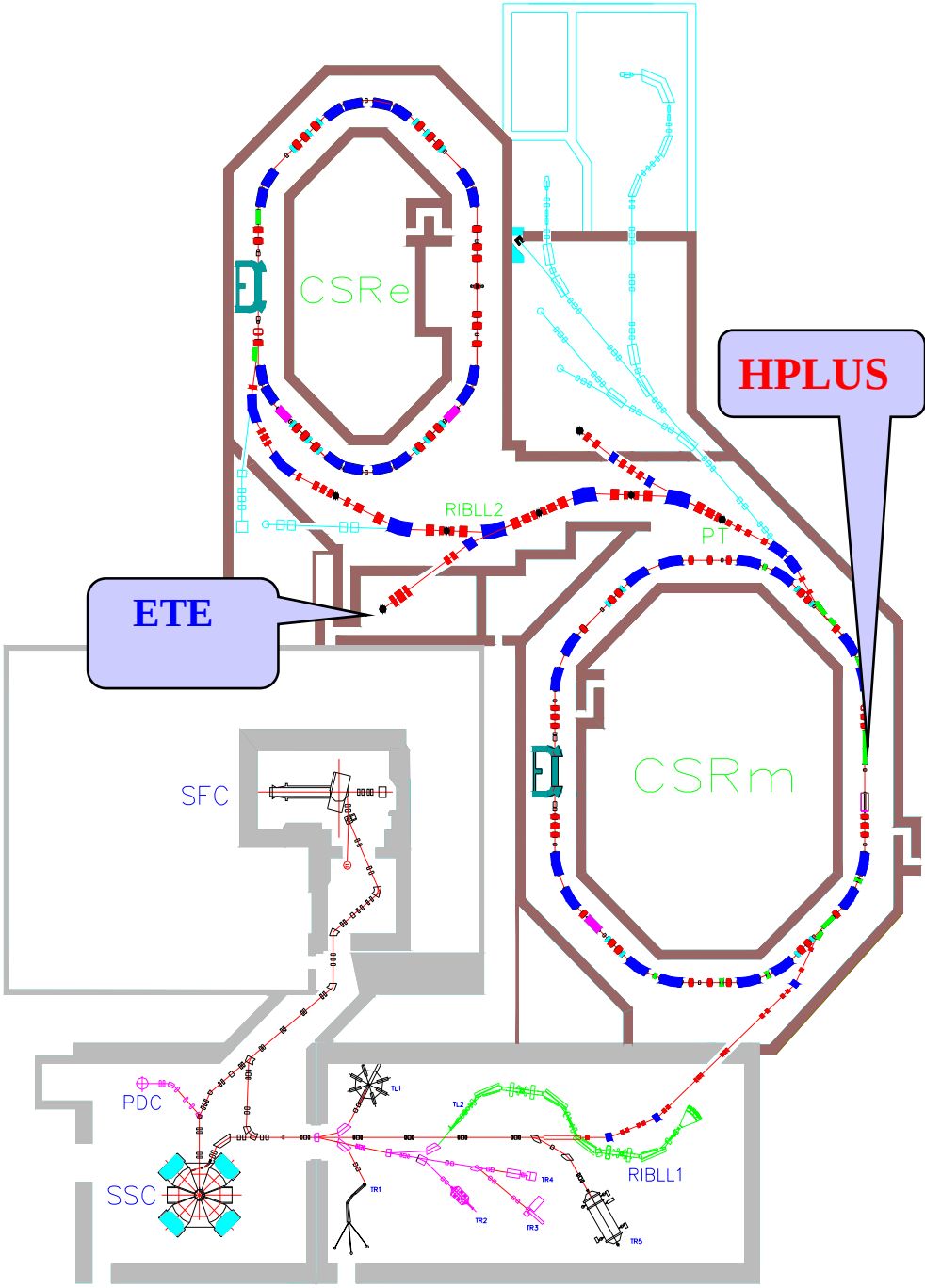
→**Nuclear Structure with RIB (Ext. Tar.)**

→**Collision dynamics， EOS, high baryon density… (Ext. Tar.)**

→High charged atomic physics

→High energy density physics

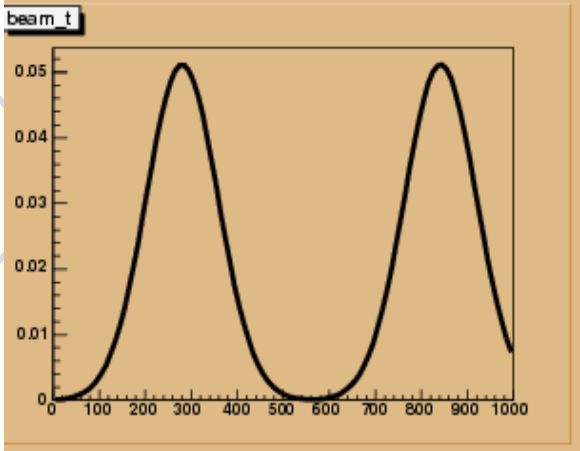
→Applications (Irradiative, therapy)

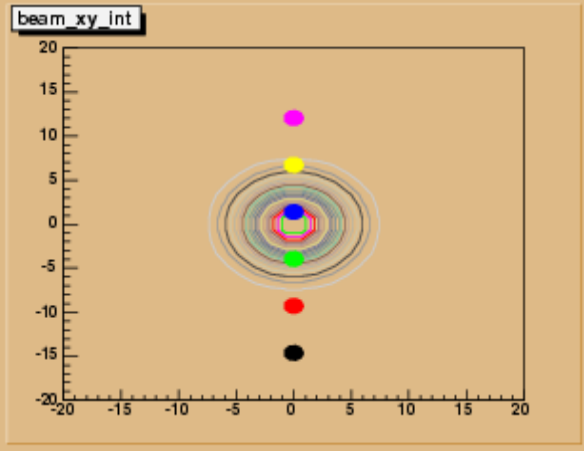


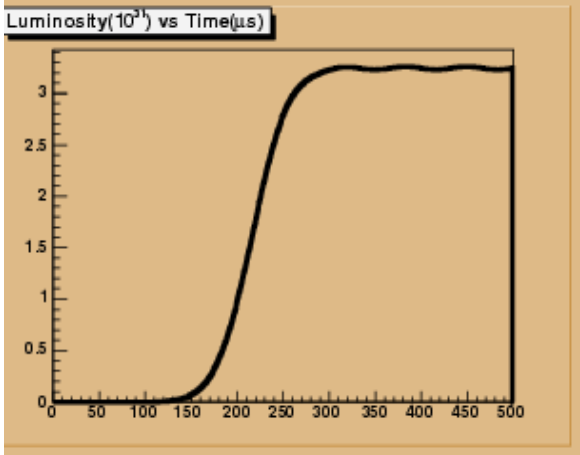
Luminosity Estimation

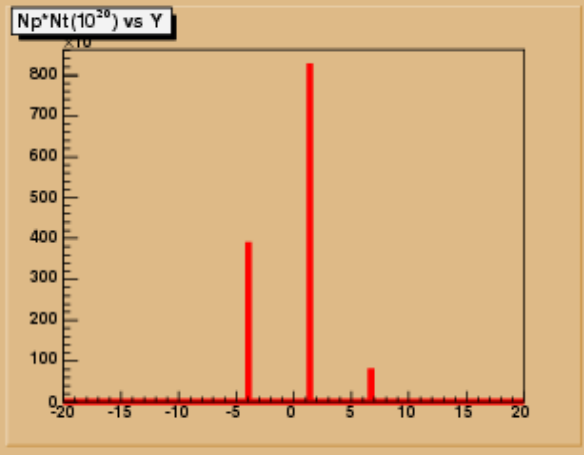
$L=3\times10^{31}\ /cm^2/s$

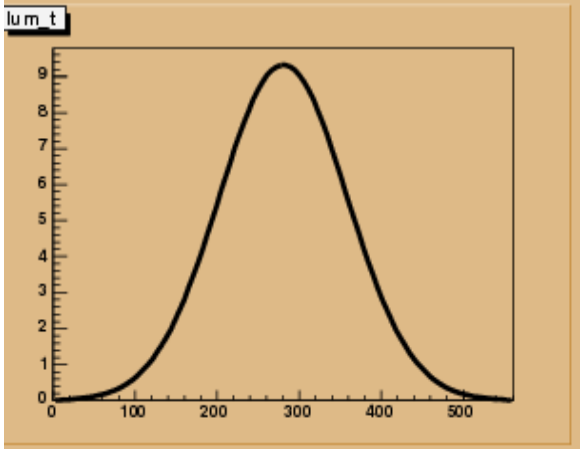
Xsection	Evt.Rate
1nbar	10^{-2}/s
1μbar	10/s
1mbar	10^4/s
50mbar	5×10^5/s











Beam Particles: 10.0×10^9
Beam Emittance: 10.0π mmmrad
Bunch Lengthσ: 50.0^o
Pellet Radius: $15.0\,\mu$m
Pellet Frequen.: 15.0 kHz
Pellet Velocity: 80.0 m/s

Luminosity: 3.2×10^{31}

- 1 HIRFL-CSR complex
- 2 Hadron Physics LanzhoU Spectrometer
  - 2.1 Hadron Physics programs
  - 2.2 Concept of Hplus based on simulation
- 3 Sub-detector R&D in progress
- 4 Summary

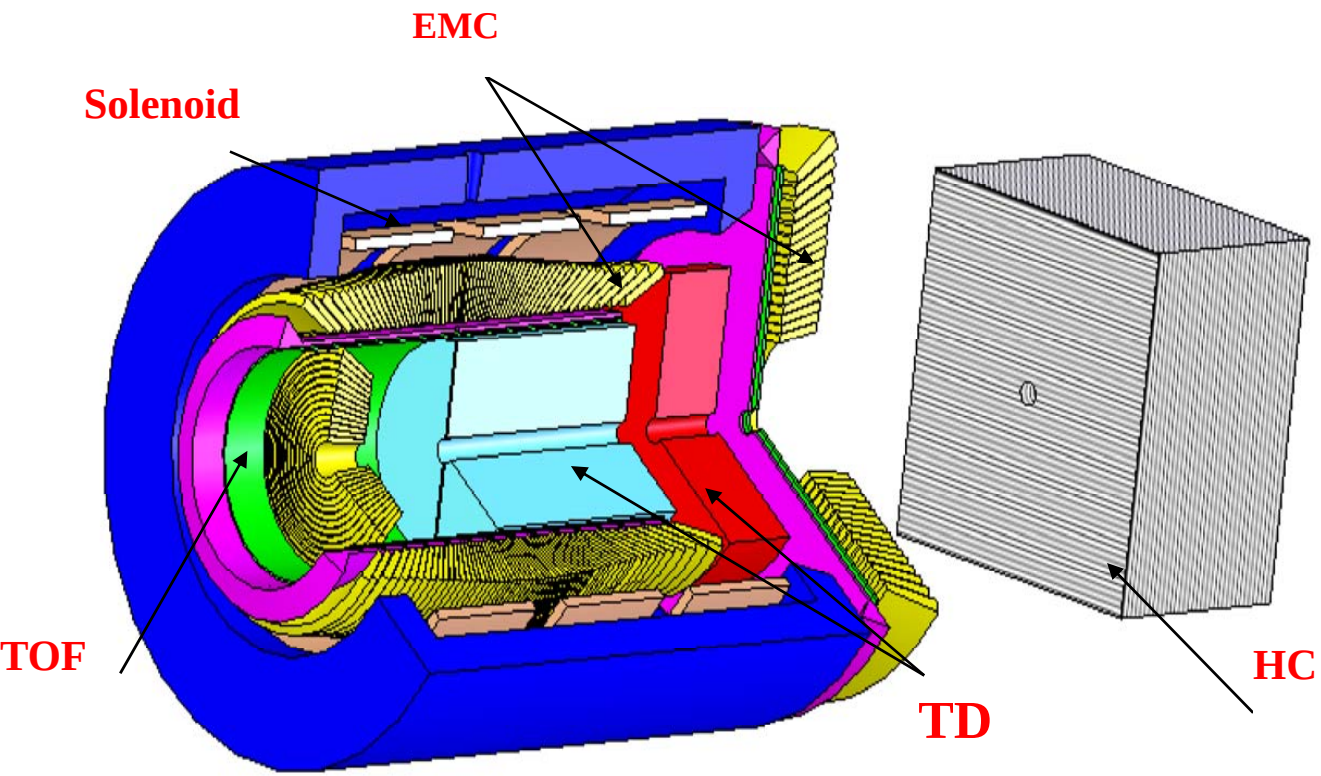
2.1 Hadron Physics programs

- Hadron **S**pectroscopy
- **S**ymmetry
- **S**pin/isospin physics

Channels	Threshold（GeV）	Physical interest
$p\bar{p}\rightarrow pp\phi\rightarrow ppK^+K^-$	2.593	Internal strange quark distribution and violation of symmetry
$pp\rightarrow pK^+\Sigma$ $(\Lambda\rightarrow n+\gamma)$	1.793(1.582)	Multi-quark states and strange constituent
$pp\rightarrow da_0(980)$ $(f_0(980))$	2.483	Mesons a_0/f_0 & internal quark-gluon structure
$pp\rightarrow ppK^+K^-$ $pd\rightarrow {}^3He\ K^+K^-$	2.494 1.731	direct K production
$pp\rightarrow pp\eta$ (η') **$pp\rightarrow pp\omega$**	1.26(2.4) 1.89	Isospin symmetry violation
$pp\rightarrow N^*$, **$\Delta^{++}(\rightarrow K\Lambda\ldots)$**	1.383	Baryon resonance
$p\alpha\rightarrow N^*\alpha$	0.795	Baryon excited states with Big σN coupling
$pA\rightarrow\rho(\omega,\eta)$ $pA\rightarrow\phi\rightarrow K^+K^-$	Sub-threhold	Medium effect

2.2 Concept of HPLUS based on simulation

Version 0



Channels in simulation

$pp \rightarrow pp\phi \rightarrow ppK^+K^-$

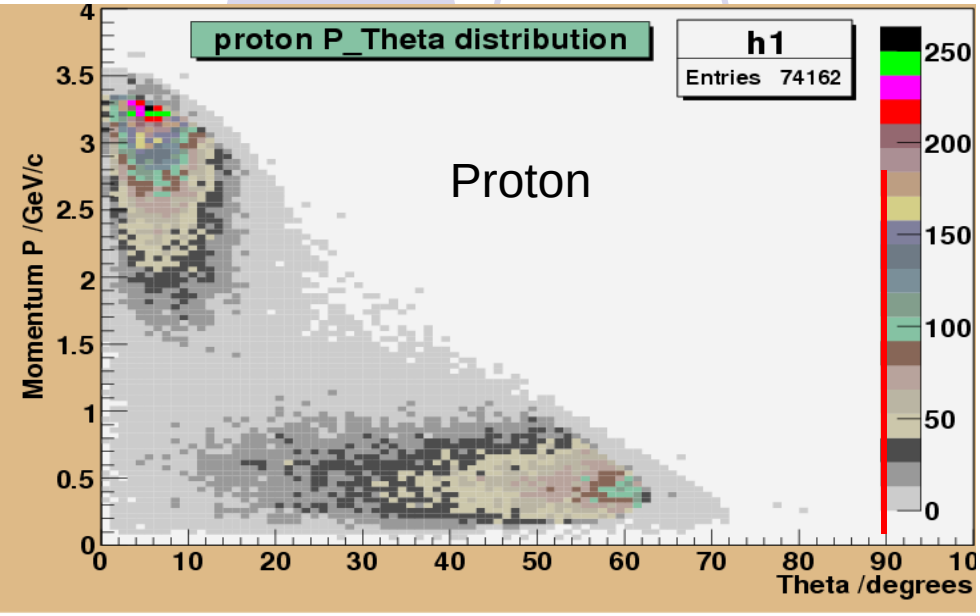
$pp \rightarrow pN^*(\rightarrow K\Lambda\ldots)$

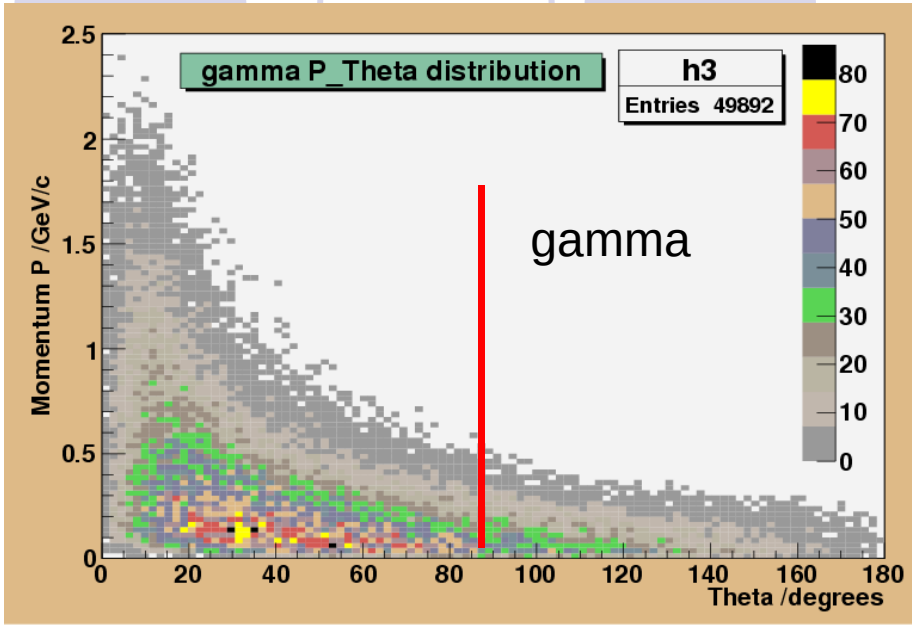
Phase space distribution

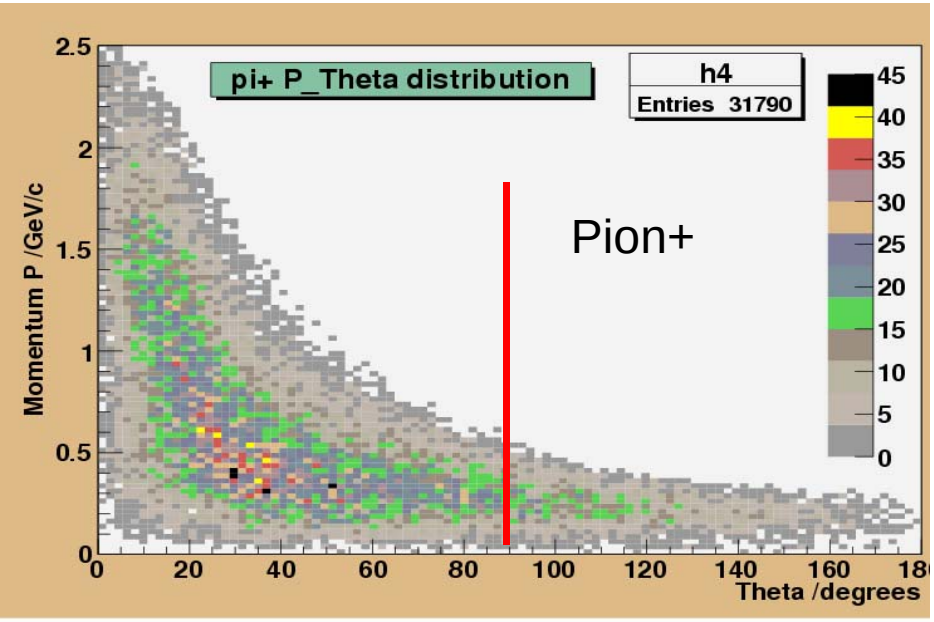
Fast trigger consideration

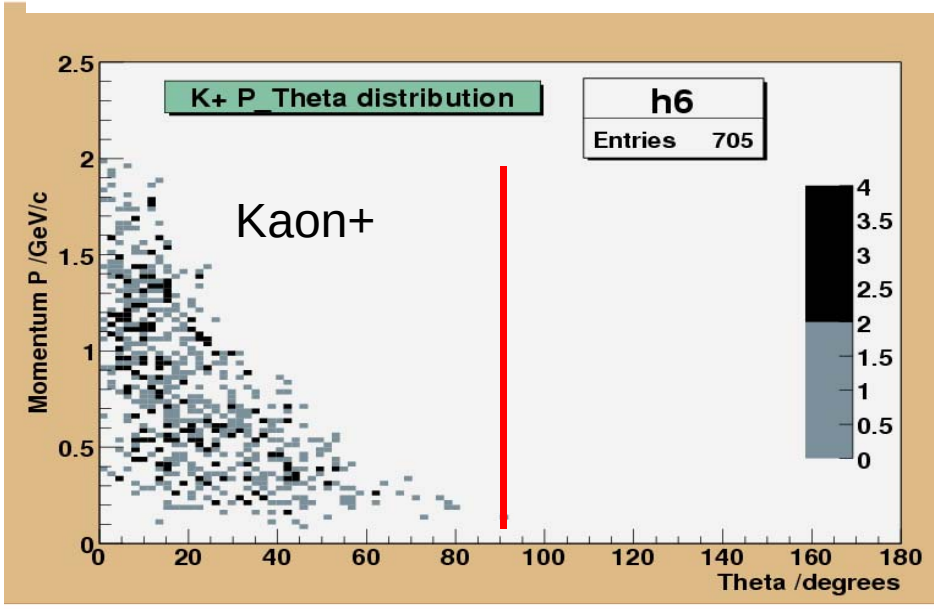
Concept → Real shape

2.8GeV pp collision in Pythia

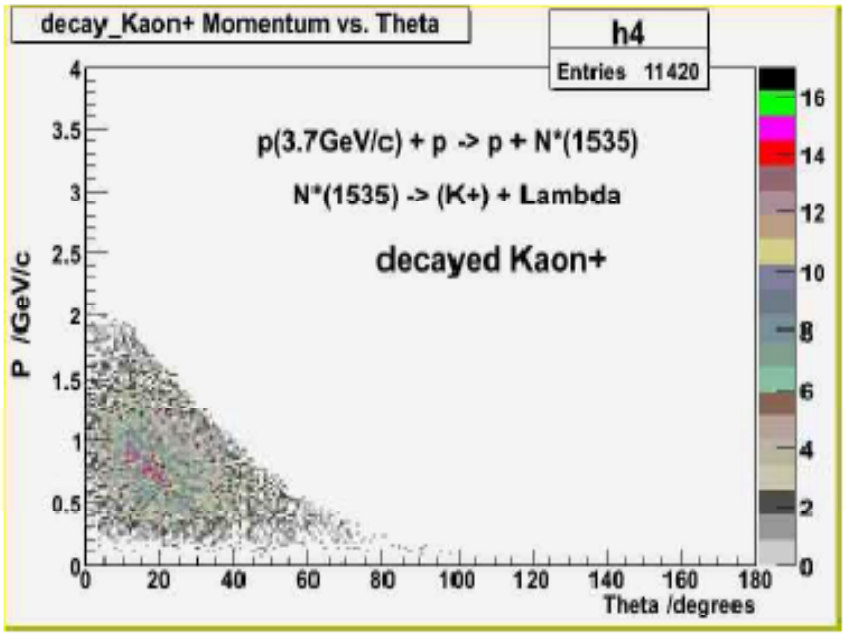


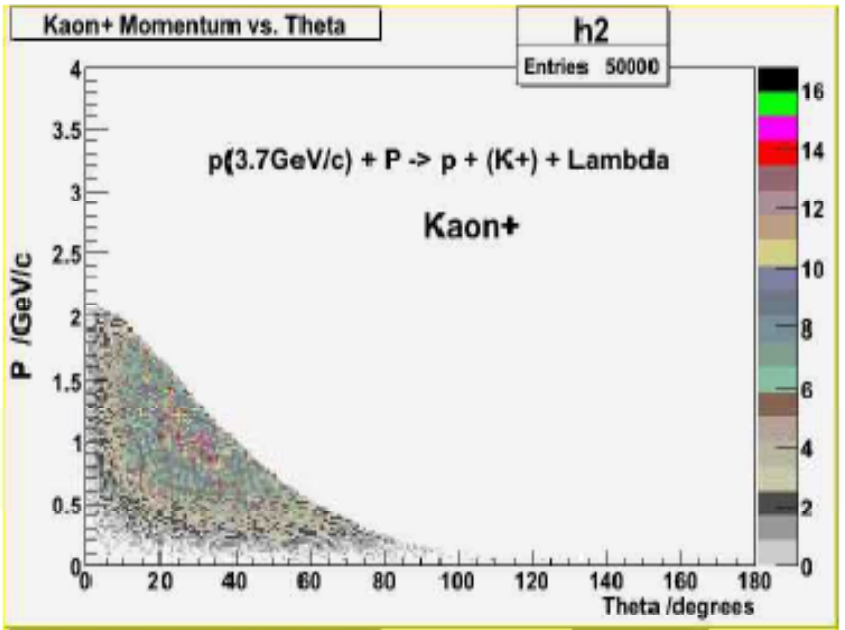


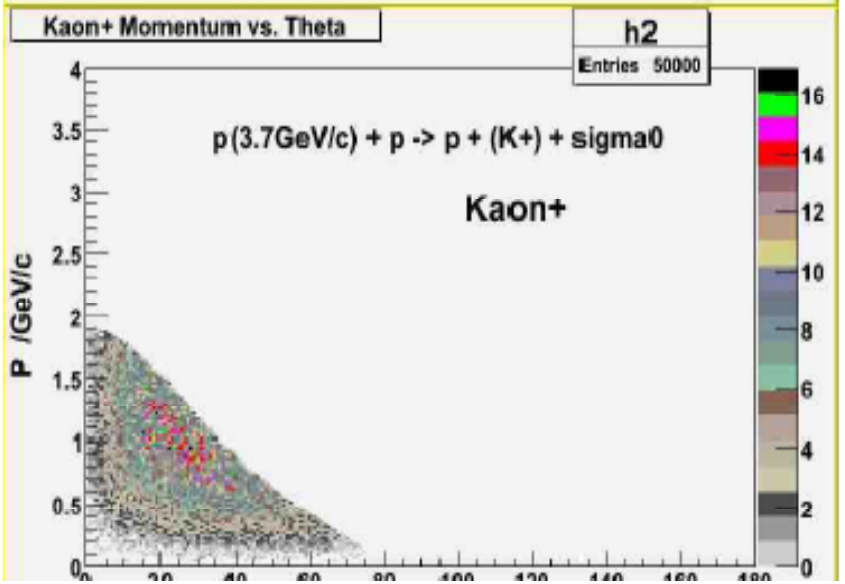




Channel 1: pp→pN*(1535)(→$K^+\Lambda$)







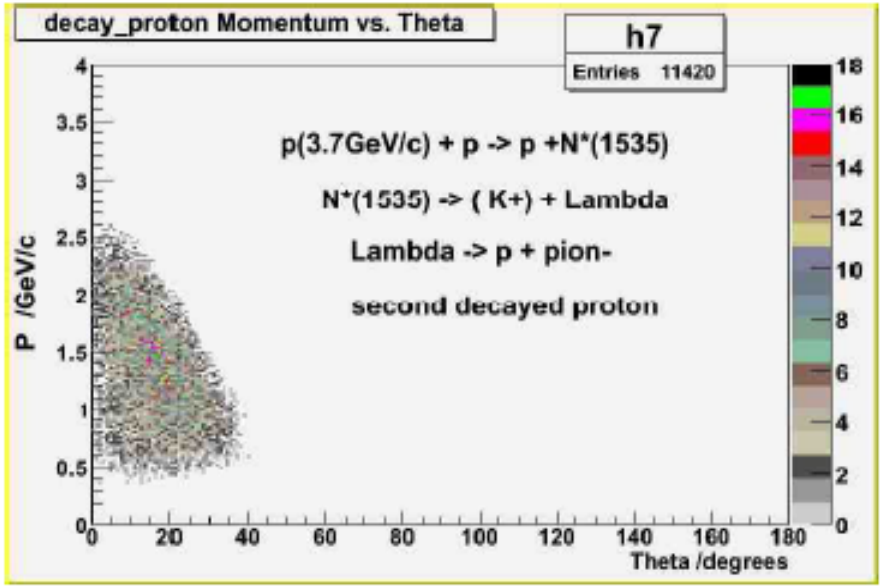
For Kaon:

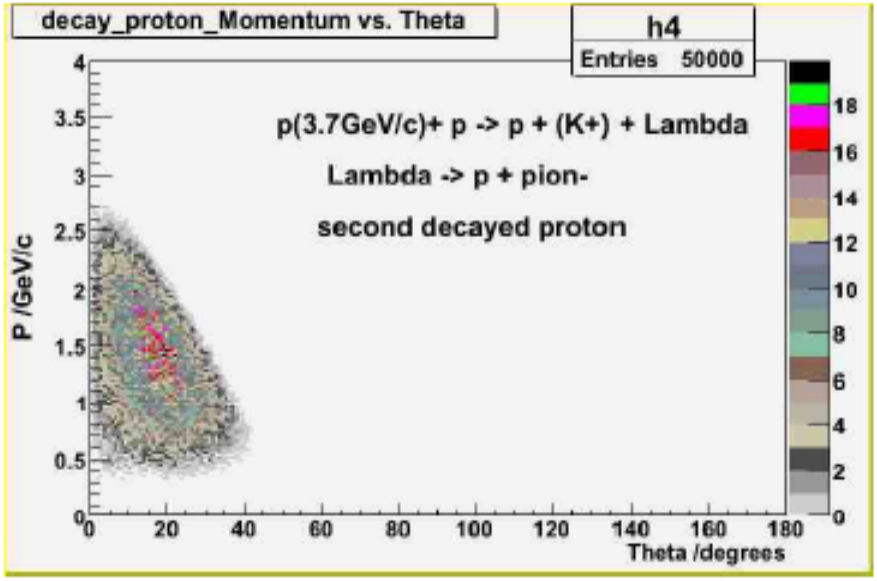
P<2GeV

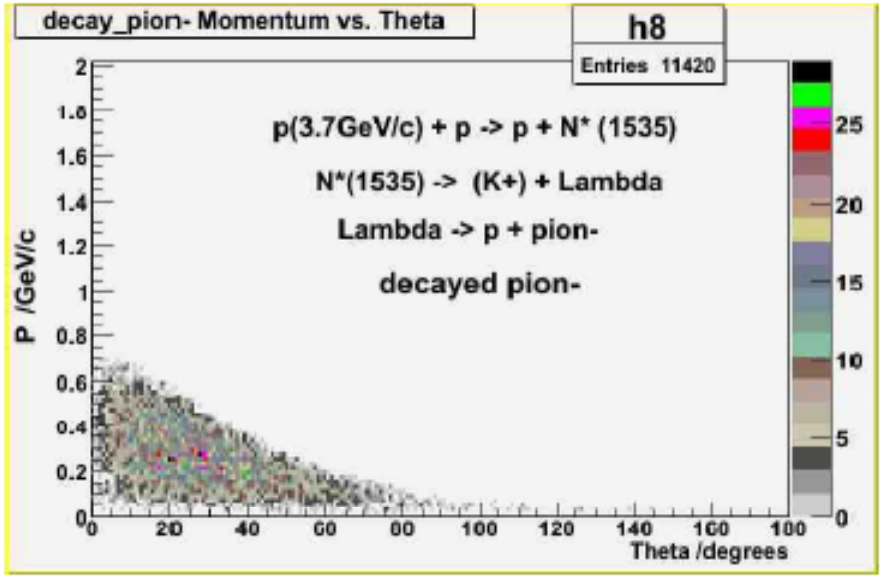
Angular: 80% in 30° (signal)

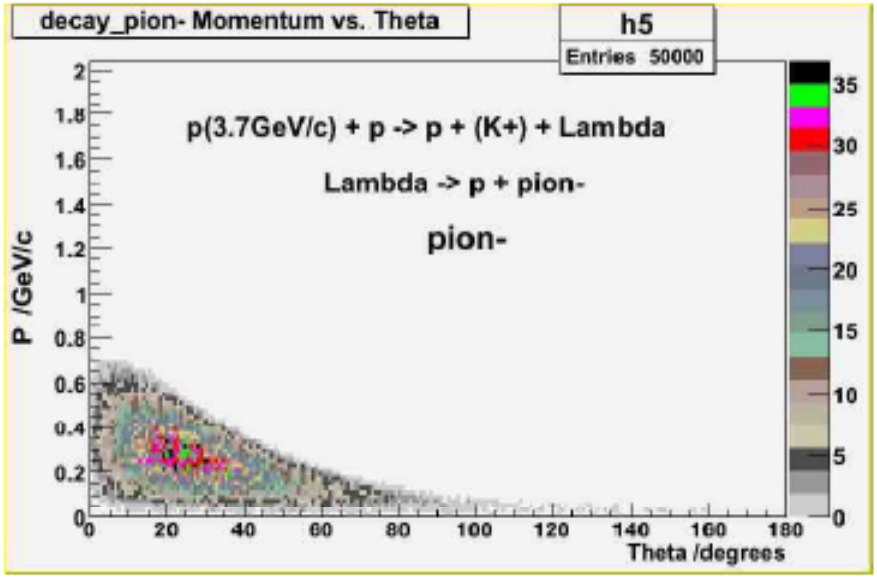
62% in 30° (bkg)

Channel 1: pp→pN*(→KΛ) decay products

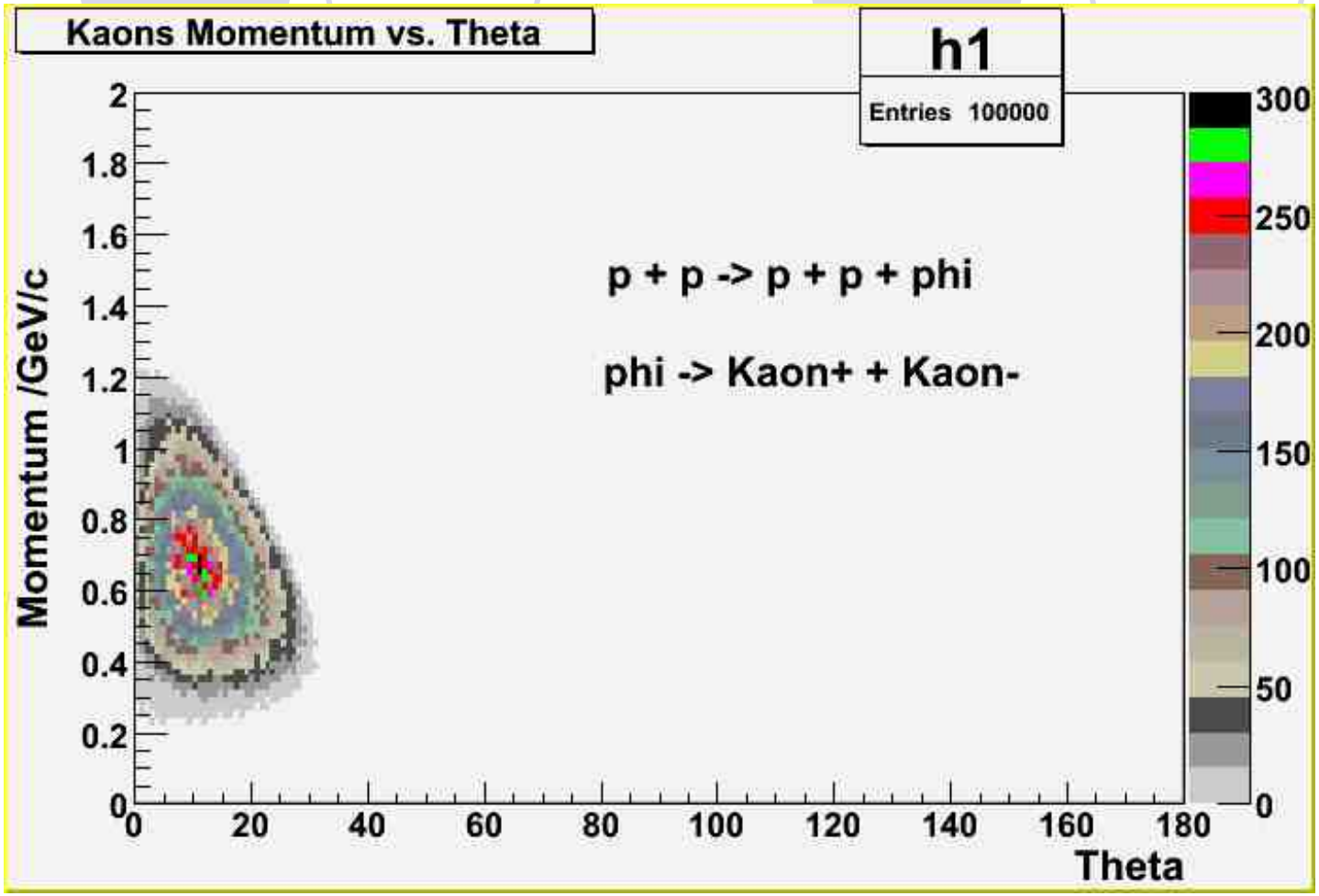




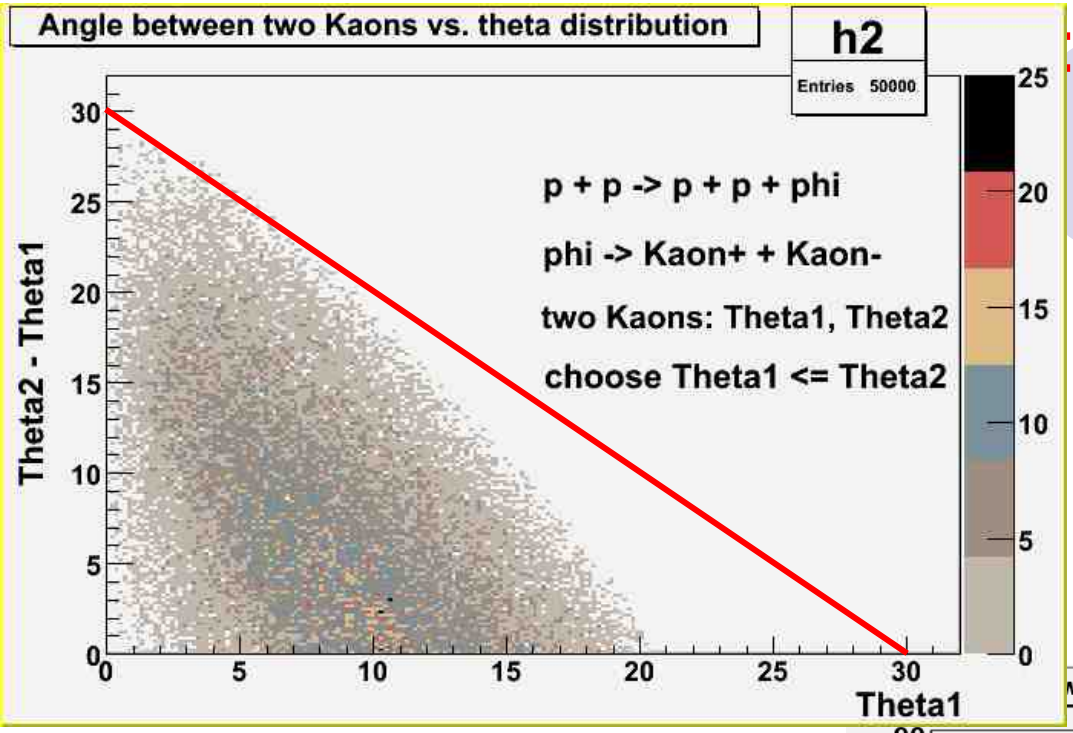




Channel 2: $pp \rightarrow pp\phi(\rightarrow K^+K^-)$

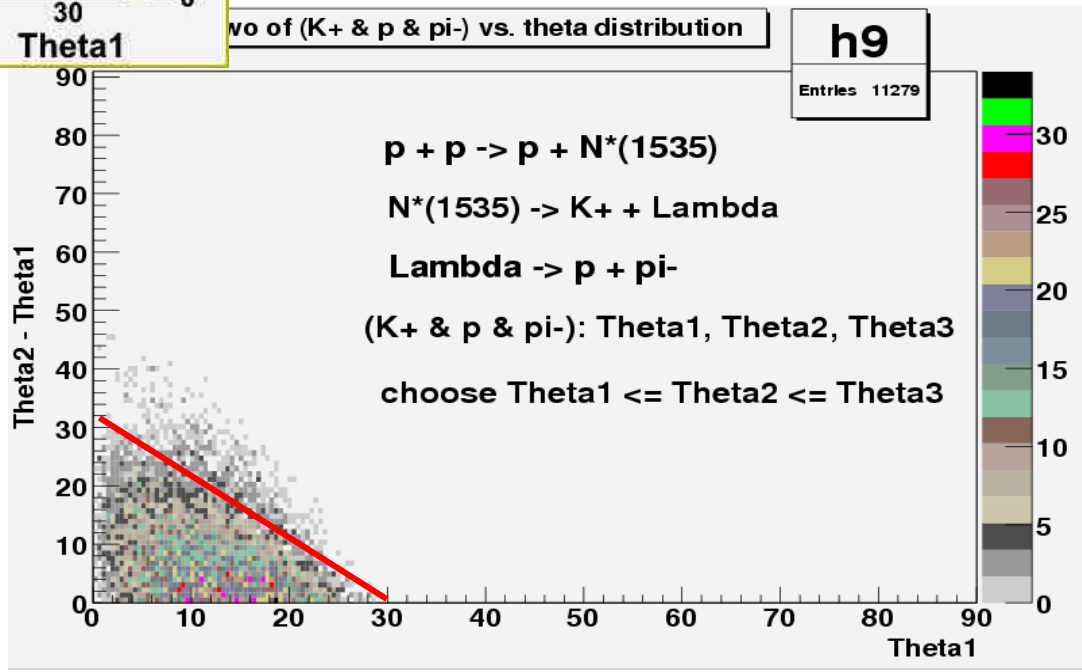


: Physical channels

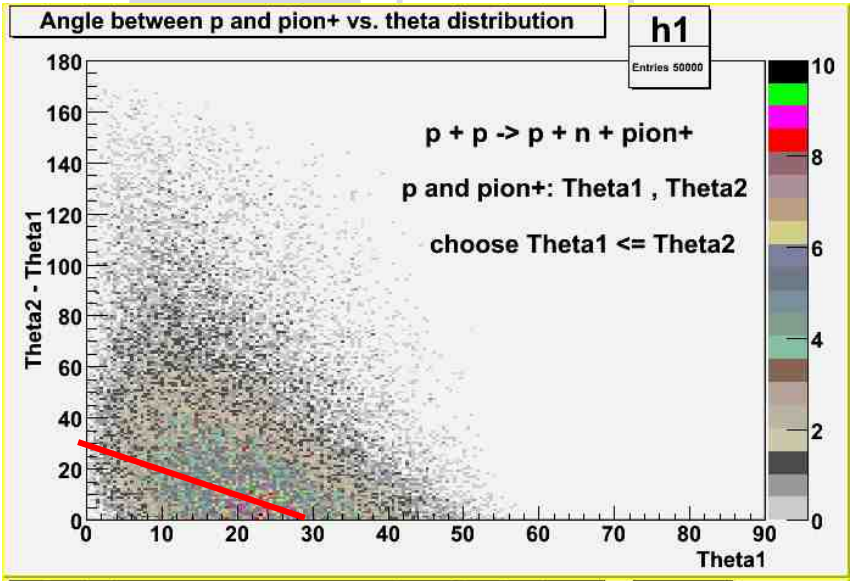


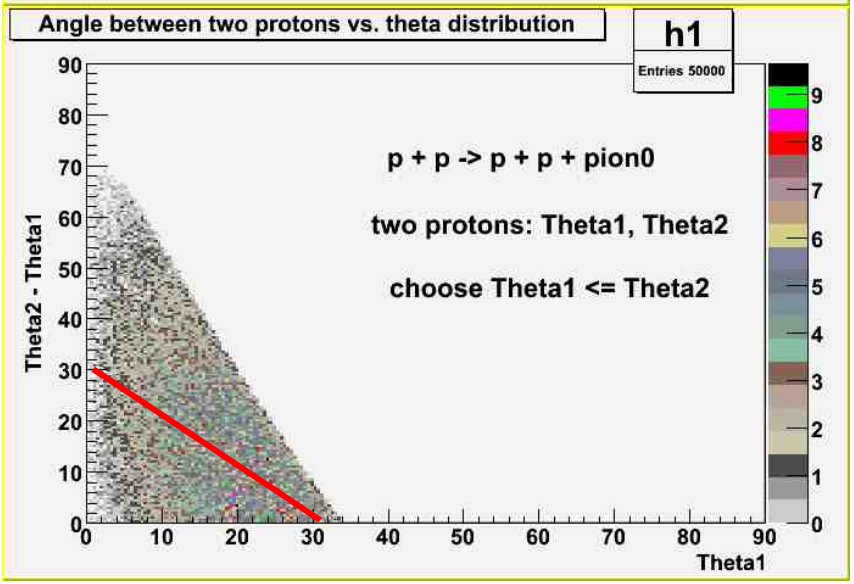
$pp \rightarrow pp\phi^{*}(\rightarrow K^{+}K^{-})$

$pp \rightarrow pN^{*}(\rightarrow K^{+}\Lambda)$

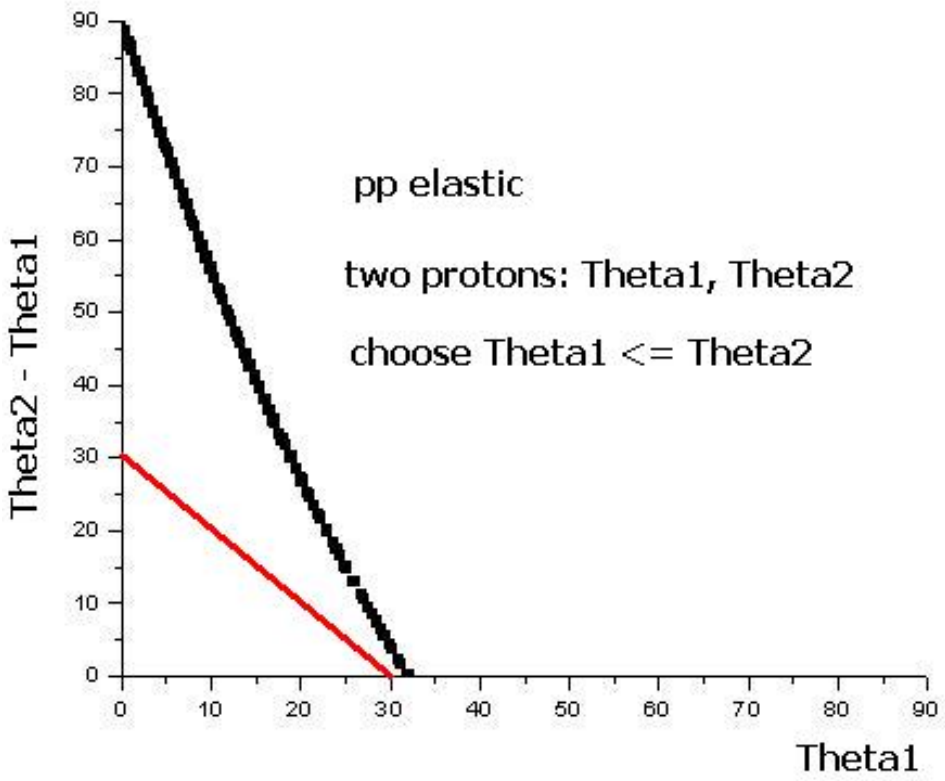


Forward region consideration: background



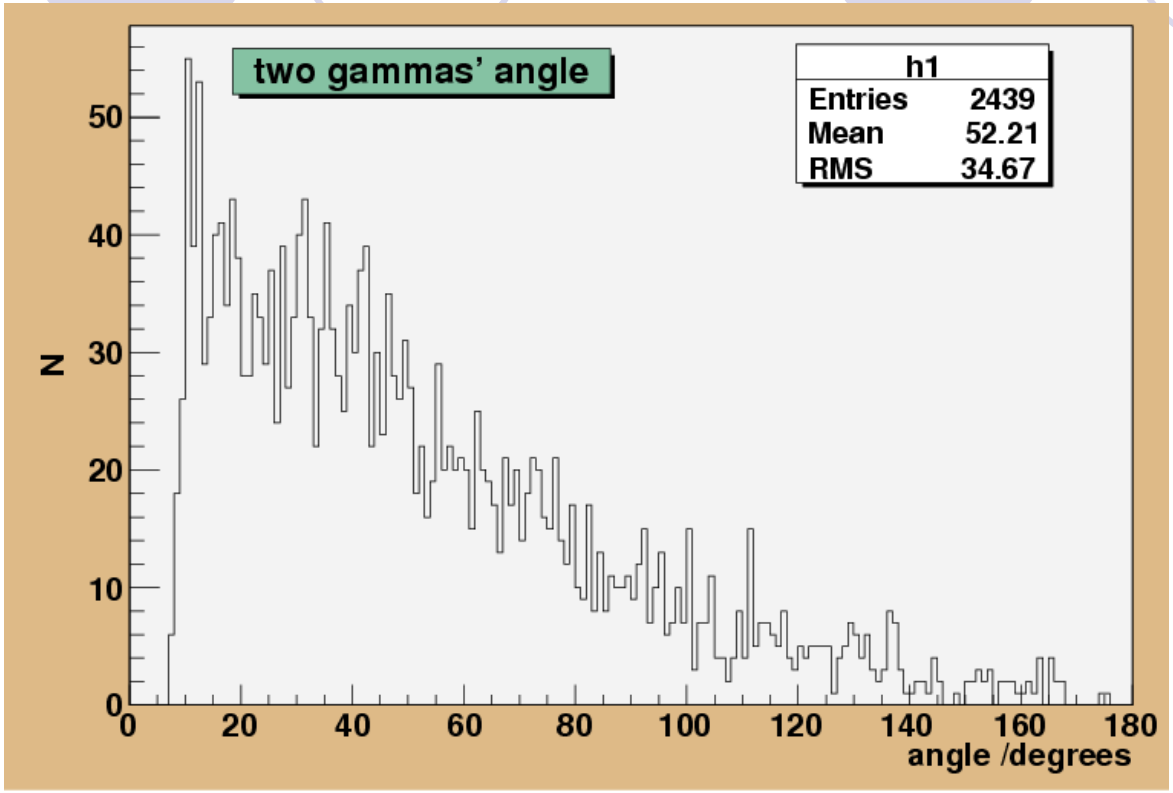


pp→pnπ



pp→pp elastic

For EMC: Two gamma from π^0

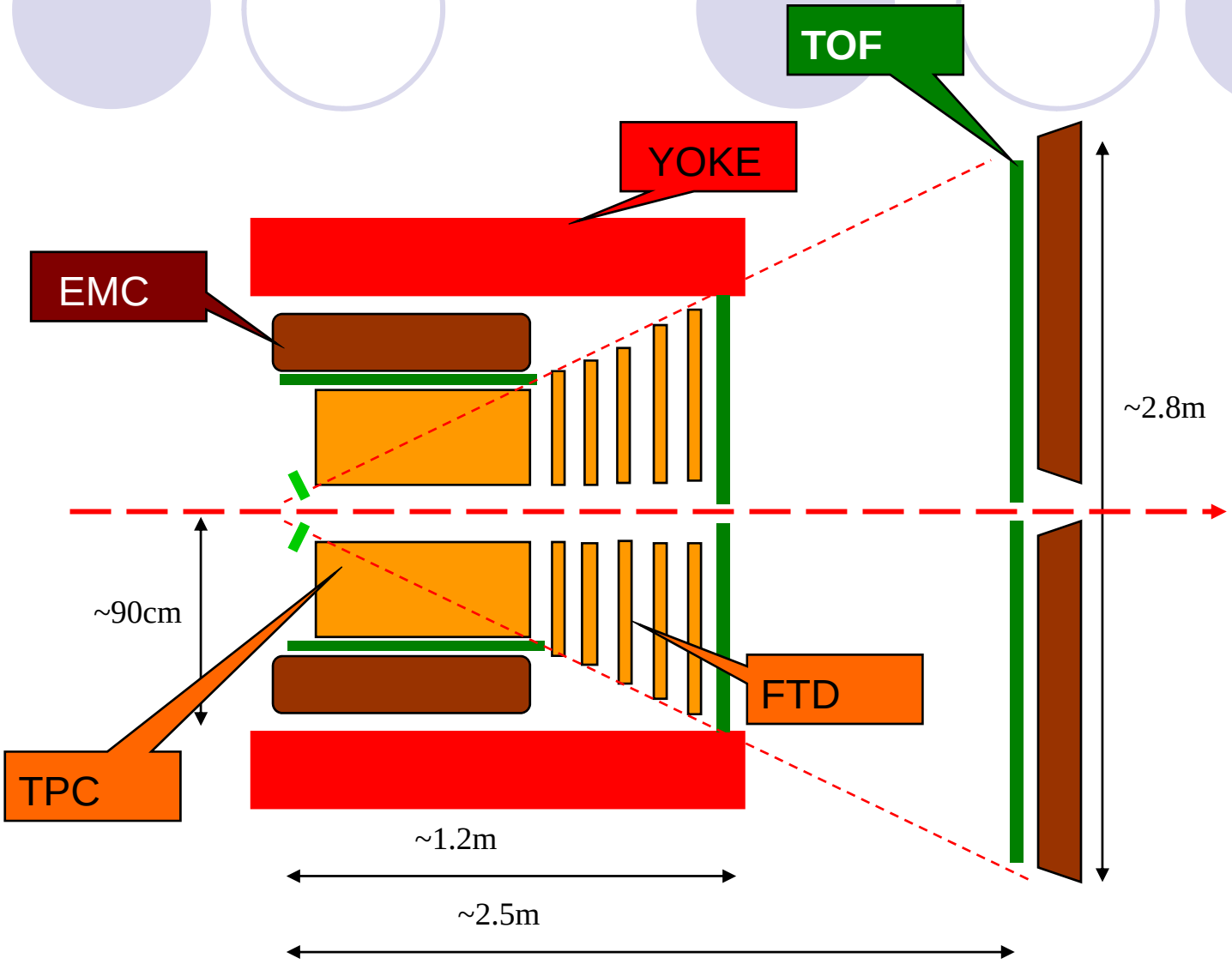


- R_M(CsI)=3.5cm
- θmin=7° → D^{min}=1m

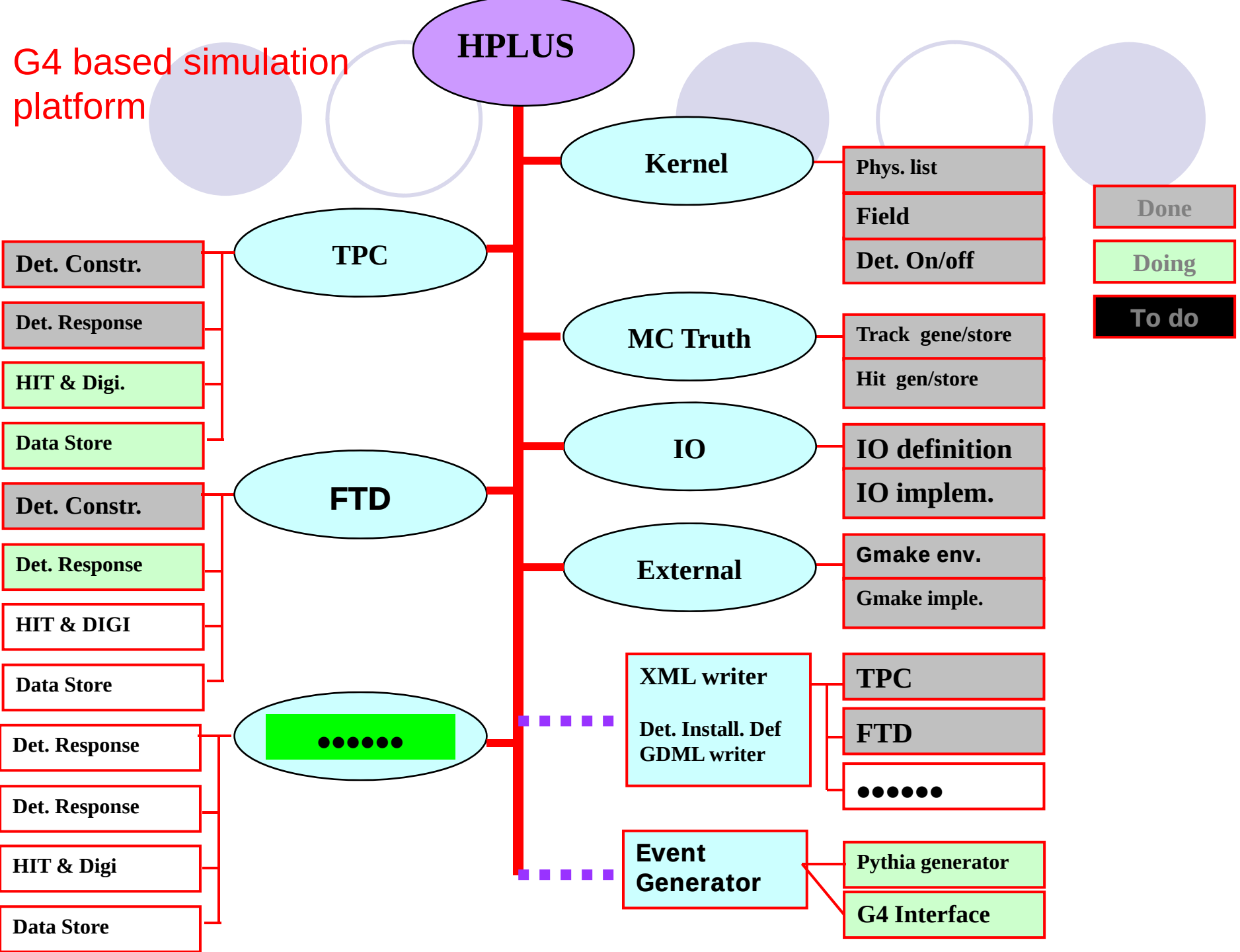
Phase space distribution for charged particles

- Dominant at forward sphere in laboratory.
- 30° defines a good boundary
- For the channels above, K^+ in forward angle could be used as a fast trigger.
- Distance of EMC to target: >1m

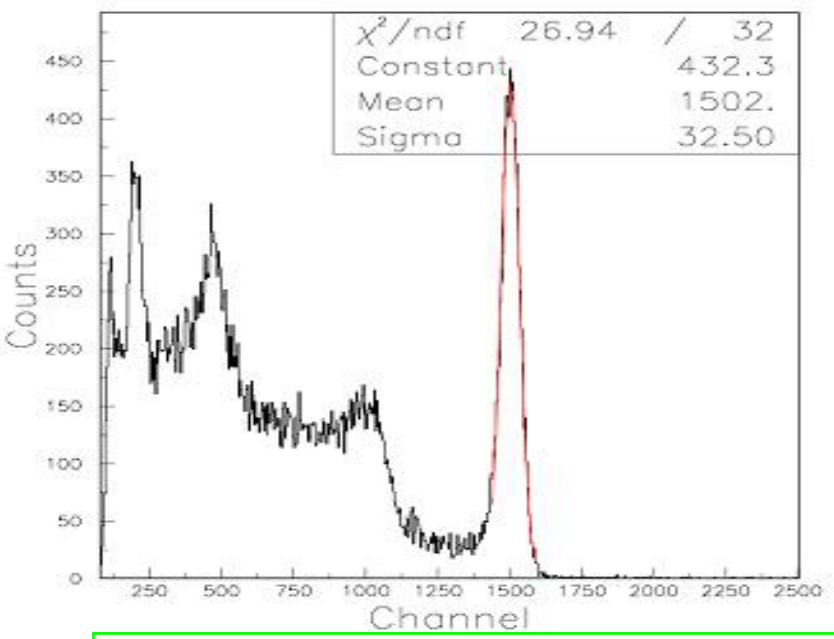
Current consideration of HPLUS



G4 based simulation platform



3.1 CsI crystals



^{138}Cs source test:

light outputs: 20% higher than Hamamatsu sample.

Energy resolution: 5.1%

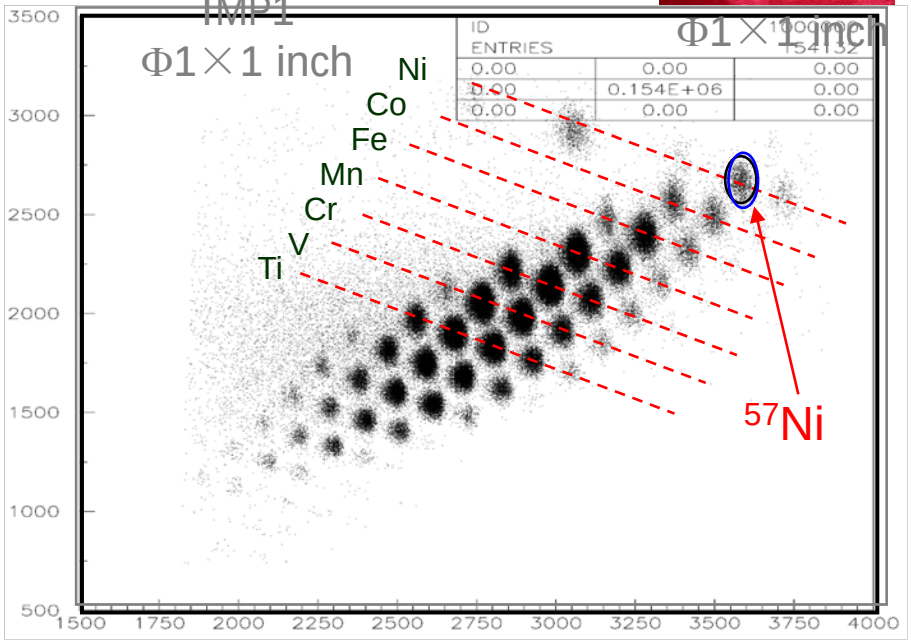
Beam test:

50 MeV/u ^{58}Ni+Ta (93mg/cm^2)

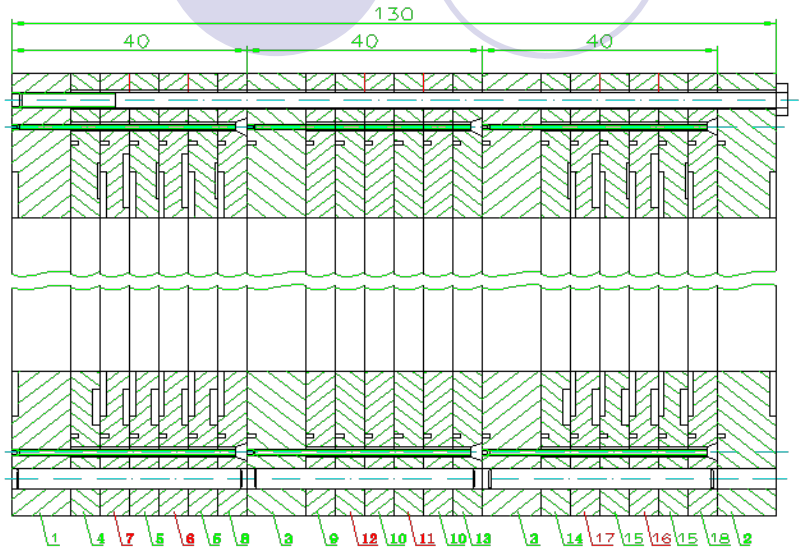
CsI(Tl):

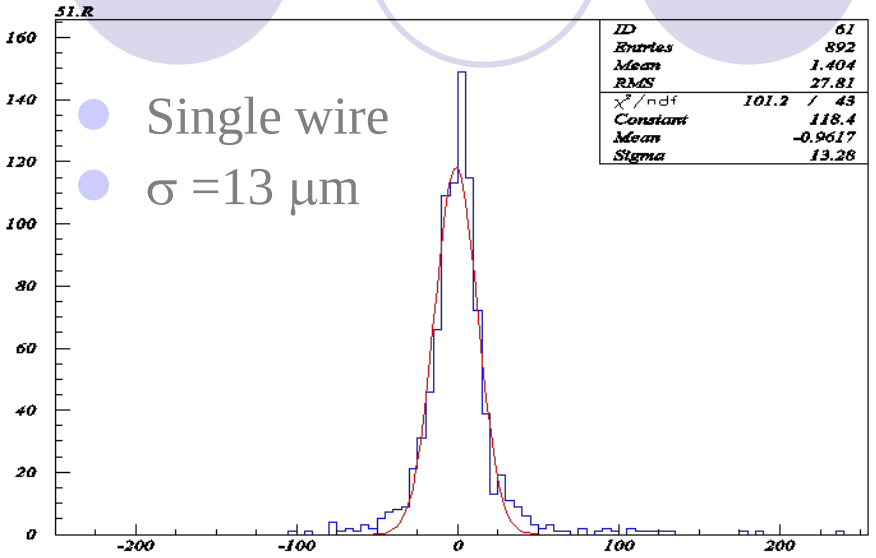
size: 20×20 ×20 mm^3

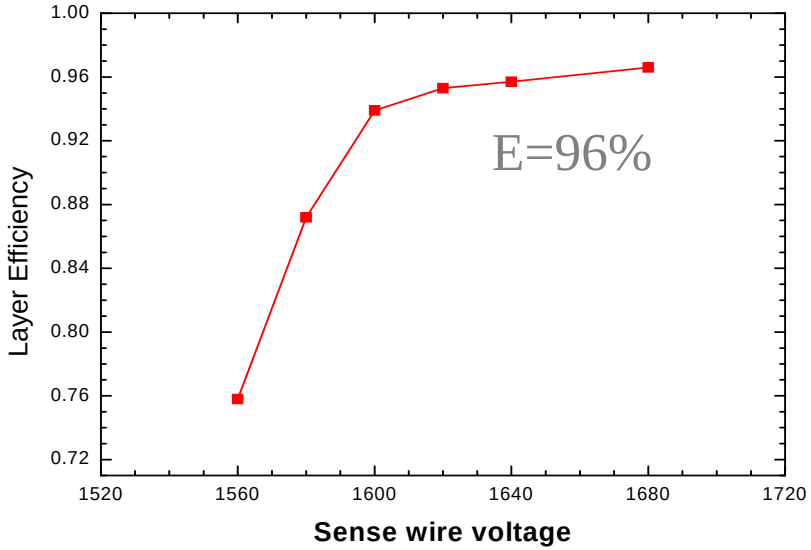
readout: PD

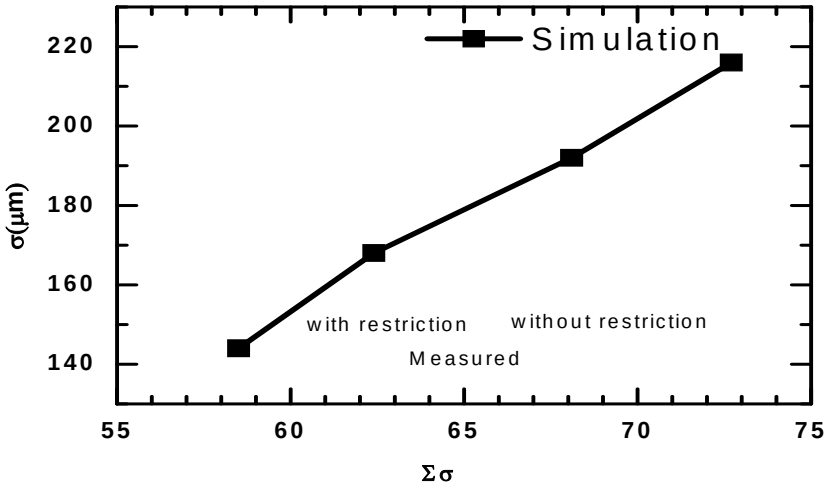


3.2 MWDC: Prototype test

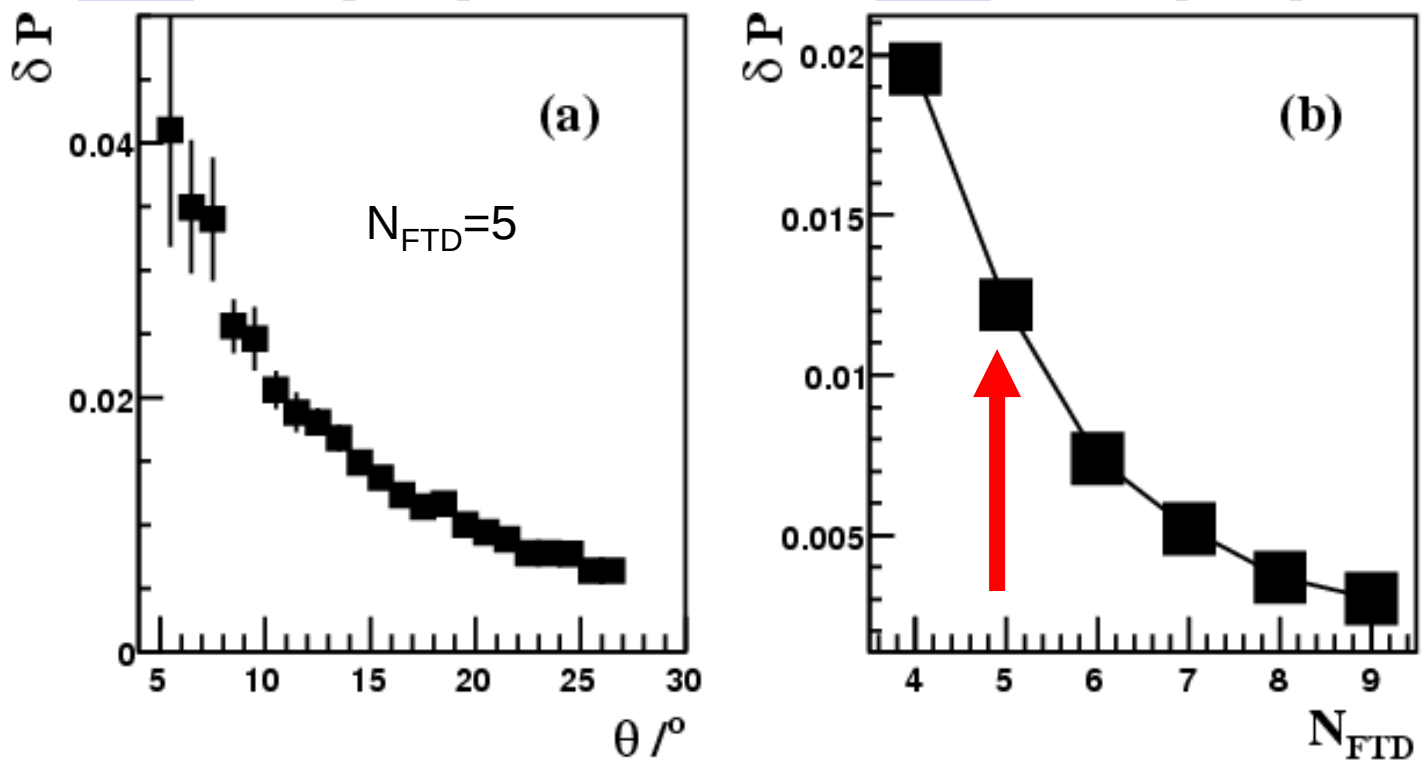








Forward tracking ability

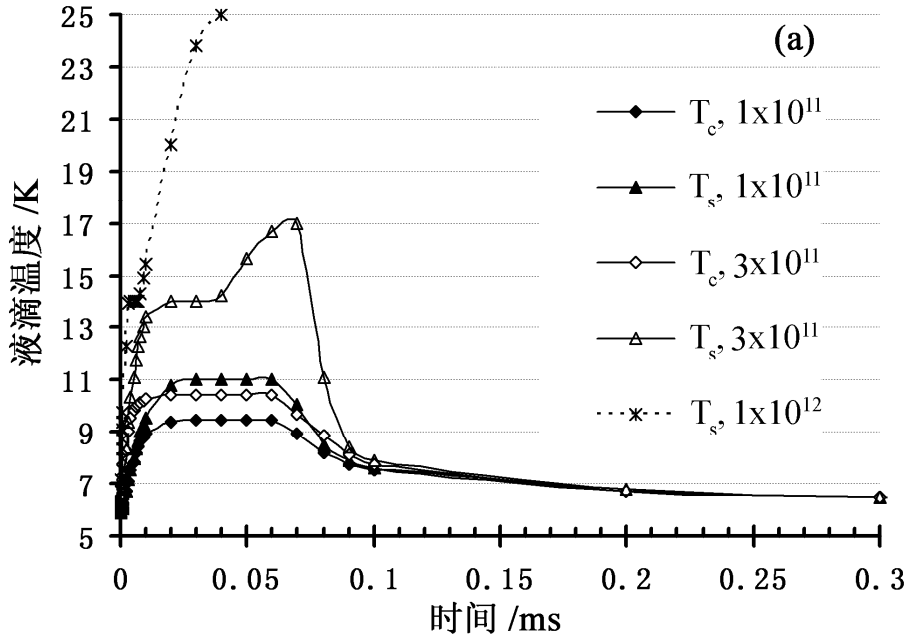


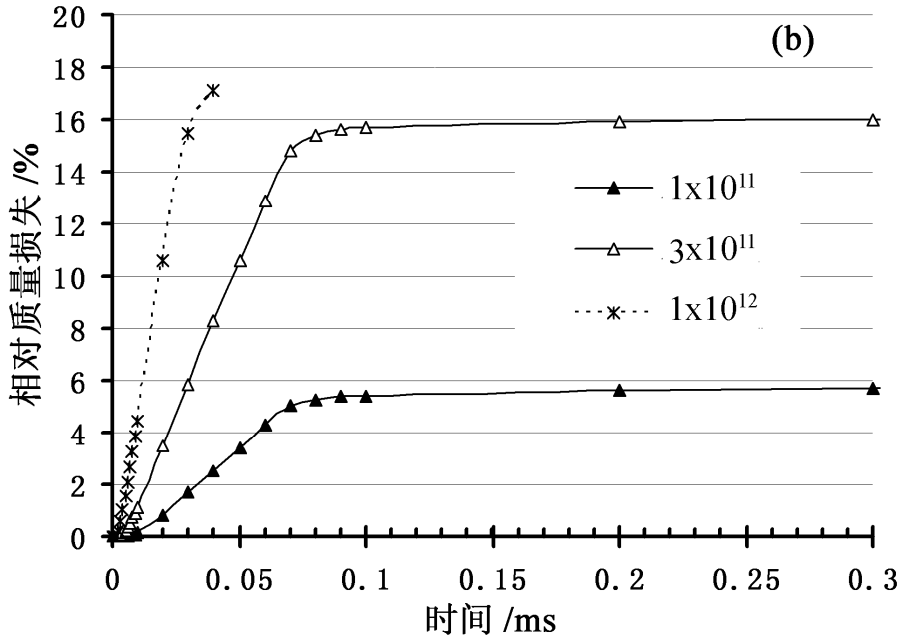
- FTD improves resolution at forward region
- We need at least 5 pieces of MWDC

4 Summary

- HIRFL-CSR provides plenty opportunities for hadron physics research with 2.8GeV proton beam.
- HPLUS is on conceptual design stage. Design will be focus at forward angle. High momentum resolution and high coverage for both charged mesons and gamma are of importance.
- Full simulations for HPLUS have been started and needs increasingly large investment. R&D of the components are in process hierarchically .

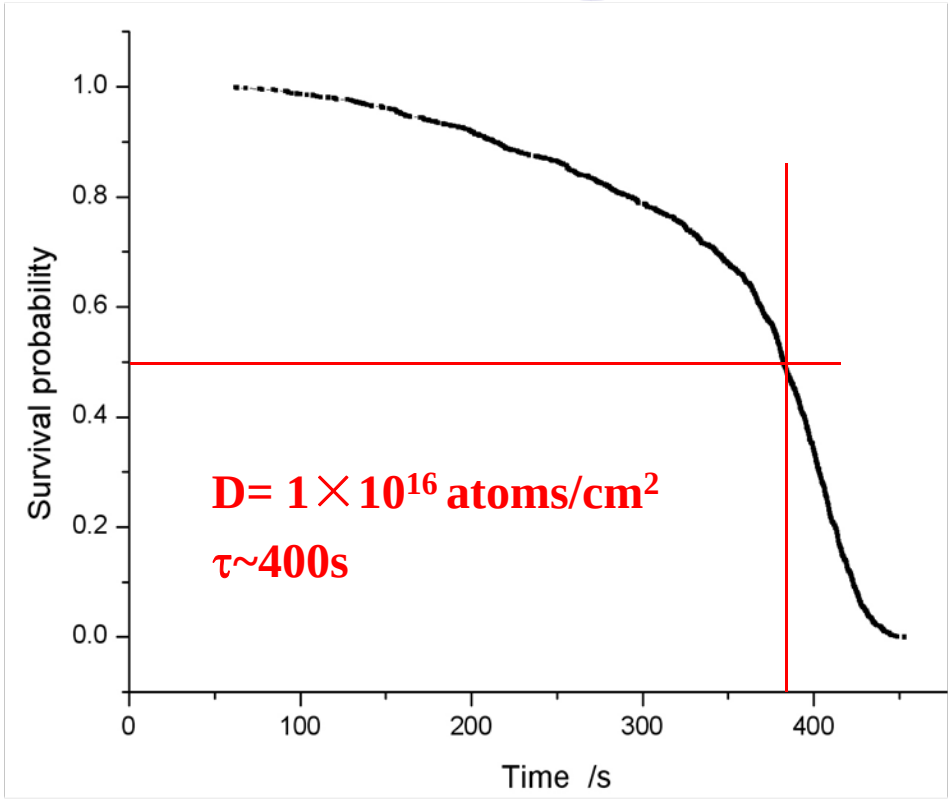
Pellet target + polarized p/d target (future)

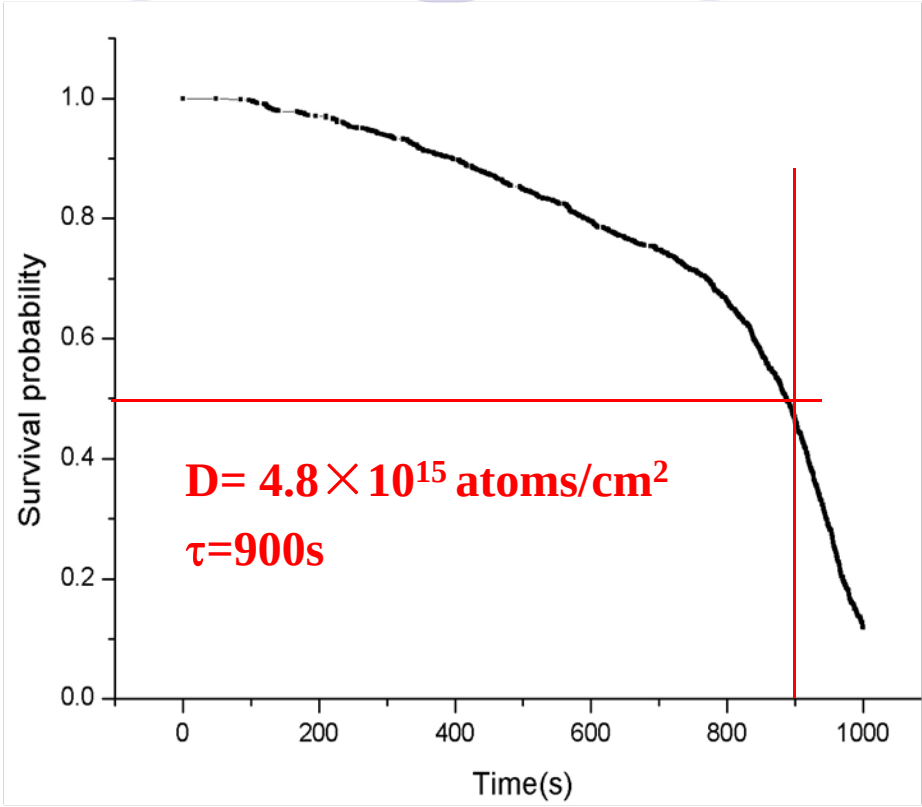




- Maximum stored ions is 3×10^{11}, pellet explored at higher intensity, correspondingly, maximum luminosity is $1 \cdot 10^{32}$ $cm^{-2}s^{-1}$ for pellet.

beam lifetime simulation





- Proton beam lifetime ~ 400s at 2.8GeV

Luminosity Estimation

- $3 \times 10^{31}/cm^2/s$

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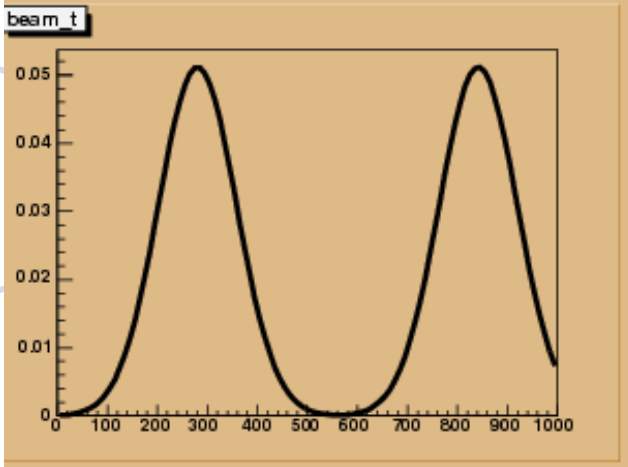

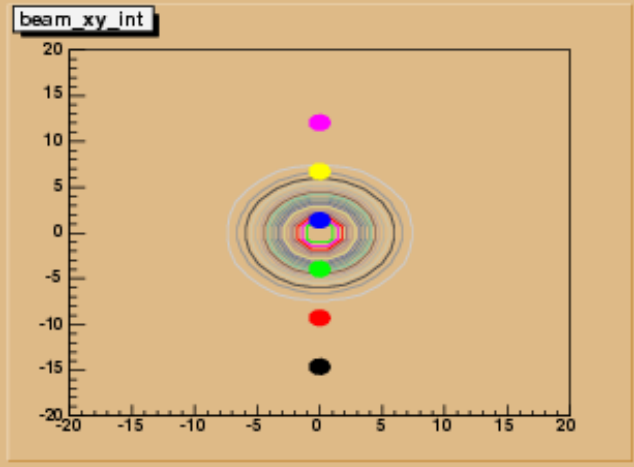

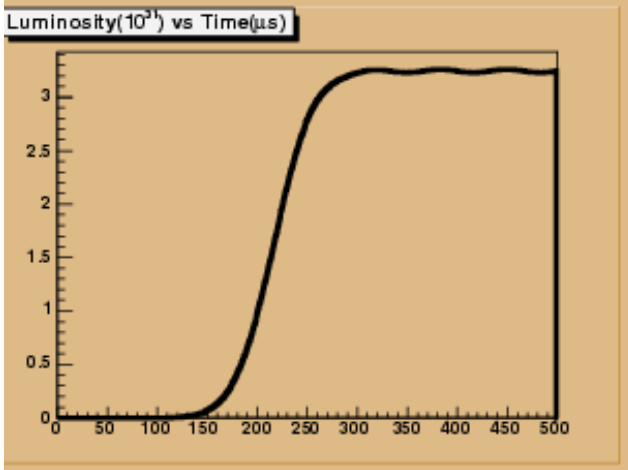

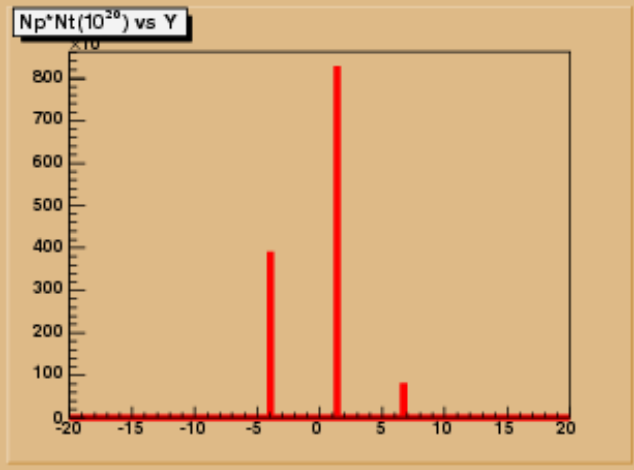

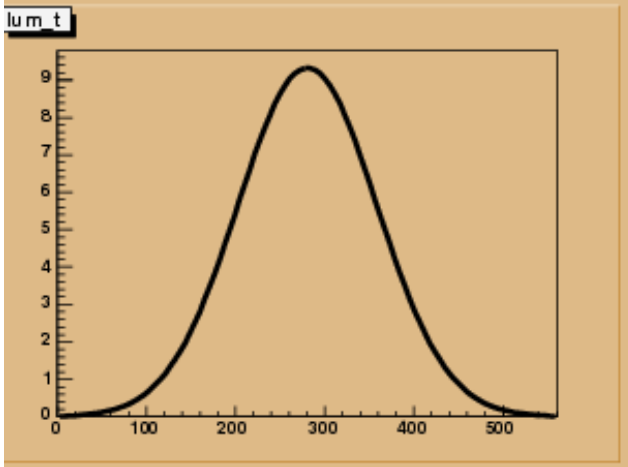

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Beam Emittance: 10.0π mmmrad
Bunch Length σ: 50.0^o
Pellet Radius: $15.0\,\mu m$
Pellet Frequen.: 15.0 kHz
Pellet Velocity: 80.0 m/s

Luminosity: 3.2×10^{31}

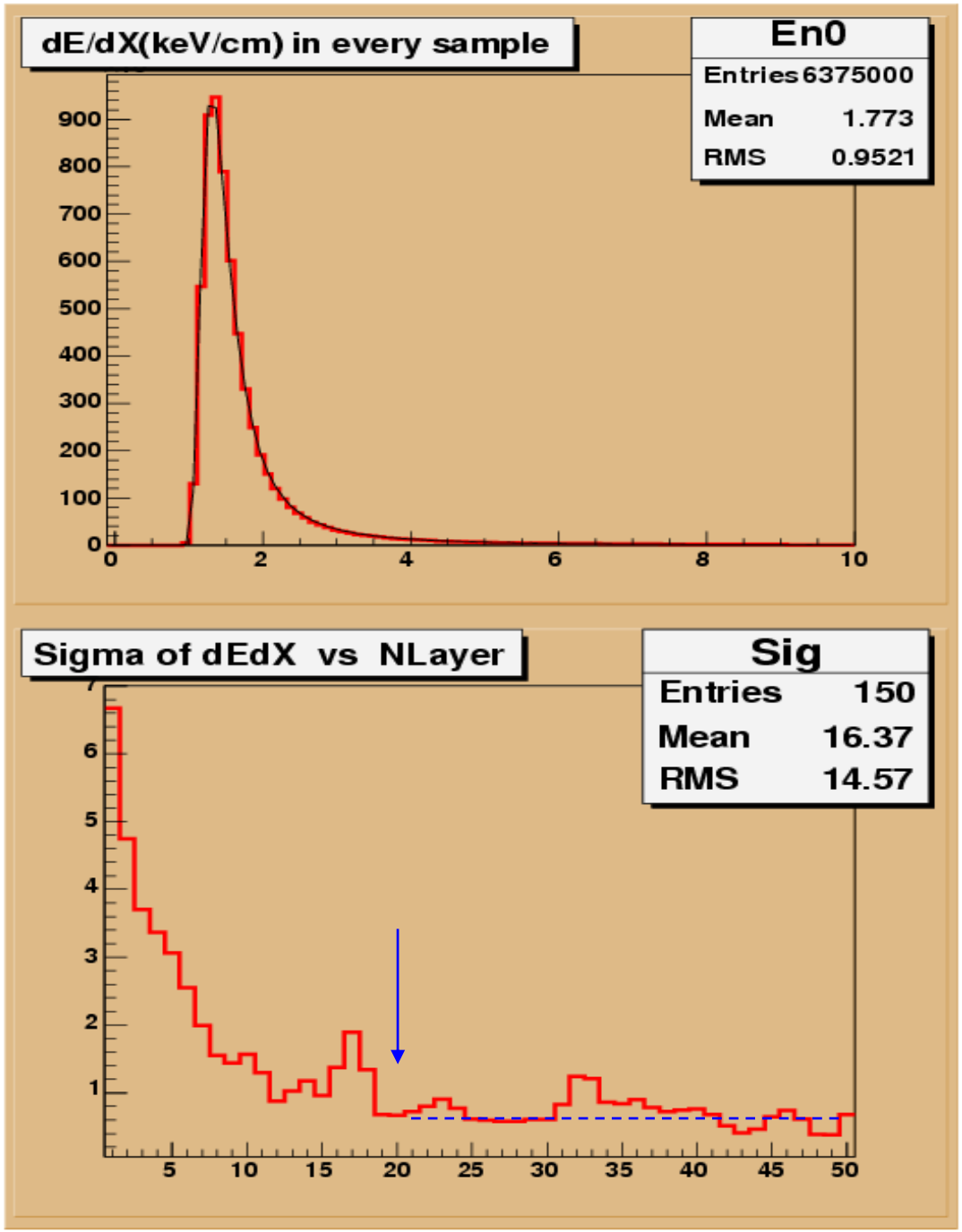
3.3.2 PID for charged particles

TPC FS: dE/dX vs Sampling Layers

- 1GeV π+
- truncate at 3.5KeV

Sig:=width/MPV

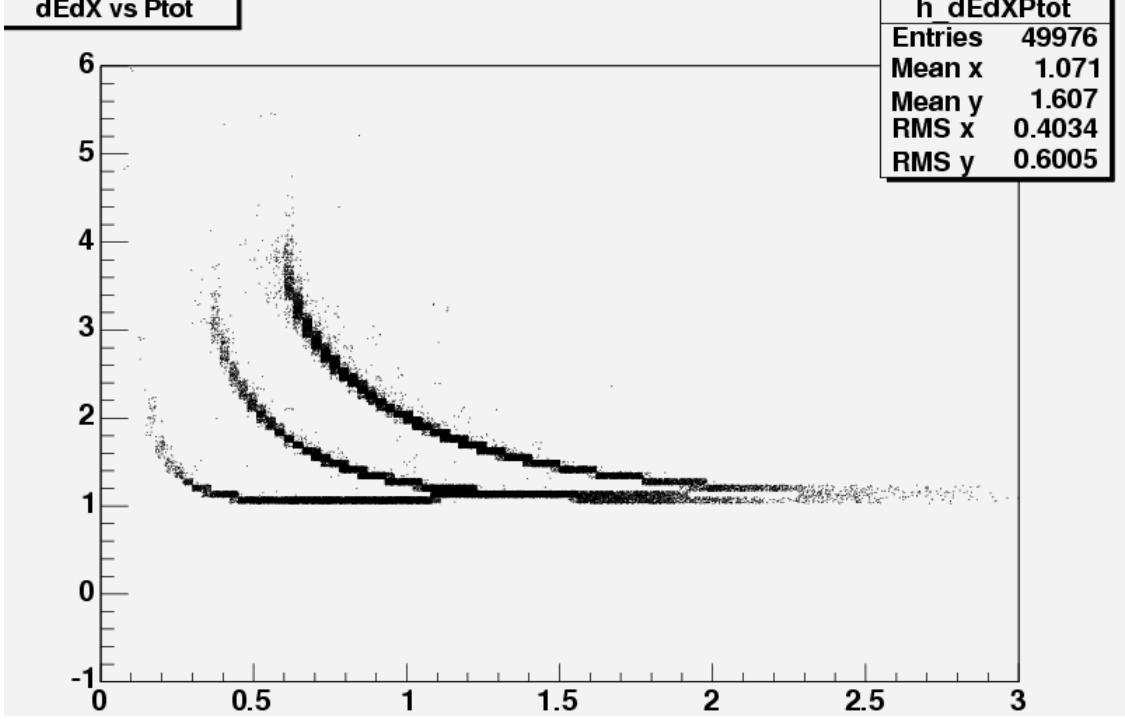
Sampling up to 20 times, dE/dX → Constant

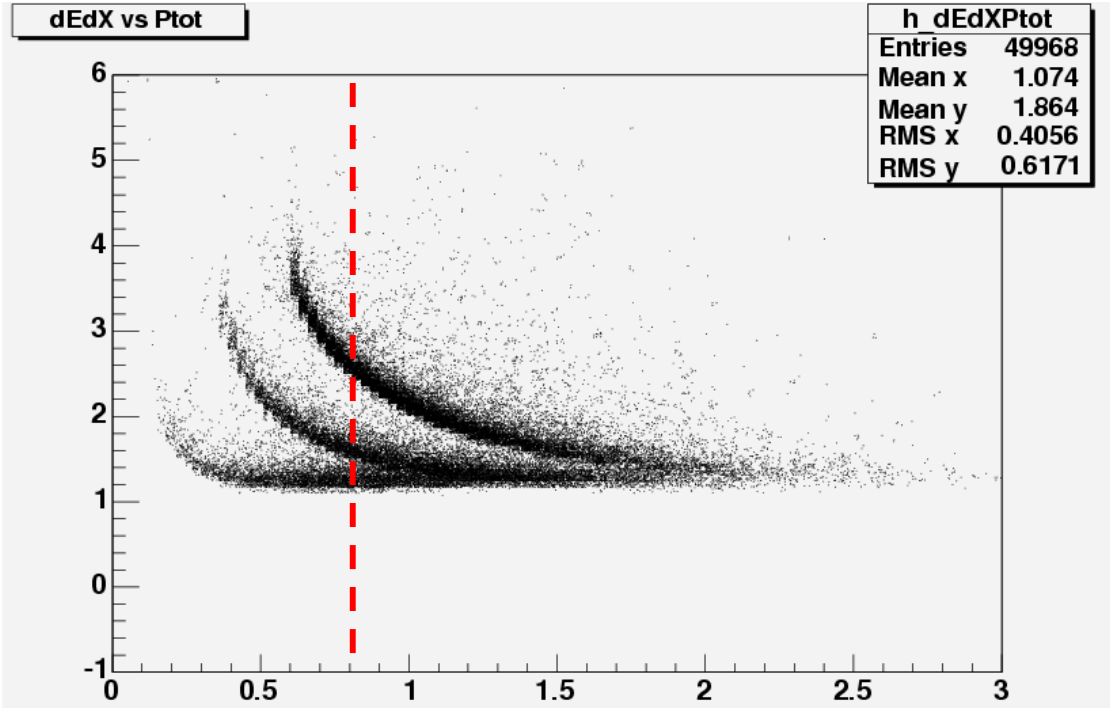


dE/dX vs P

50 Samplings Landau +

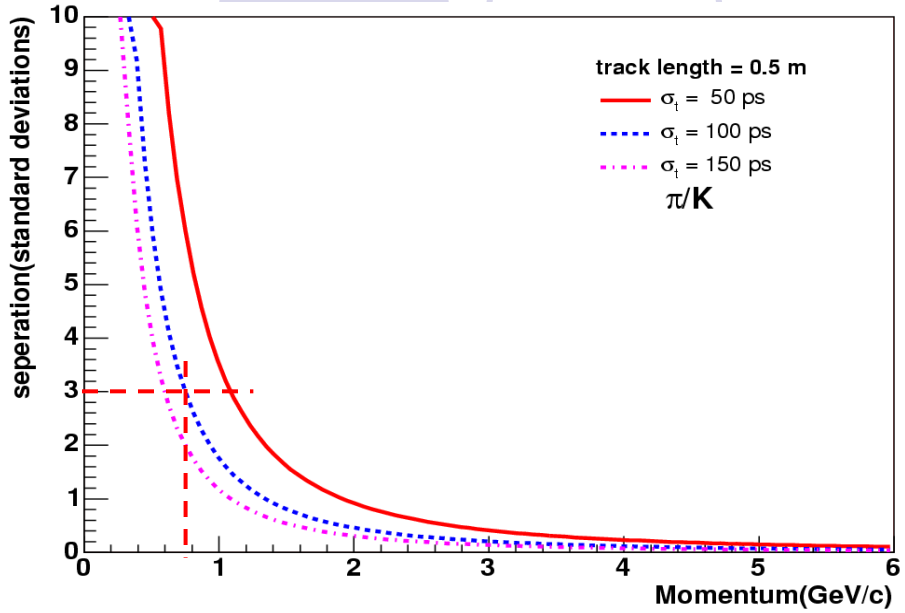
5% Gaussian Electronic fluctuation

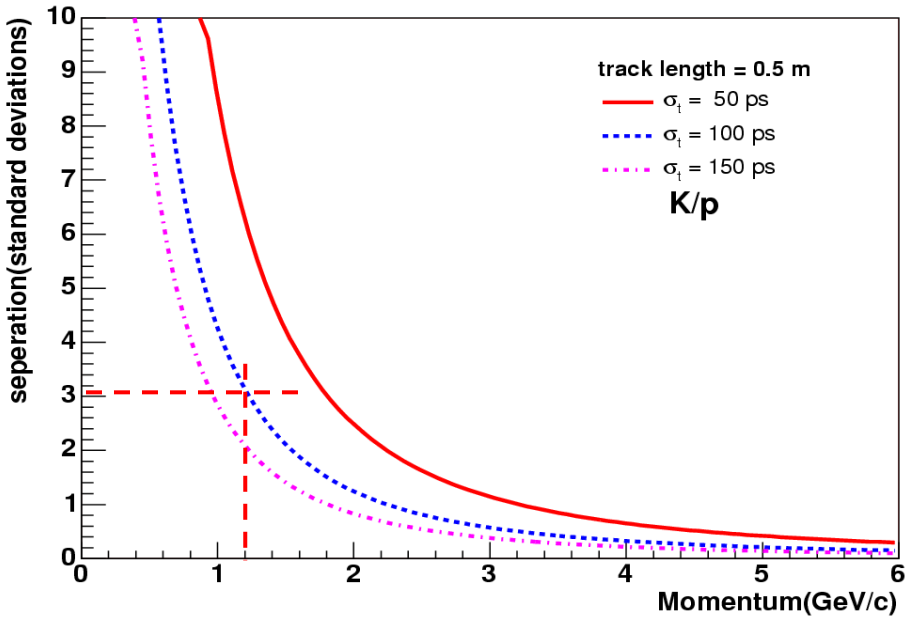




- Ideal case: PID of π^+ and K+ up to ~0.8GeV/c
- Regardless the large difference between the yield of π^+/p and K^+.

Barrel – Short flight length





Typical flight length ~ 0.5m

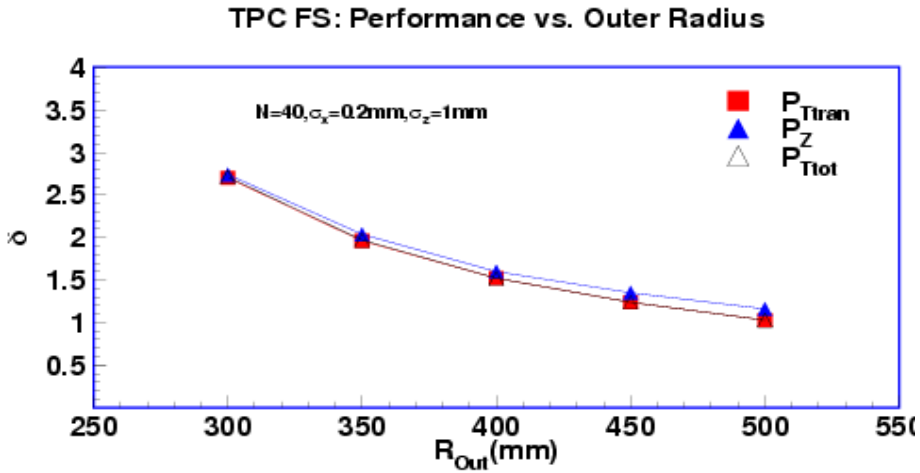
Due to short flight length, TOF PID can't extend the PID range of *dE/dx* much.

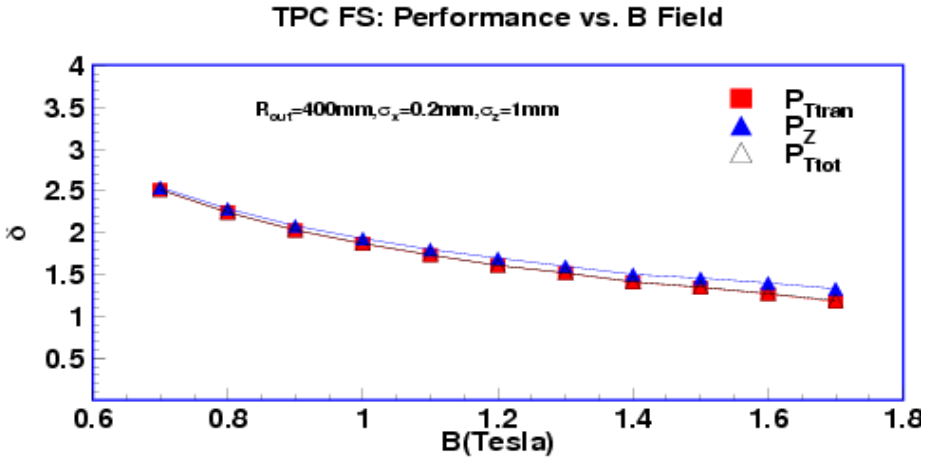
TOF-Barrel used as trigger detectors only

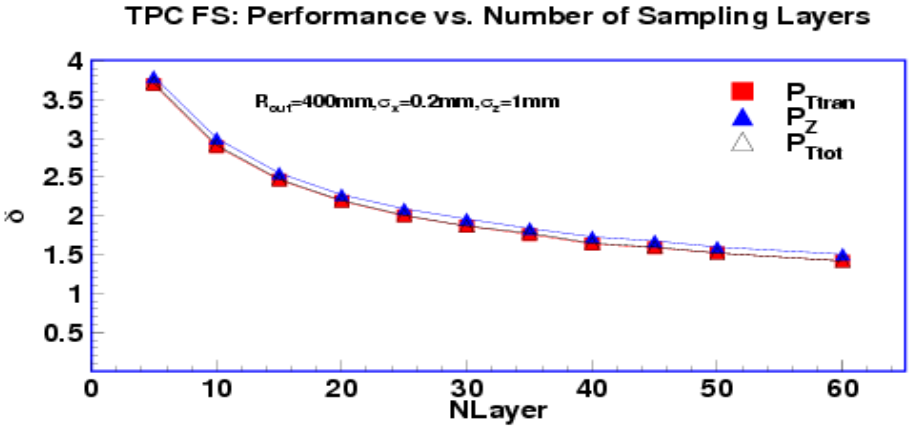
For high momentum particle identification, DIRC option.→ Challenge 1.

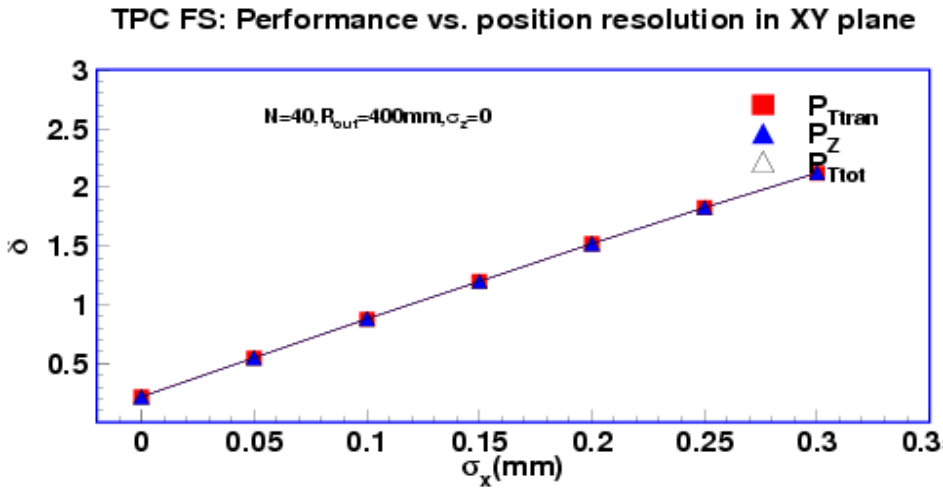
3.3.3 TPC resolution simulation

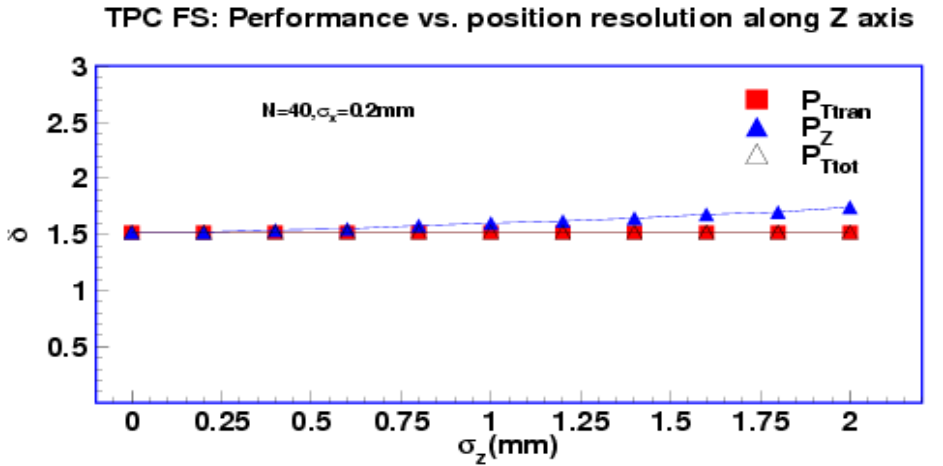
average ~1.5% momentum resolution is possible











3.3.4 TPC under high event rate → Challenge 2

Event time difference ~ 2μs

Full drift time (1.5m TPC) 30 μs

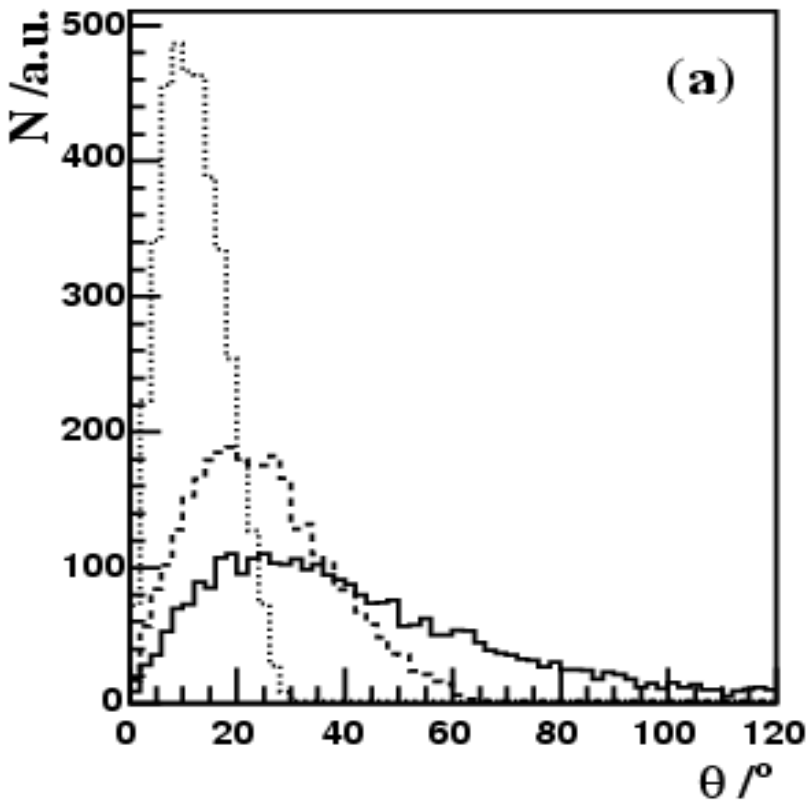
Multi-event multiplicity in TPC ~ 45

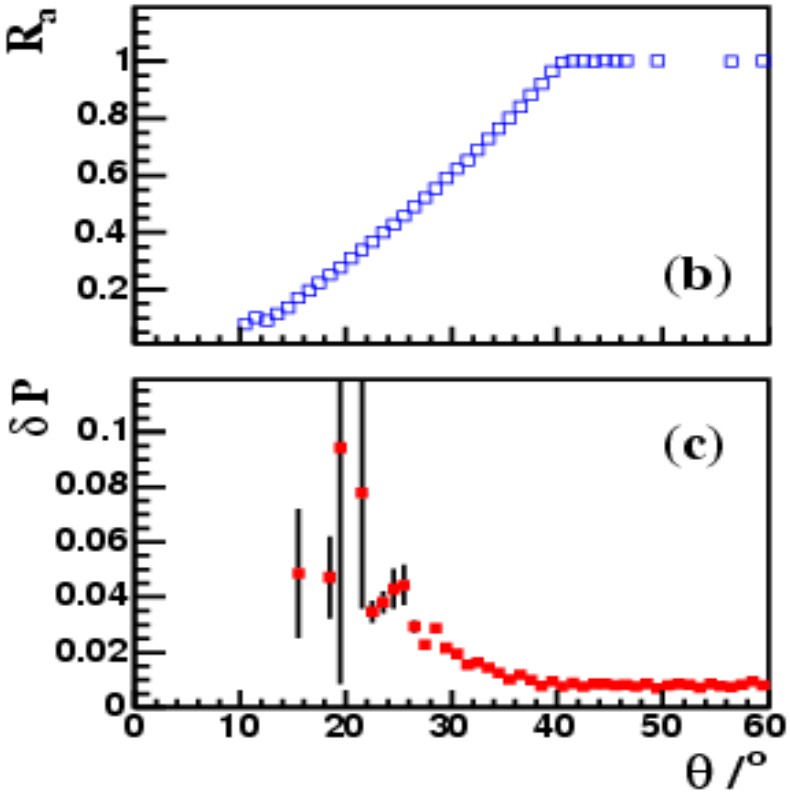
Mean track Multiplicity/event in TPC ~3

Tracks rate in TPC 1.5×10^{6}/s

- Possible solution: with the aid of TOF barrel to do event stamping
- Simulation going on

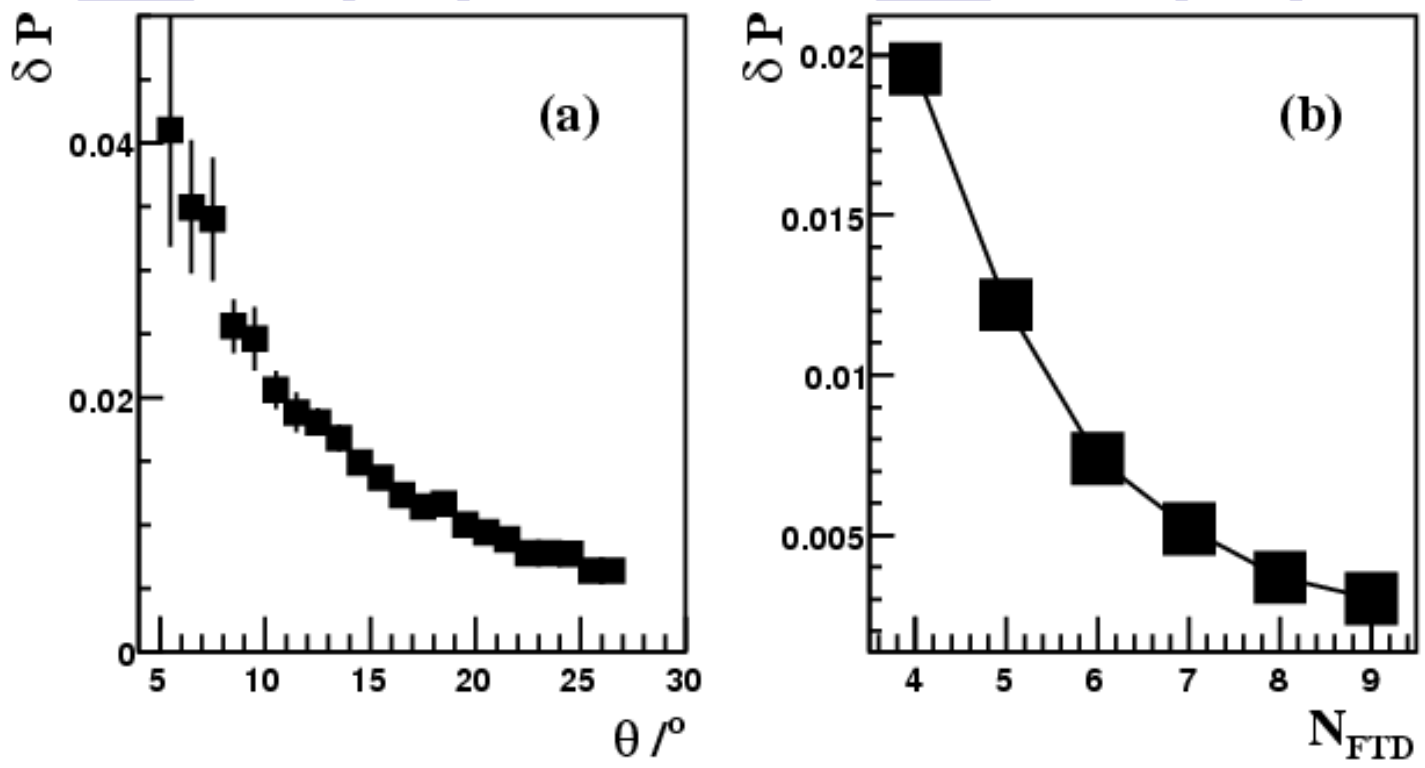
Necessity of forward tracking





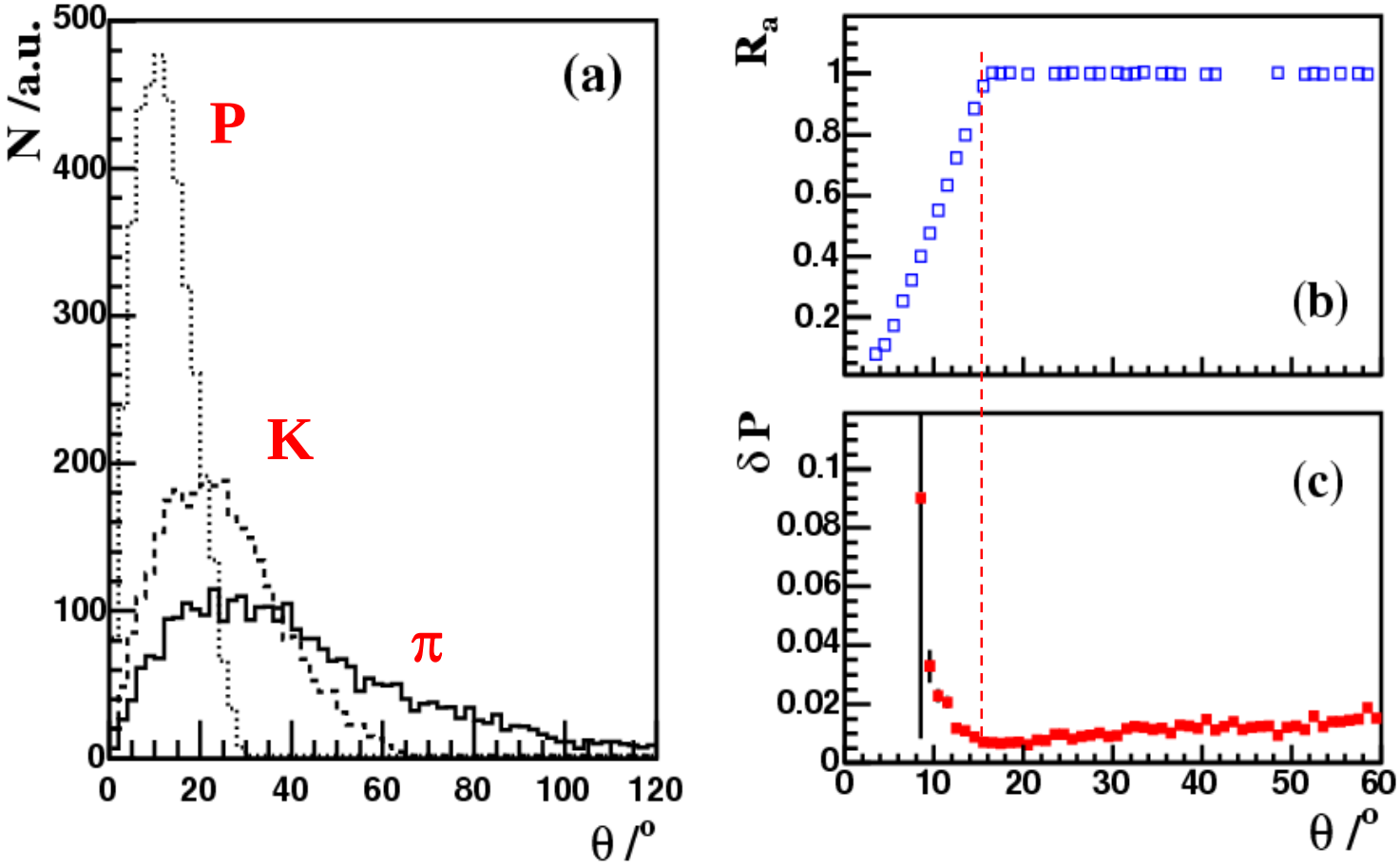
- TPC not sufficient for PID at forward region

Necessity of forward tracking



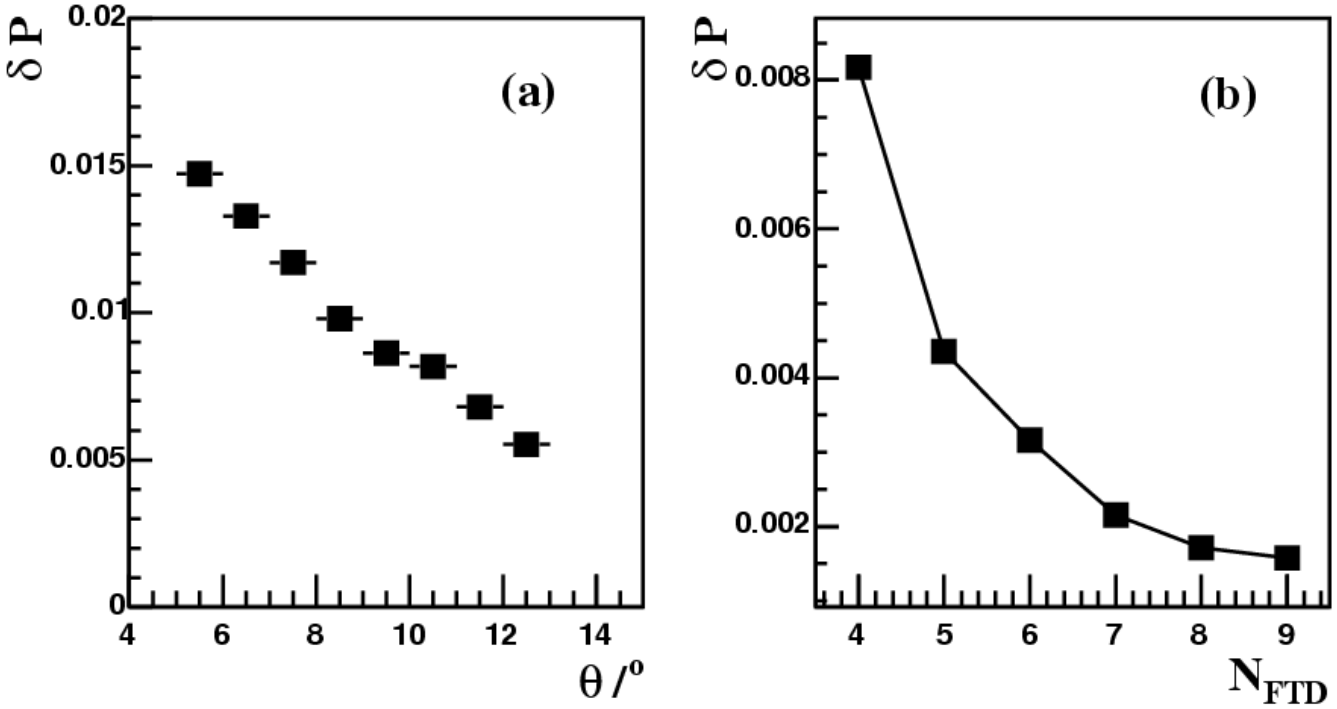
- FTD improves resolution at forward region

Necessity of forward tracking



- TPC ability weak at forward region

3.3.5 Necessity of forward tracking



- FTD improves resolution at forward region

Outline of the simulation

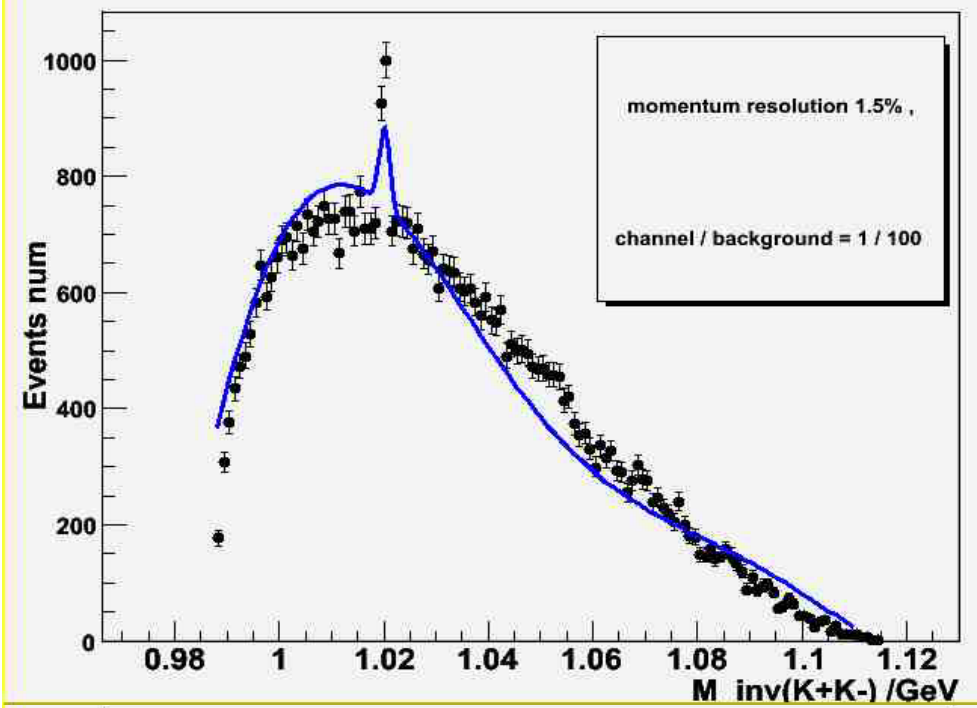
- Background and channel simulation shows that in lab most of products dominate at forward angle, → design should focus at forward angle in lab
- Strangeness meson used for fast trigger
- TPC not sufficient, FTD and long TOF time necessary
- → A later version of design
- Outlook → Full simulation and final optimism

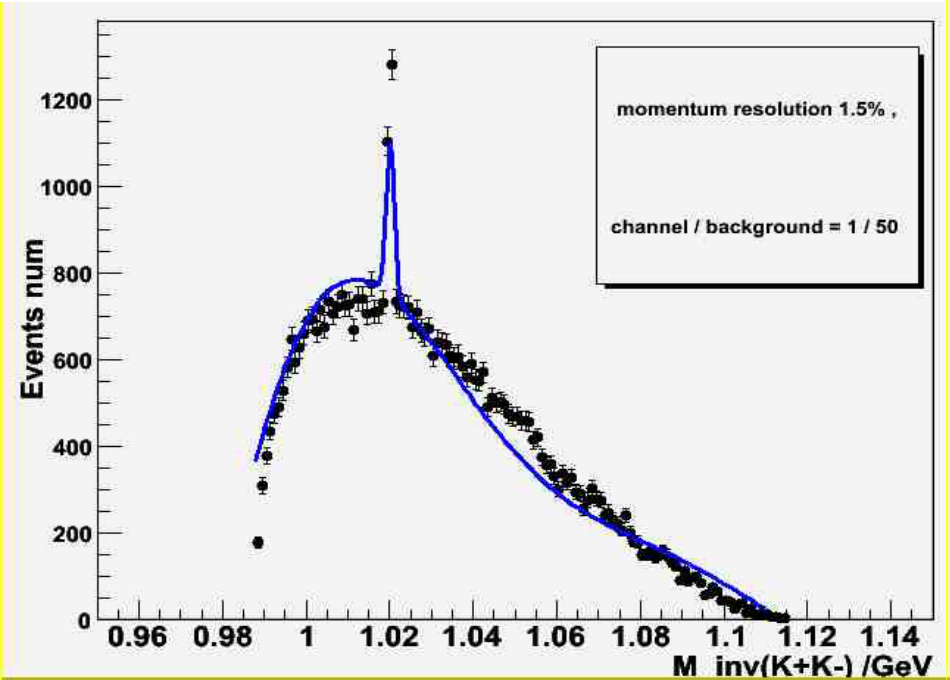
→ Increase manpower investment

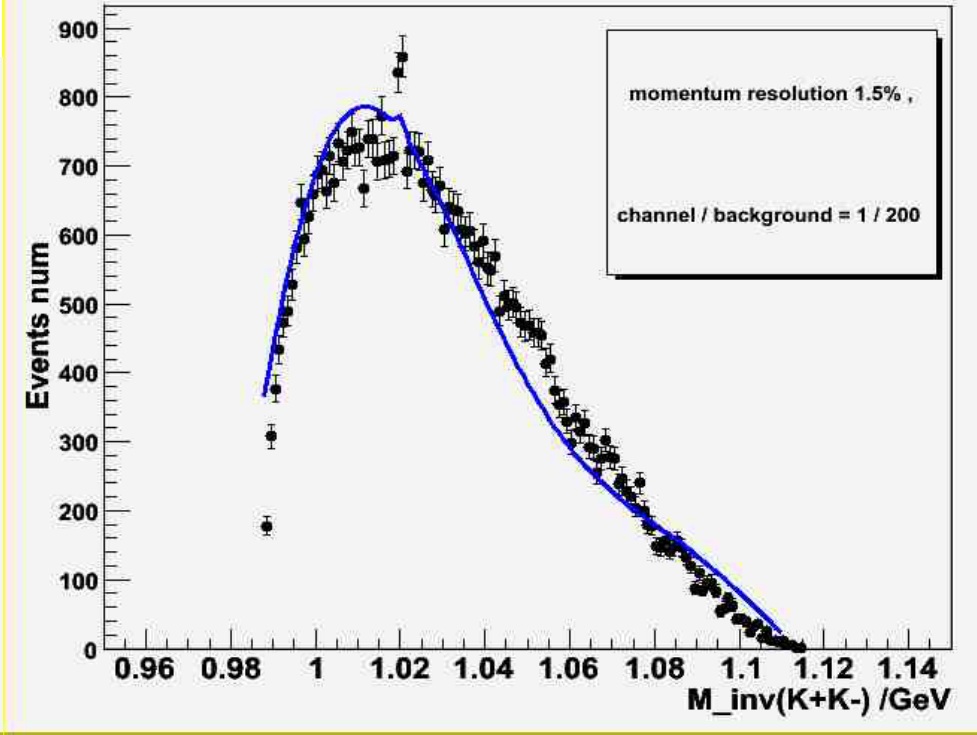
§ 2.3 Simulations for HPLUS

- 2.3.1 Phase space distribution
- 2.3.2 PID ability of TPC / TOF
- 2.3.3 Fast trigger, Necessity of forward tracking
- 2.3.4 Recent consideration of HPLUS

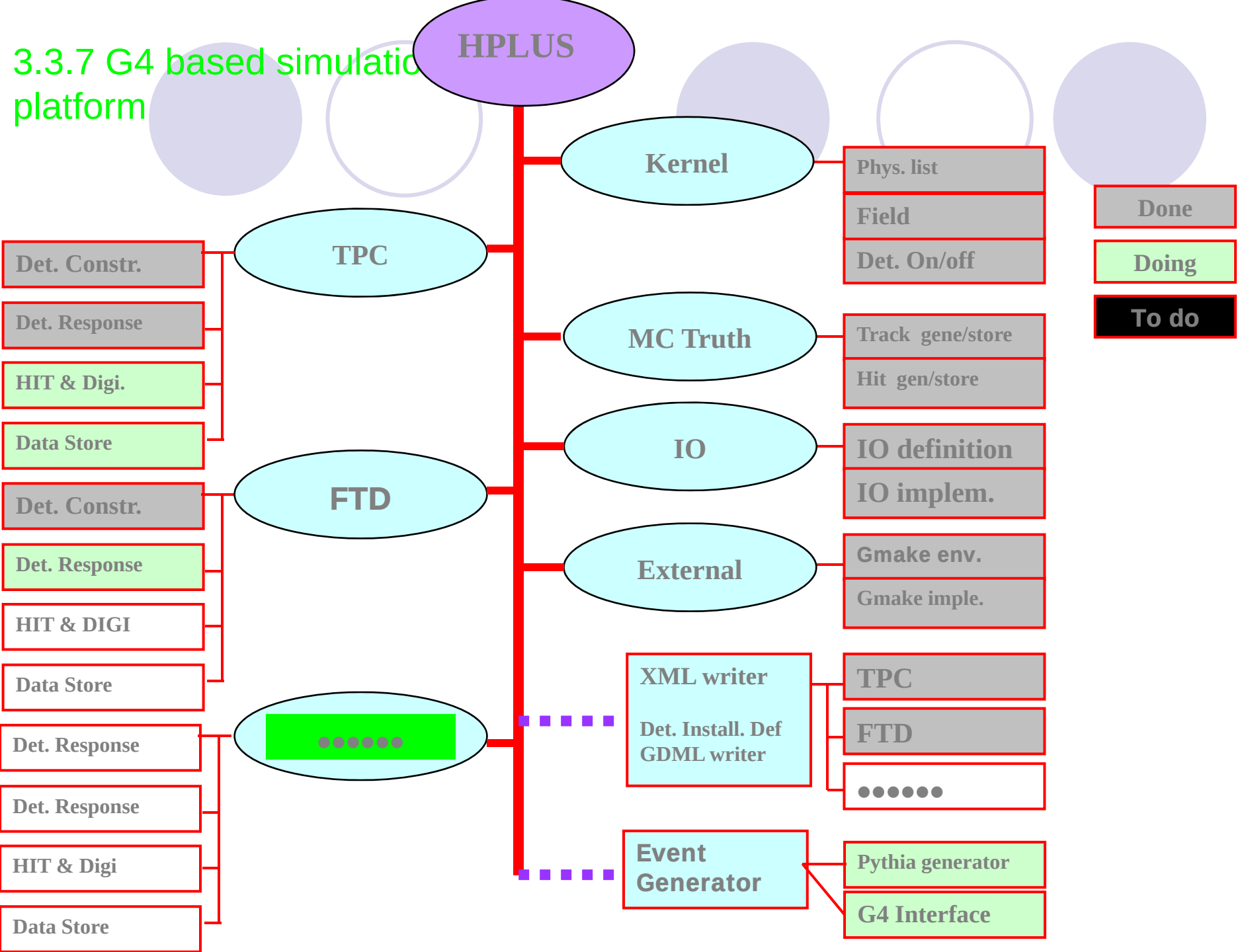
3.3.6 $pp \rightarrow pp\phi \rightarrow K^+ K^-$ with smeared momenta







3.3.7 G4 based simulatio platform



3 Projects in progress

- 3.1 CsI crystal growth, simulation and test
- 3.2 Neutron Wall R&D
- 3.3 Drift Chamber R&D

- 1 HIRFL-CSR complex
- 2 Hadron Physics LanzhoU Spectrometer
- 3 Projects in progress
  - 3.1 CsI crystal growth, simulation and test
  - 3.2 Neutron Wall R&D
  - 3.3 Drift Chamber R&D
- 4 Summary

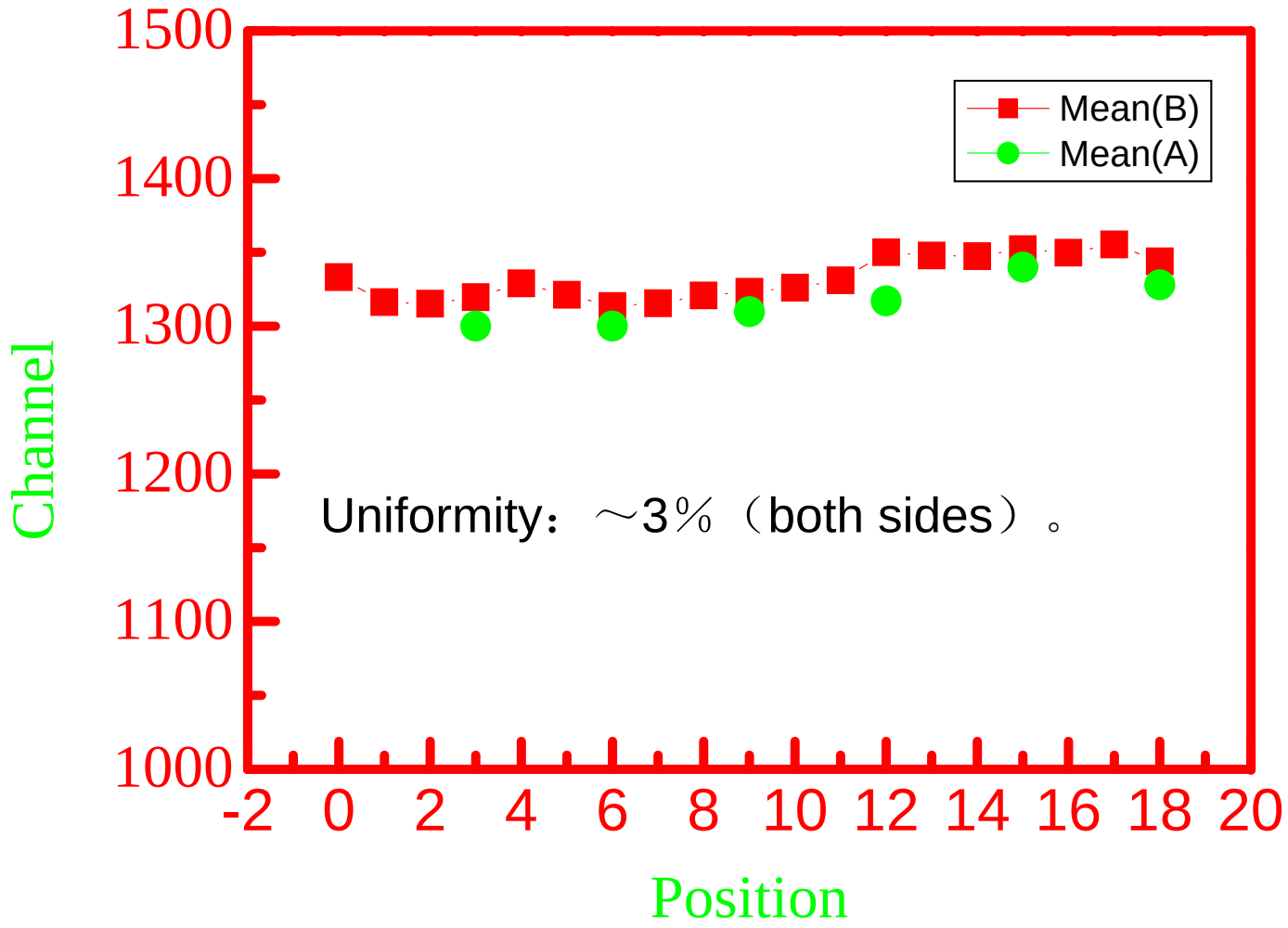
§ 4.1 CsI crystal growth /test

- 1020 crystal needed in EMC,

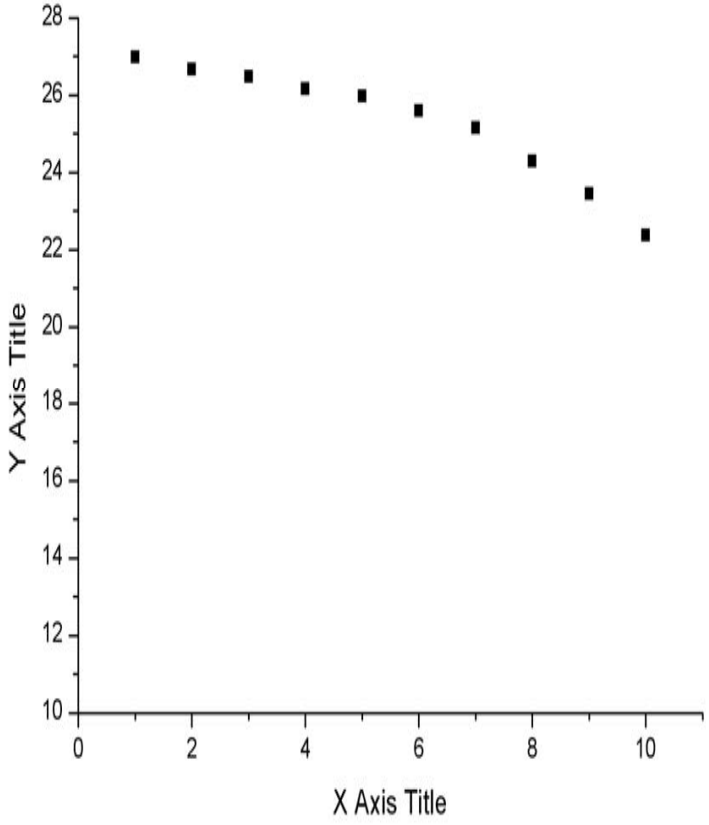
  δE/E ~3%
- ϕ11cm×35cm

  CsI crystal growth in IMP possible.
- Machining and test in progress

Uniformity test(190*60*50)



Efficiency Simulation



Surface & decay length	Efficiency
No Surf. Reflect λ=35cm	22.8%
Full reflection λ= 35cm	31.5%
Full reflection λ= 60cm	51.3%
Full reflection λ= 120cm	81%

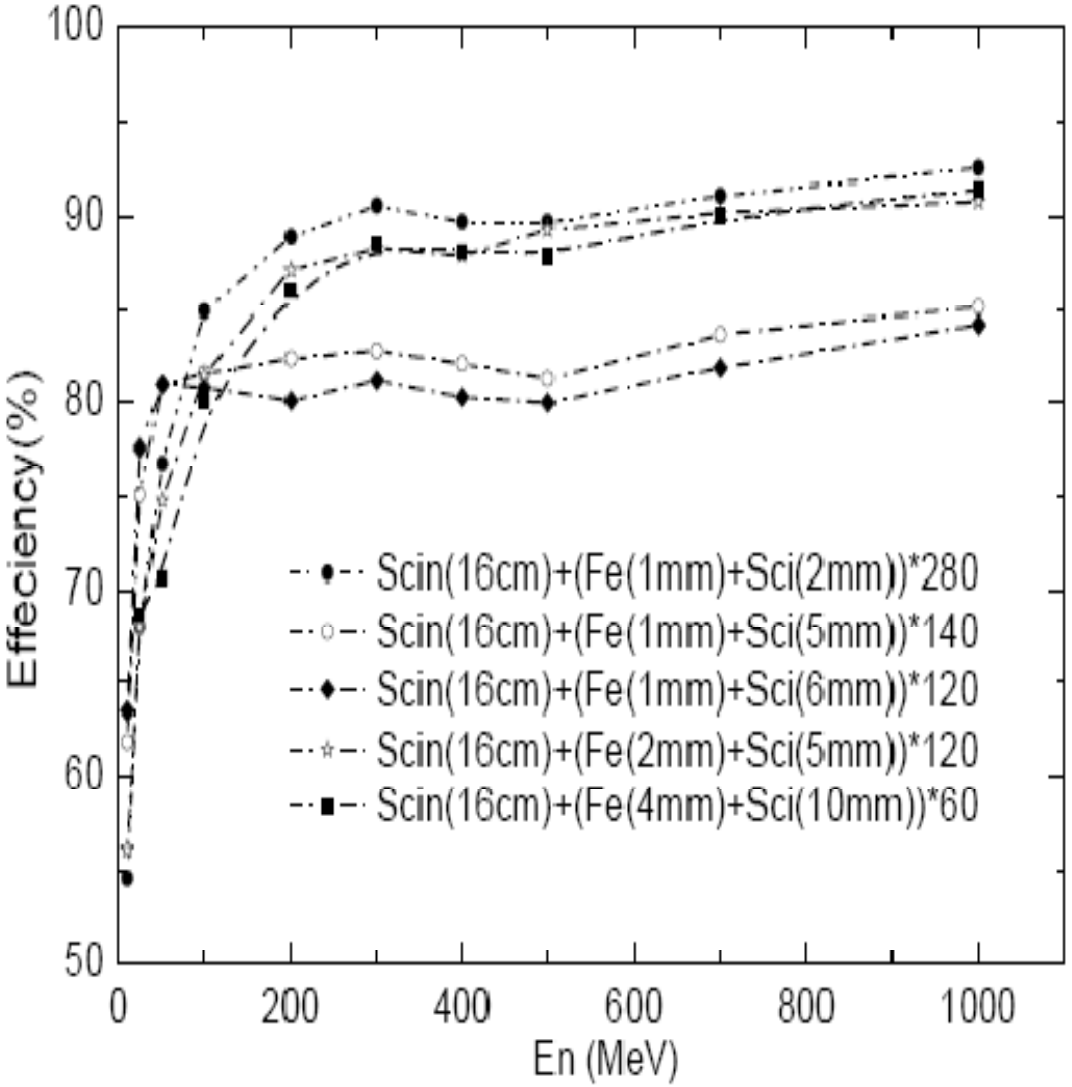
Single scintillator simulation going on

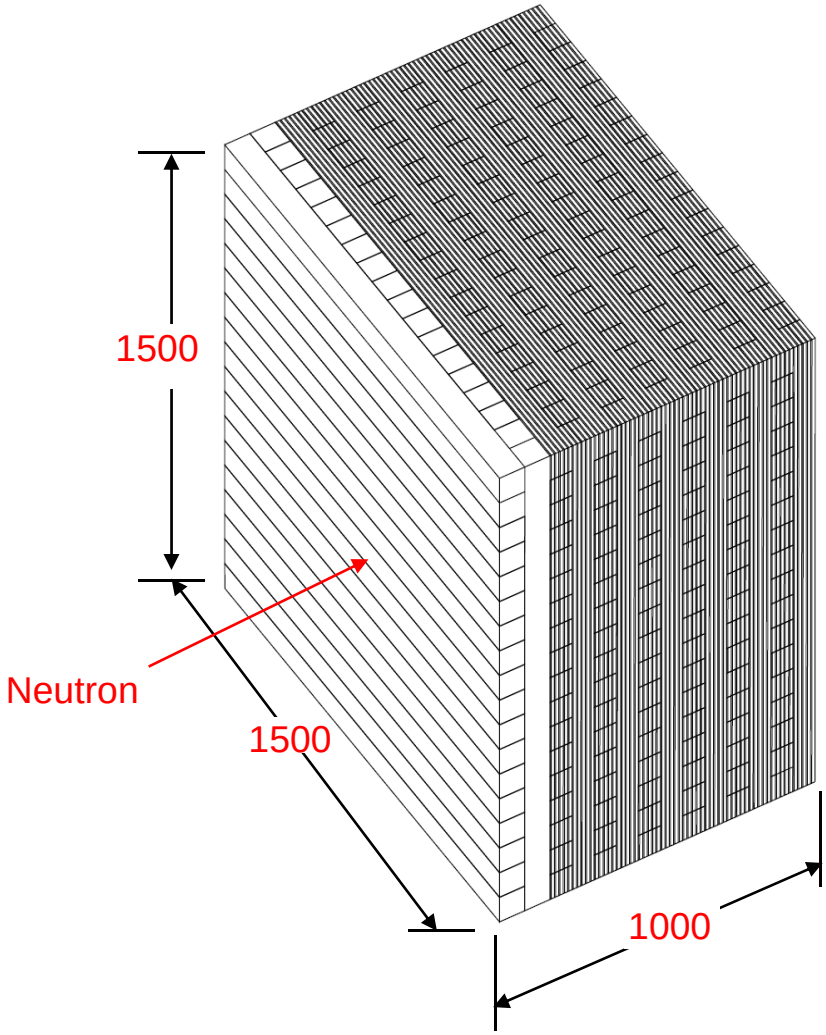
To do: EMC construction and simulation

§ 4.2 Neutron Wall R&D

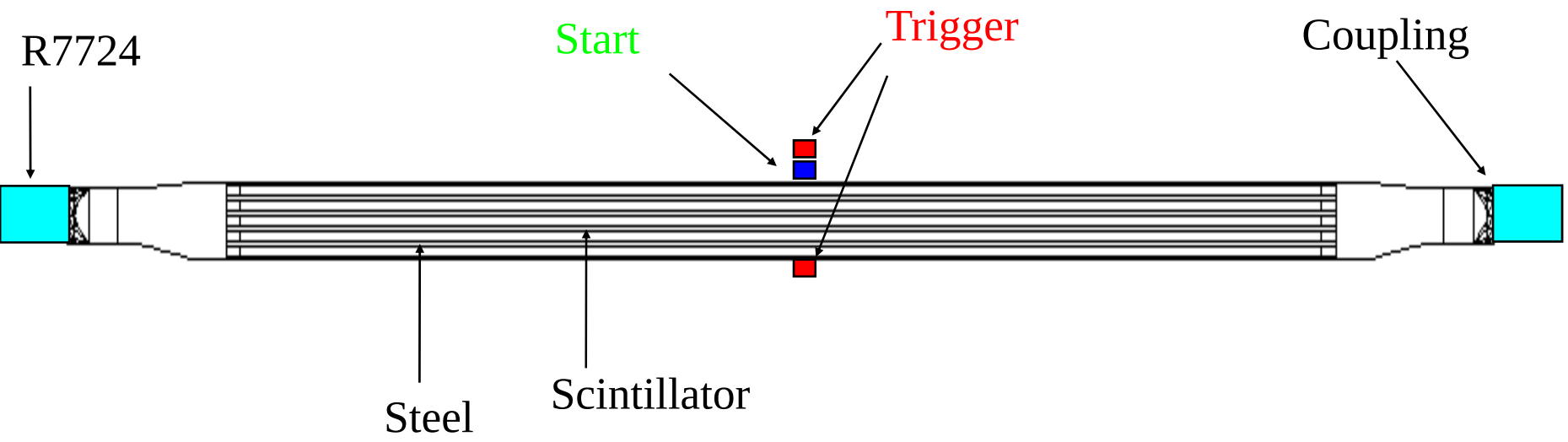
Active area	1.5×1.5m^2
Thickness	1m
Acceptance	±3.8^0
coverage	11~20 mSr
Angular resolution	0.3^0
Efficiency （1GeV n）	>90%
Position resolution	±8cm
E resolution（<1GeV n）	≤5 %

Design and structure





Calorimeter unit consistence and test

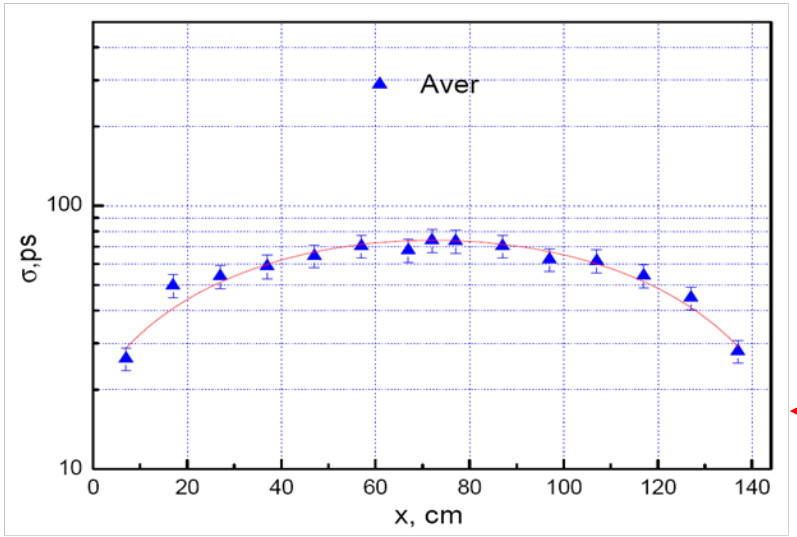


- CU: 5 scintillator layers + 6 absorber layers
- 12 CU in total

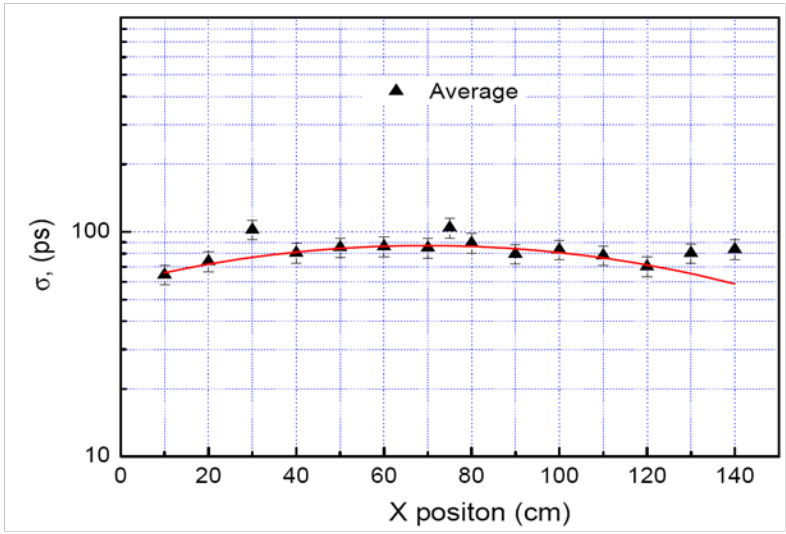
Prototype test/simulation results

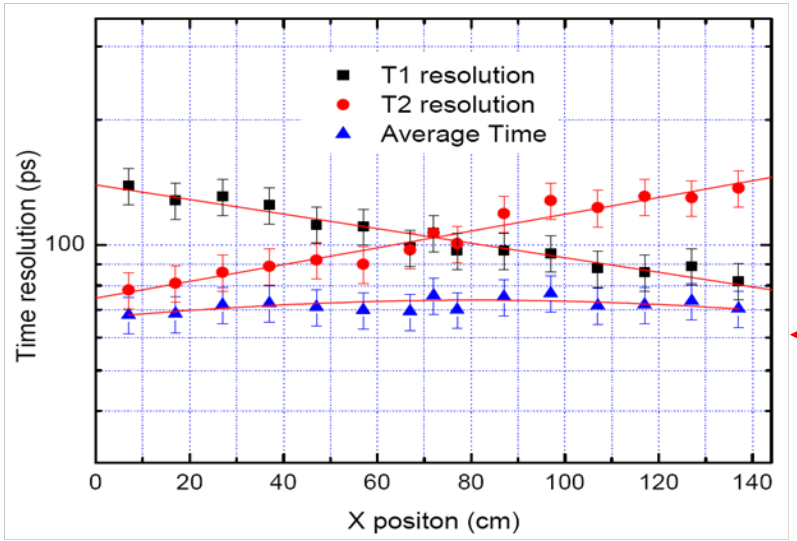
Scintillator : σ<80

Calorimeter: σ<100

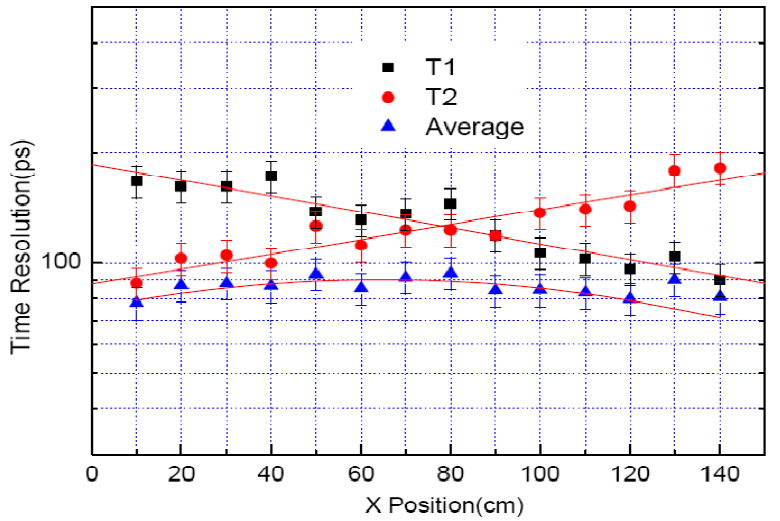


Real Test



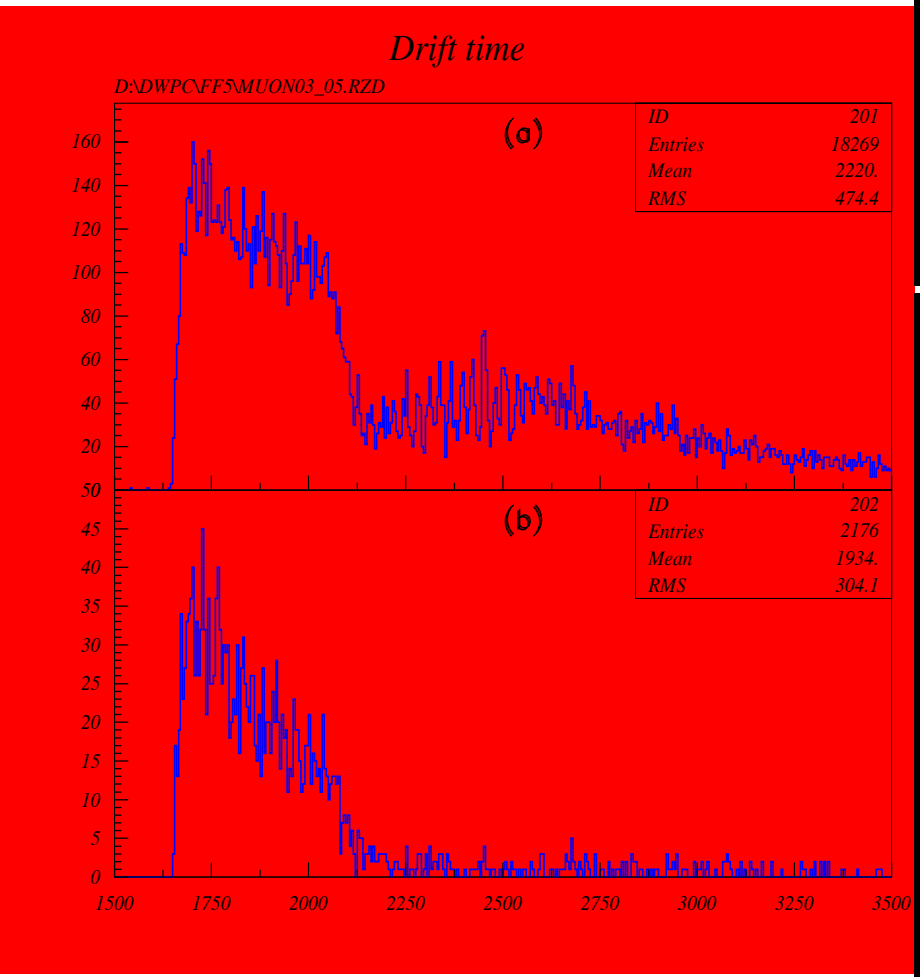


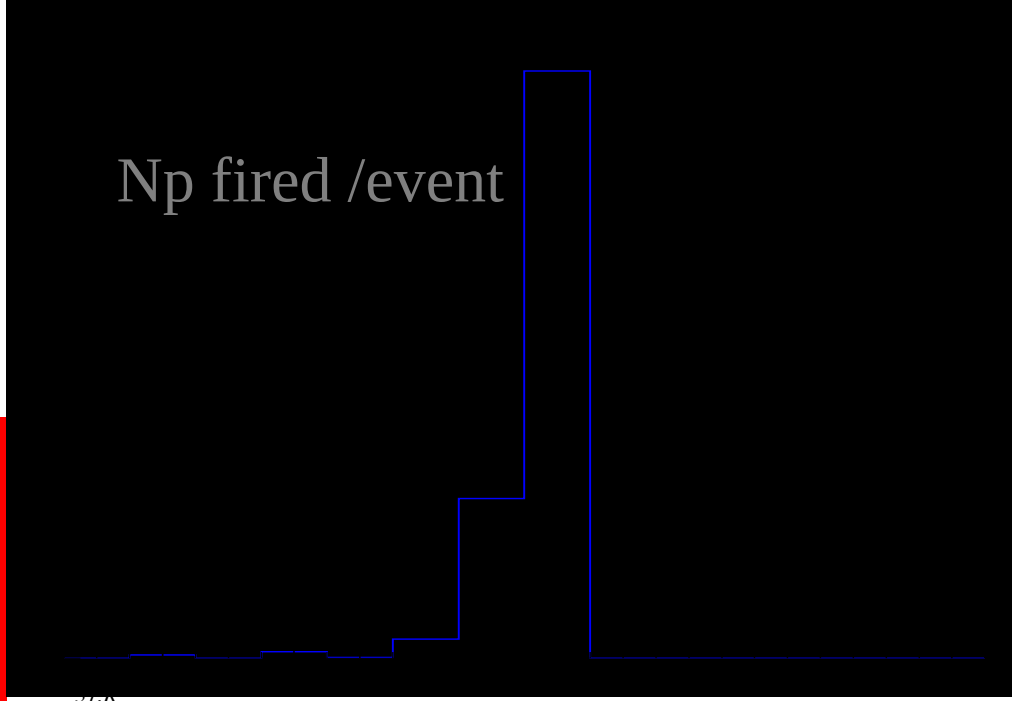
Simulation

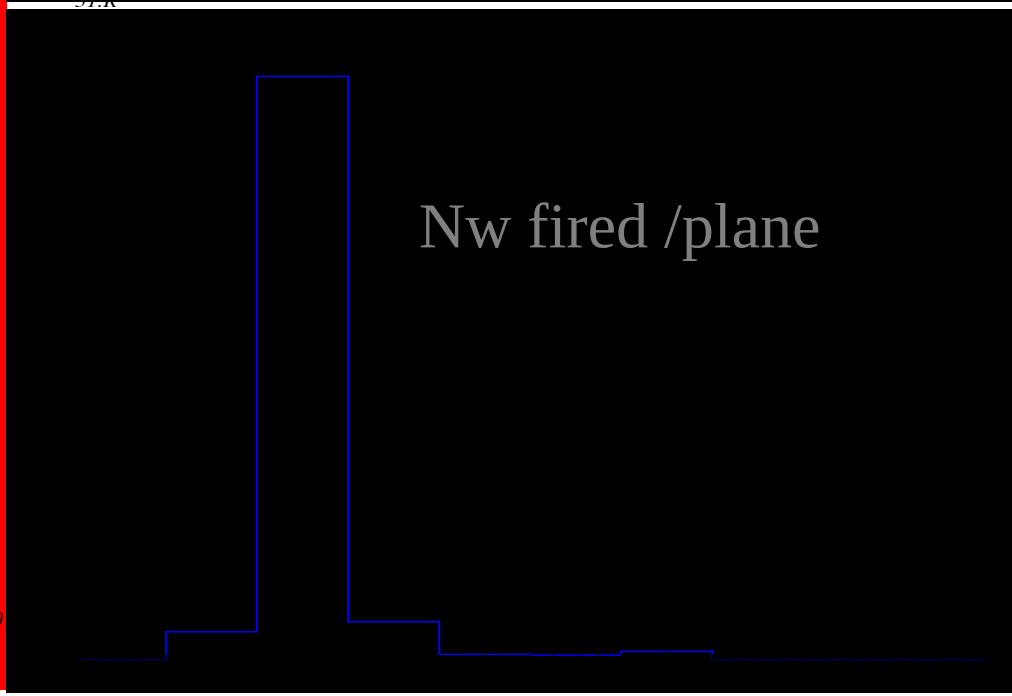


Test results

- <Np>~6, <Nw>~1

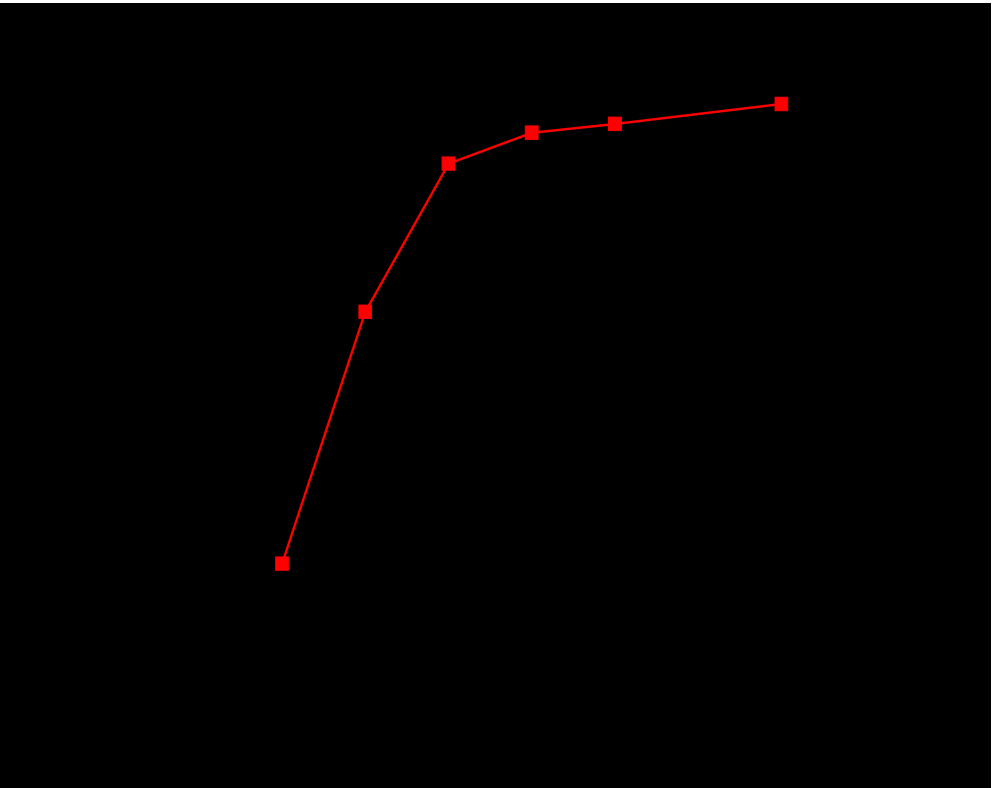




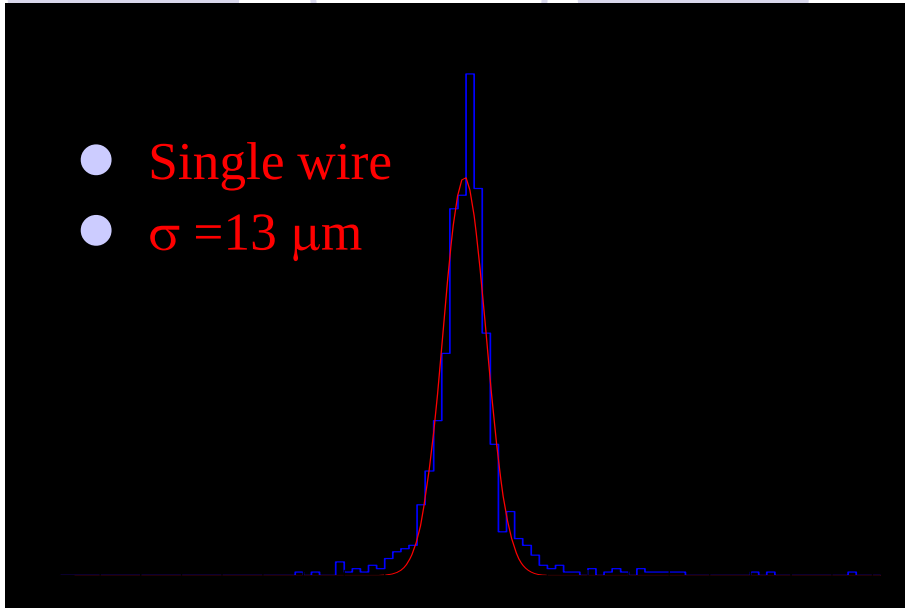


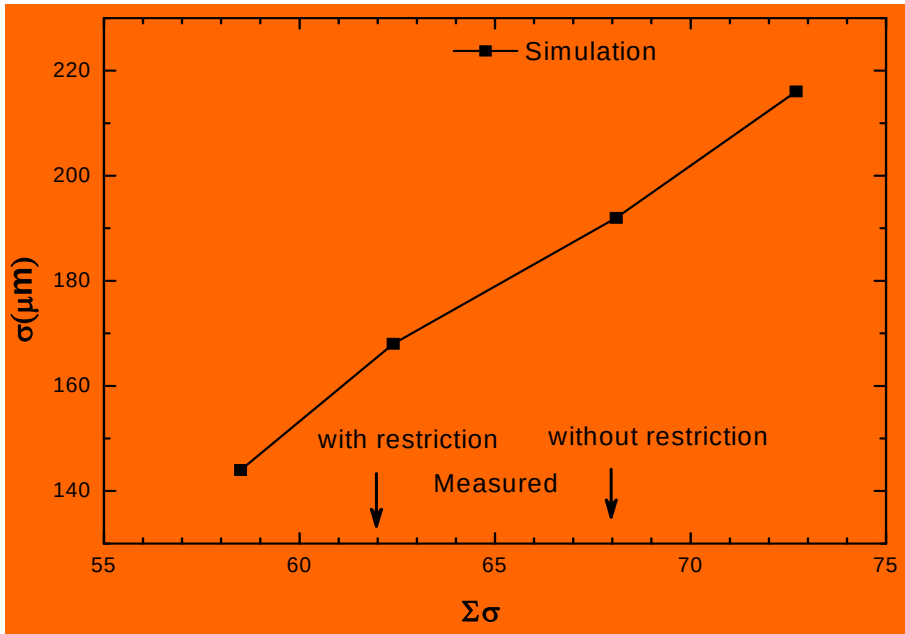
Efficiency and resolution

- ~96% efficiency
- <200μm position resolution



Track-hit Residual





5 Summary

- HIRFL-CSR provides plenty opportunities for hadron and nuclear physics research at 1AGeV region.
- HPLUS is on late conceptual stage. Fast simulation is going on and likely supports current configuration. PID for high momentum particles and TPC running at high event rate are two challenges.
- Full simulations for HPLUS have been started and needs increasingly large investment. R&D of the components for both experiments are processing hierarchically .

Thank you!