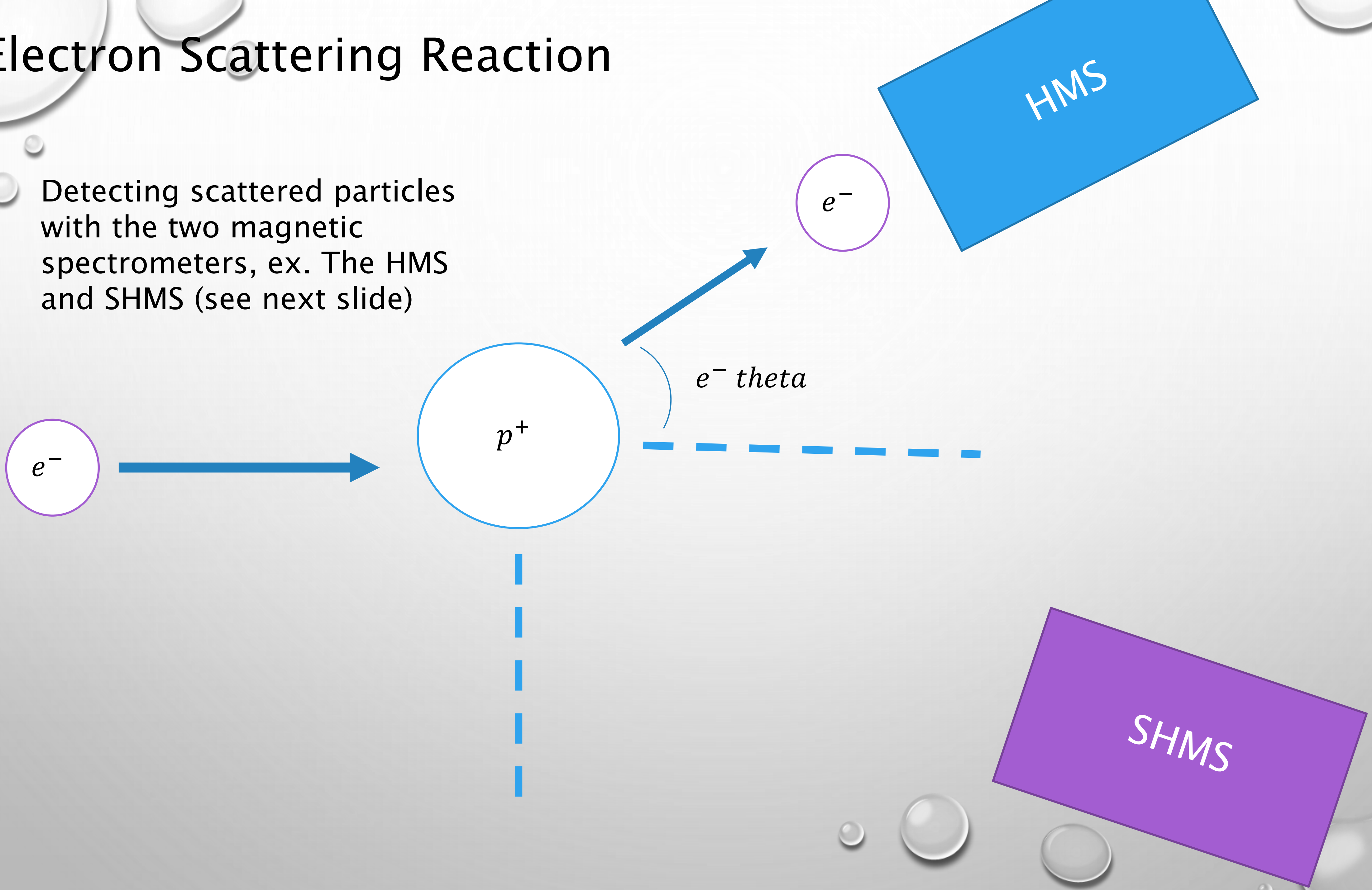
POTENTIAL STUDIES INTO THE PION FORM FACTOR USING A KAON EXPERIMENT

Goals

- DETERMINE THE NUMBER OF PIONS PRODUCED BY THE KAON EXPERIMENT
- TO MAKE THESE PROJECTIONS NEED TO USE A MONTE CARLO SIMULATION OF THE EXPERIMENT
- VALIDATE THE SIMULATION USING PREVIOUS HALL C ELASTIC DATA FROM THE HMS SO THAT THE PROGRAM CAN BE USED TO MAKE PREDICTIONS ABOUT THE KAON EXPERIMENT
- MAKE PREDICTIONS ON THE NUMBER OF KAONS PRODUCED DURING THE EXPERIMENT WHICH WILL BE DETECTED IN THE SHMS (SPECTROMETER).
- MAKE PREDICTIONS ON WHERE PIONS CAN BE DETECTED IN THE KAON EXPERIMENT
- DETERMINE WHETHER ENOUGH PIONS ARE CREATED TO BE STUDIED

Electron Scattering Reaction

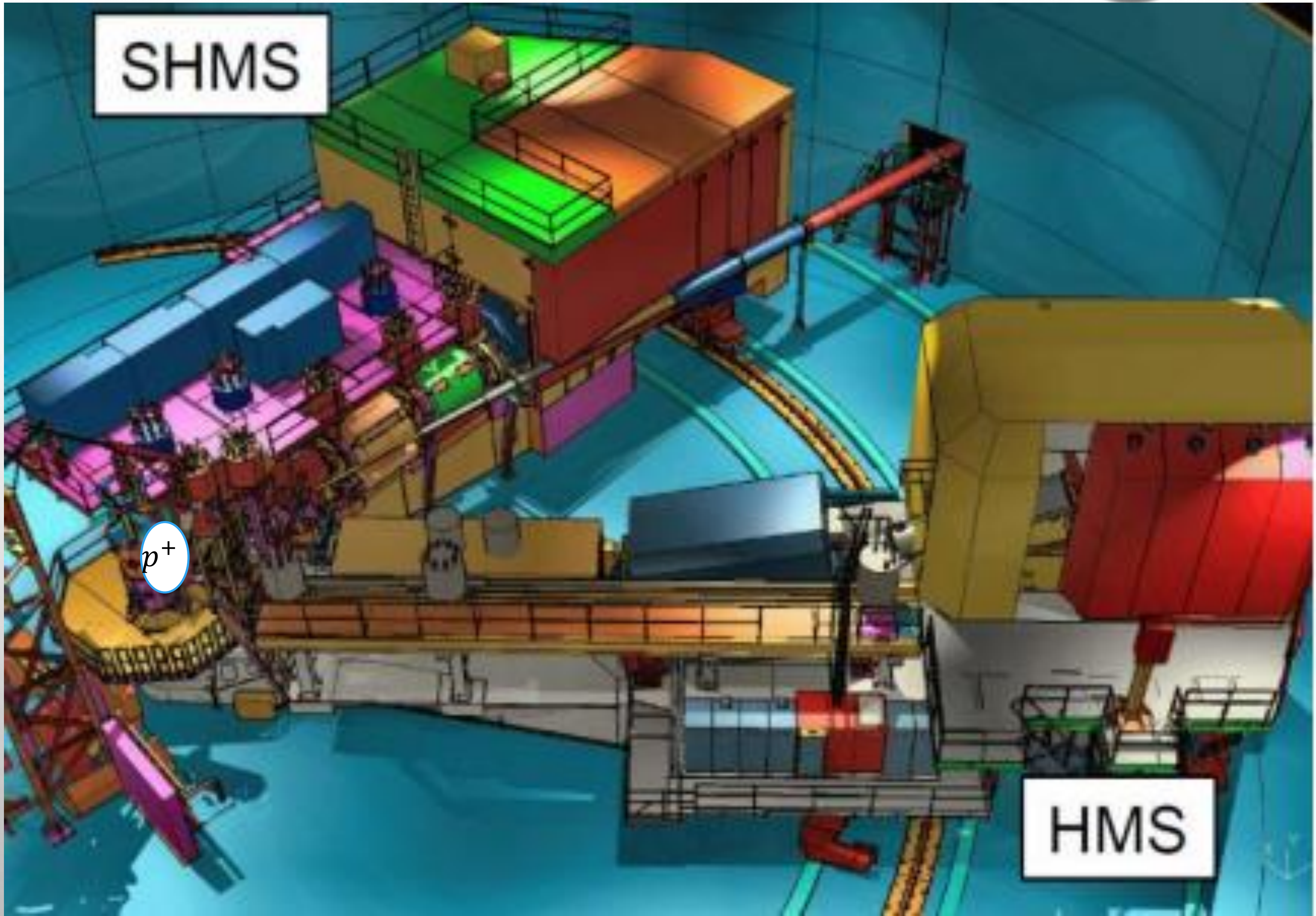
- Detecting scattered particles with the two magnetic spectrometers, ex. The HMS and SHMS (see next slide)



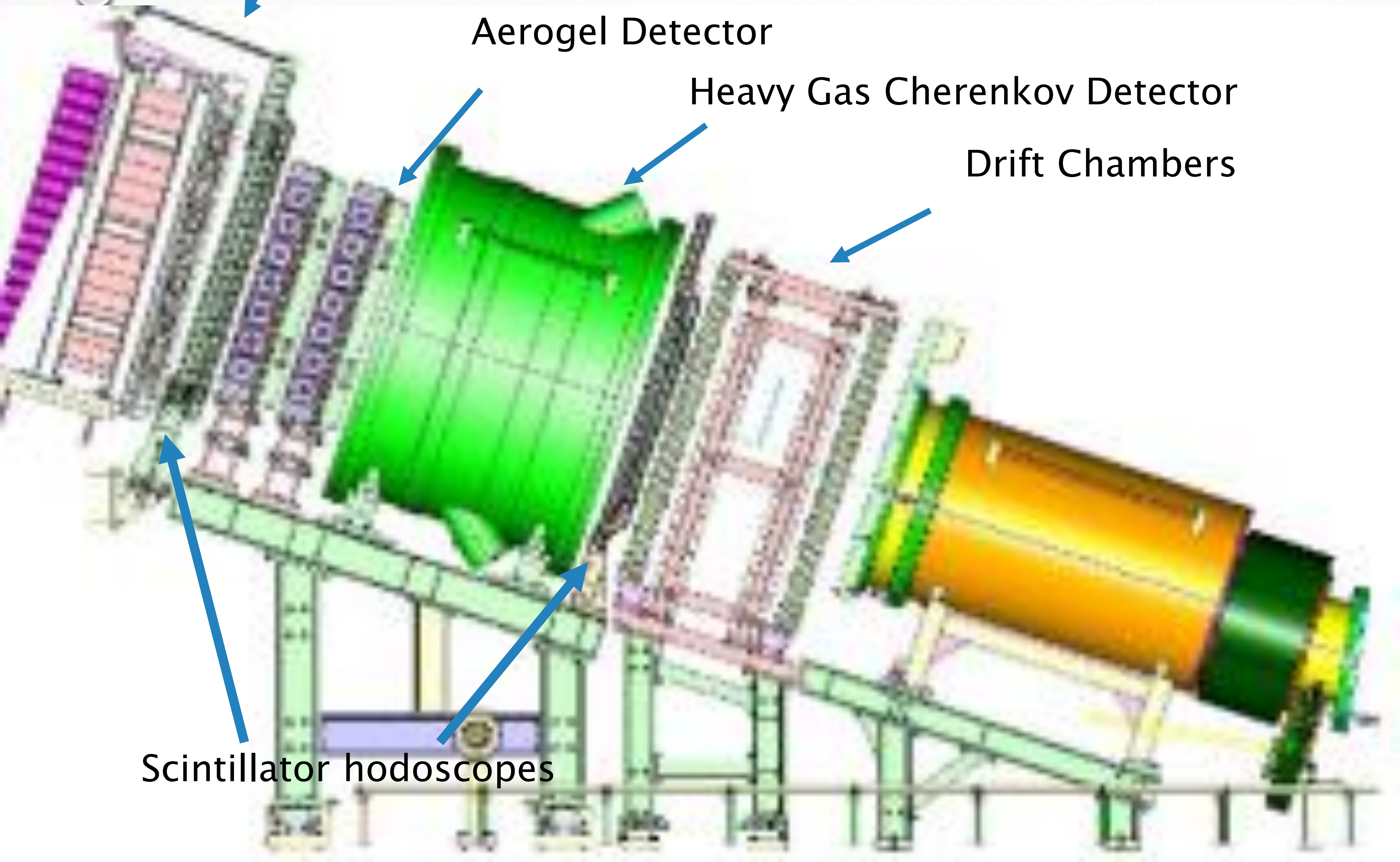
Hall C Spectrometer Set Up

- The SHMS is new and up-graded to 12 Gev from the prior SOS spectrometer.
- The HMS is an existing spectrometer

e^-



PARTICLE DETECTORS LOCATED IN THE SPECTROMETERS

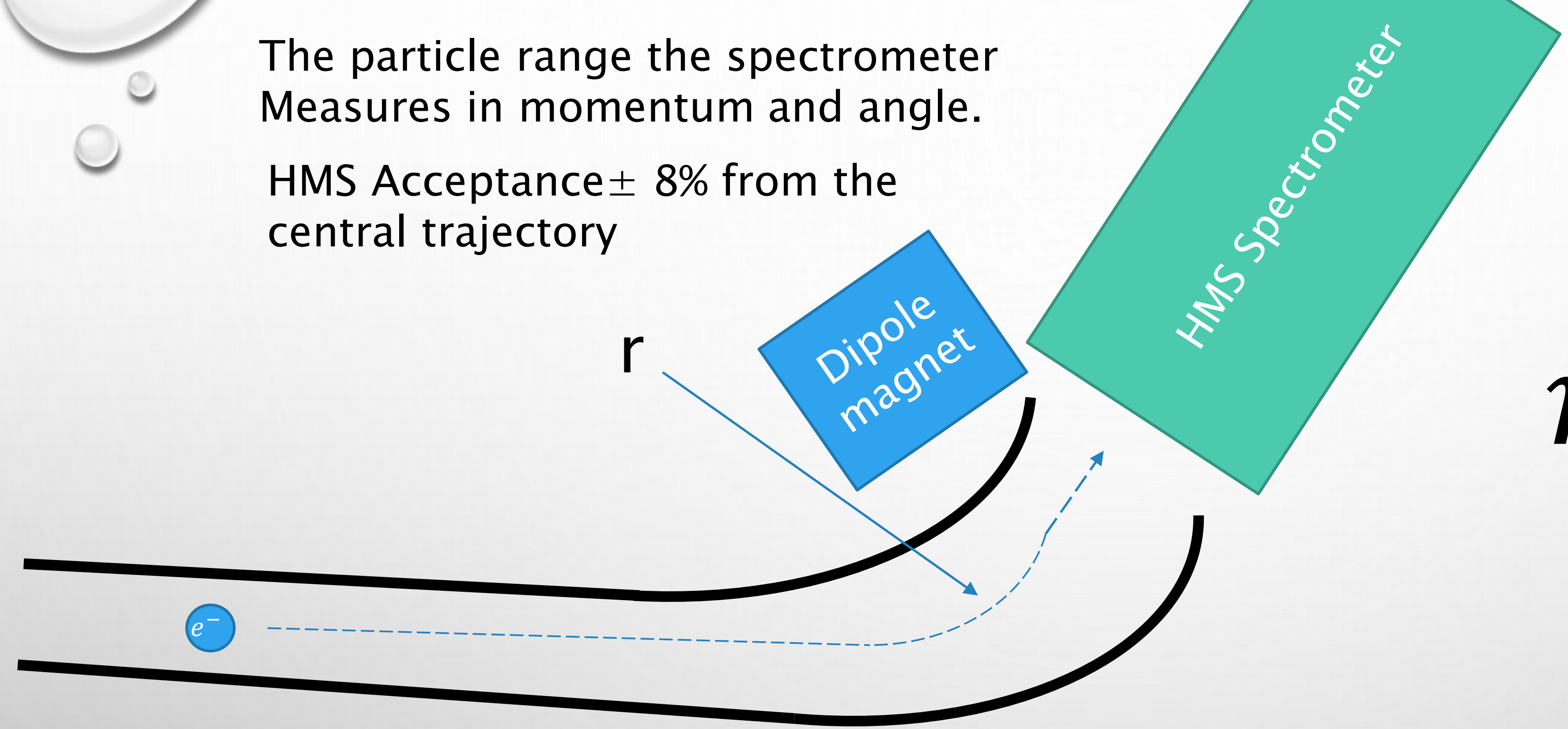


- To detect electrons use: gas Cherenkov detector and the electromagnetic calorimter
- For Kaon/Pion detection use: the Heavy Gas Cherenkov and the Aerogel Detector
- Other detectors such as the Drift Chambers are used for particle trajectories, whereas the scintillator hodoscopes are used for for timing data

Spectrometer Acceptance: Momentum and Angle

The particle range the spectrometer
Measures in momentum and angle.

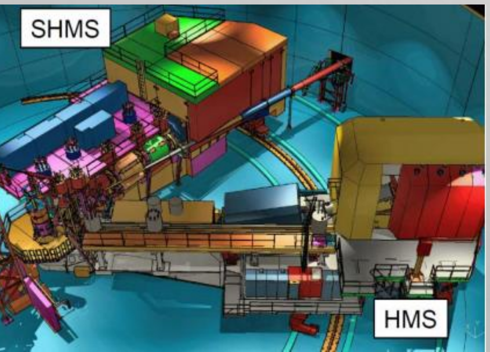
HMS Acceptance $\pm$ 8% from the
central trajectory



$$r = \frac{mv}{qB}$$

Electric Charge

Magnetic Field



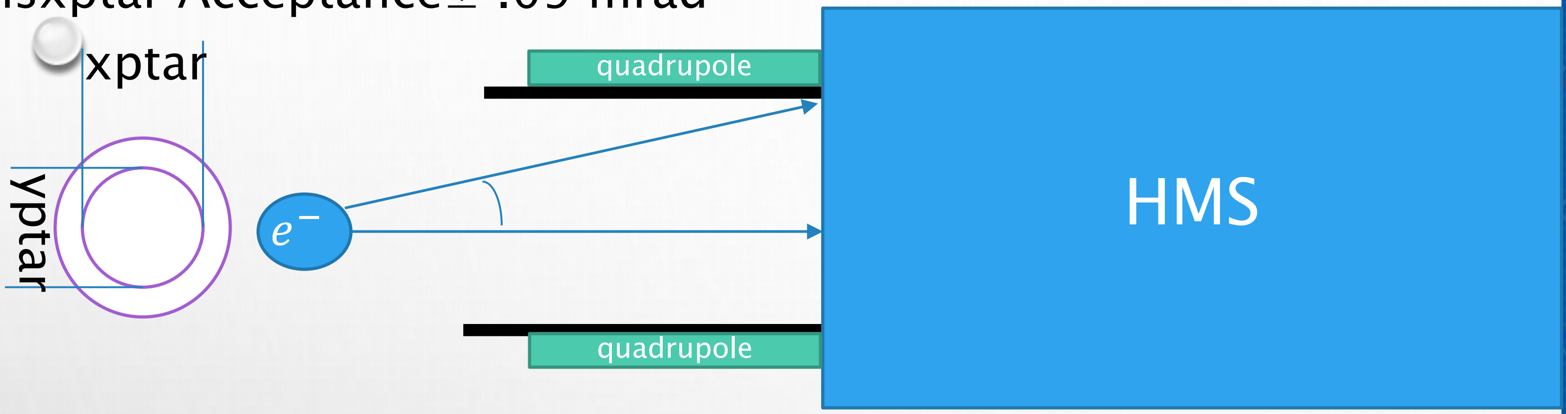
Spectrometer Angular Acceptance

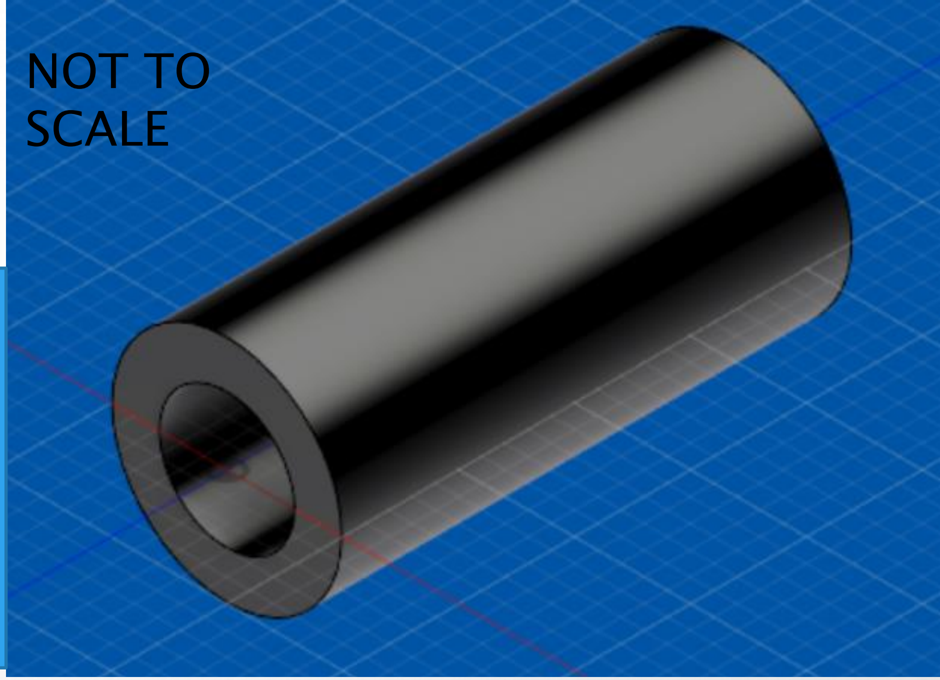
Top View

NOT TO SCALE

Out of Plane Angle (hsxptar)

hsxptar Acceptance± .09 mrad

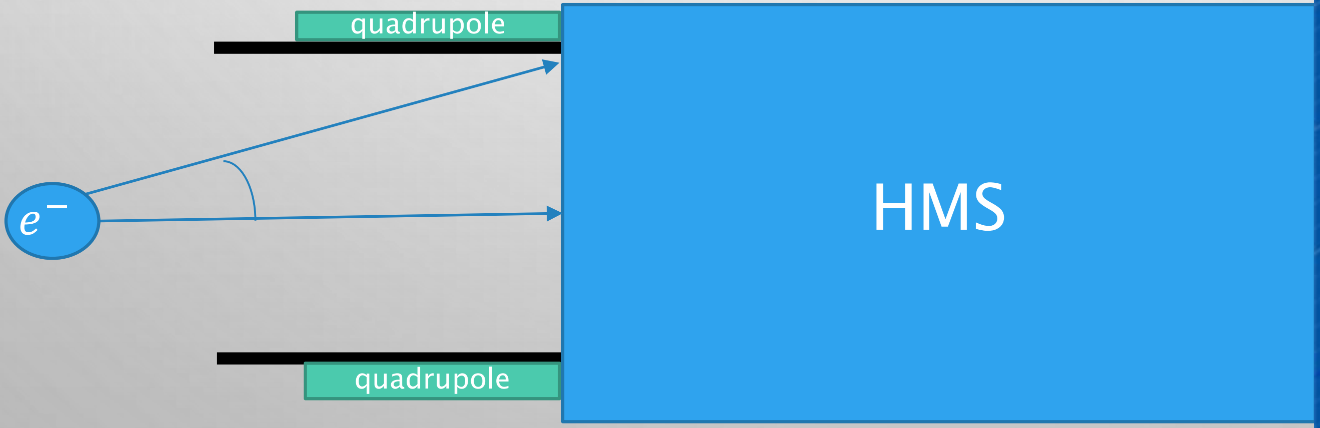


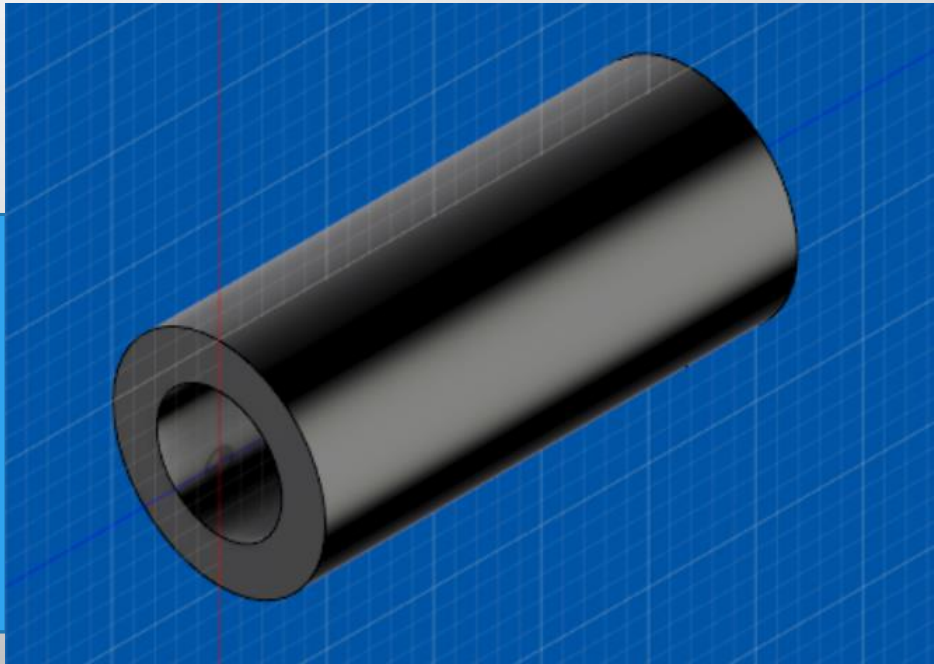


In Plane Angle (hsyptar)

Side View

hsyptar Acceptance± .055 mrad

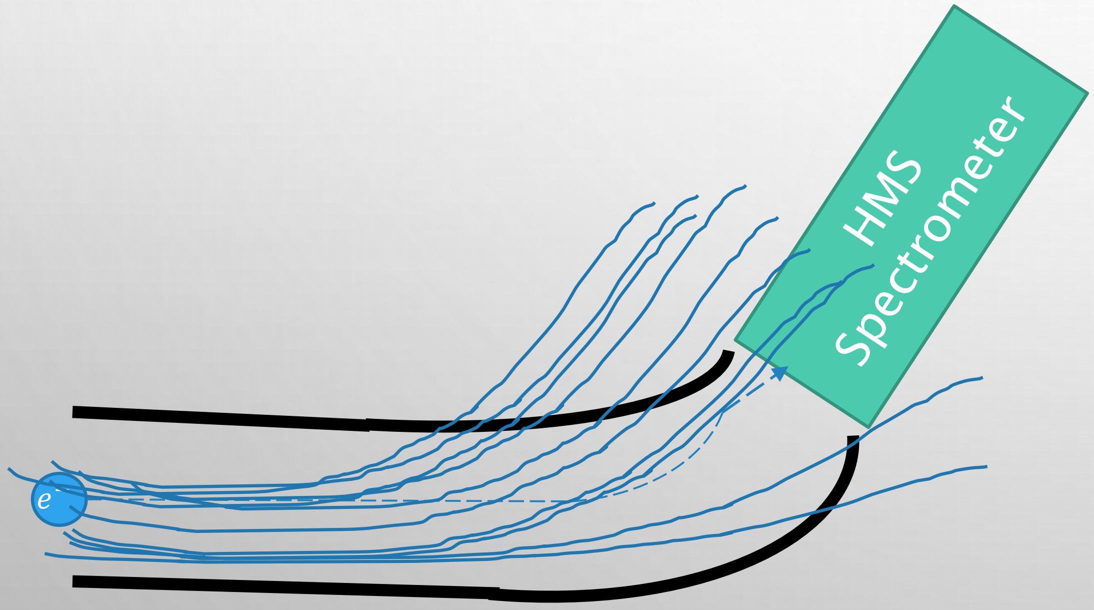




What are cuts? Why are they applied?

Sim Data Before cuts are applied	Sim Data After Cut Applied

The paths represent the acceptance

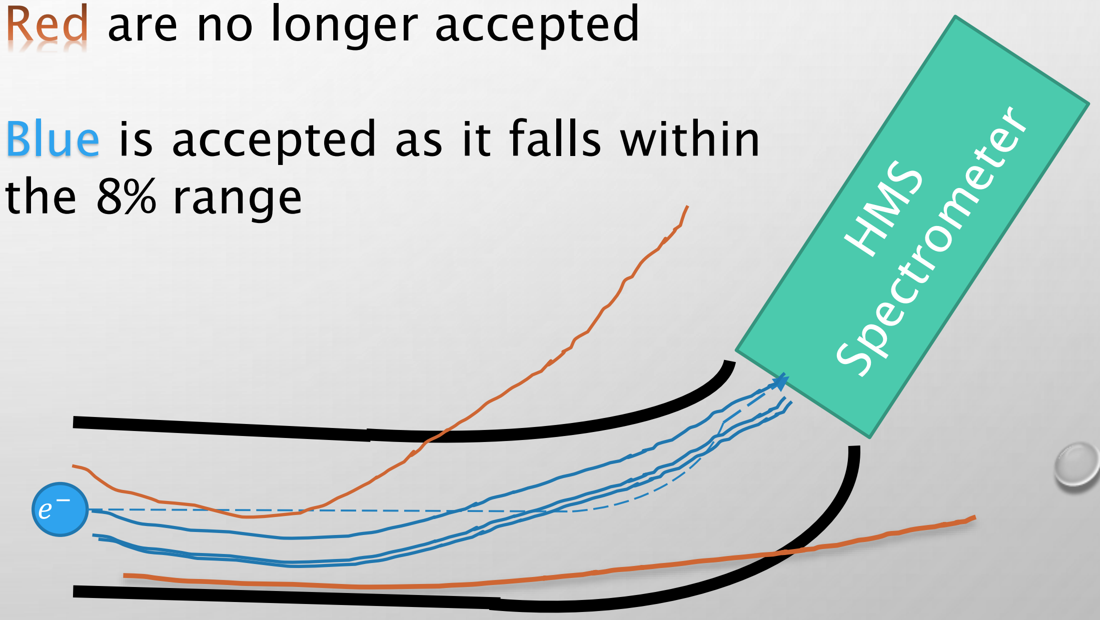


The paths represent the acceptance

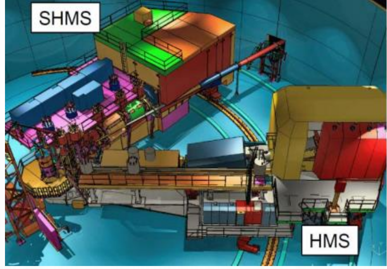
Red are no longer accepted

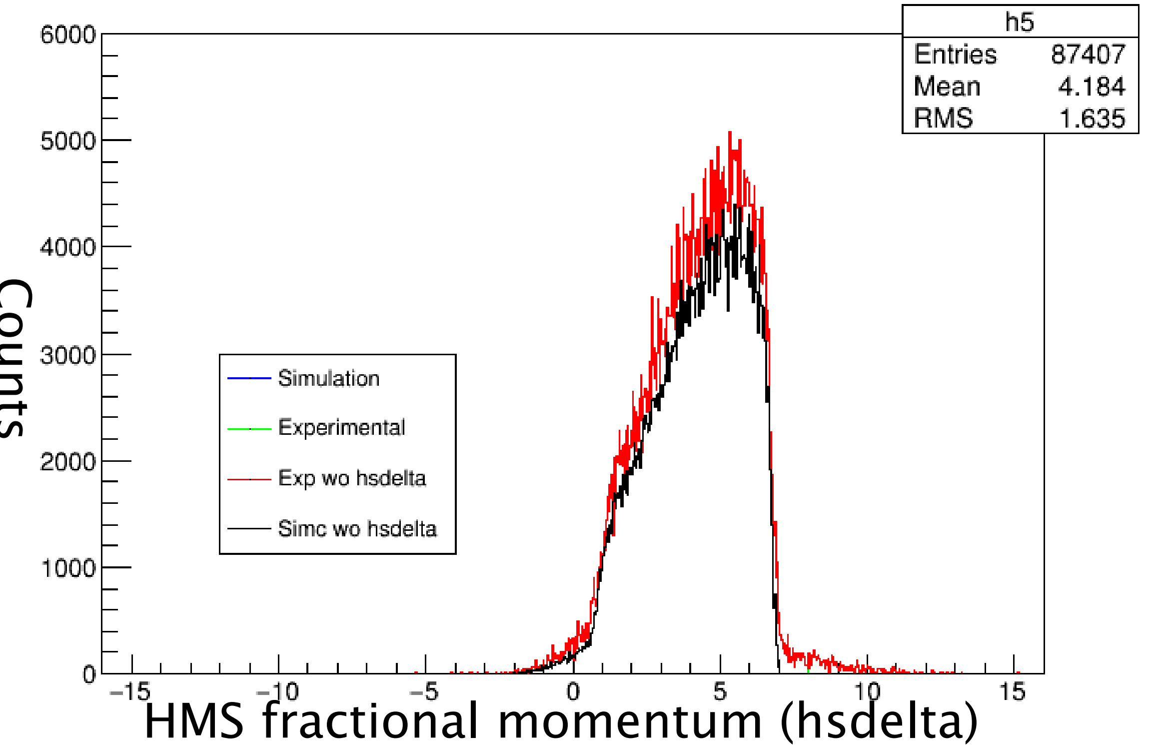
Blue is accepted as it falls within the 8% range

HMS Acceptance± 8%

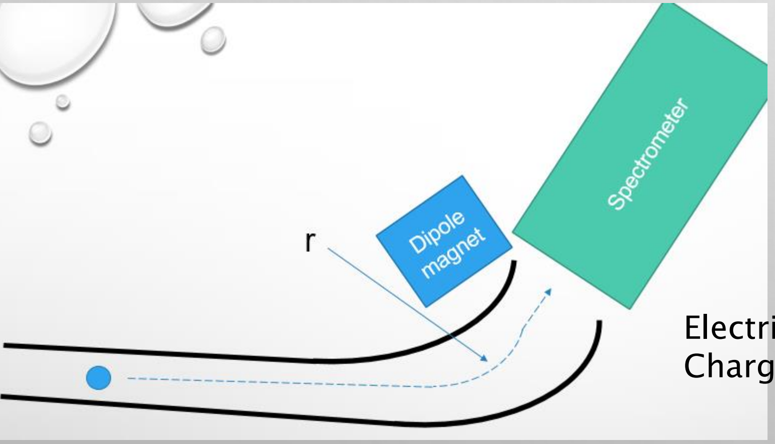


Example of a Simulated HMS Momentum Distribution for Elastic Electron Scattering with Cuts Applied





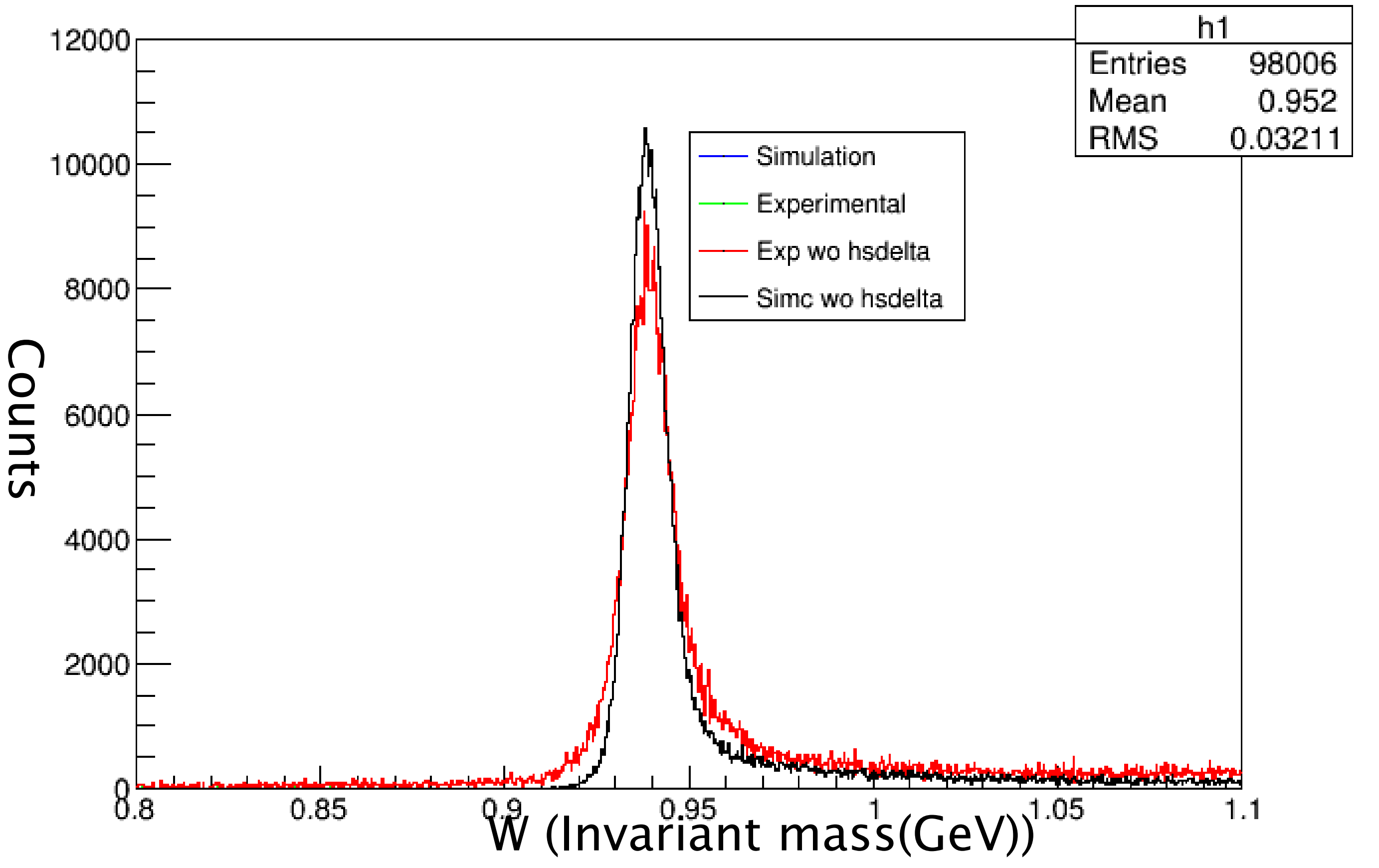
To verify that the simulation correctly produced electrons from elastic scattering, the invariant mass W is calculated – the distribution should be centered on the proton mass (0.94 Gev)



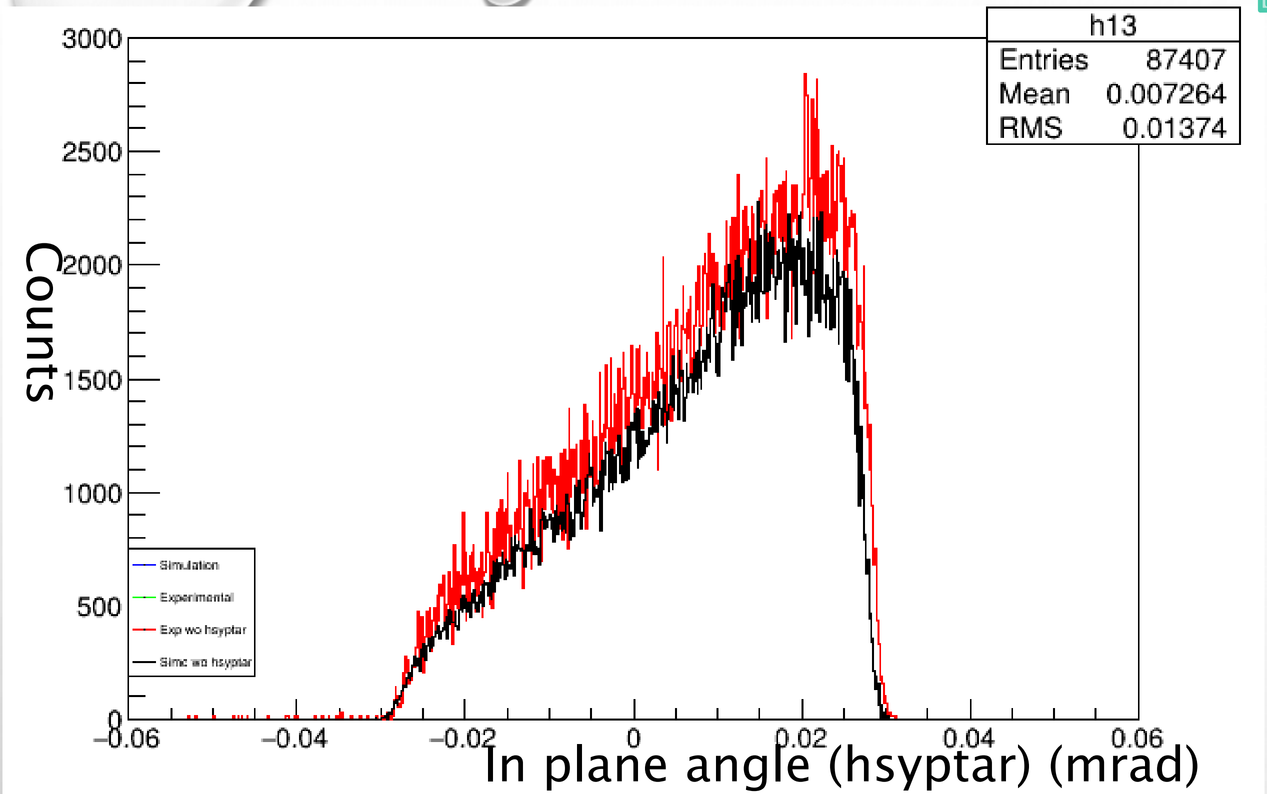
$$r = \frac{mv}{qB}$$

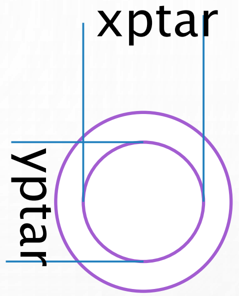
Electric Charge

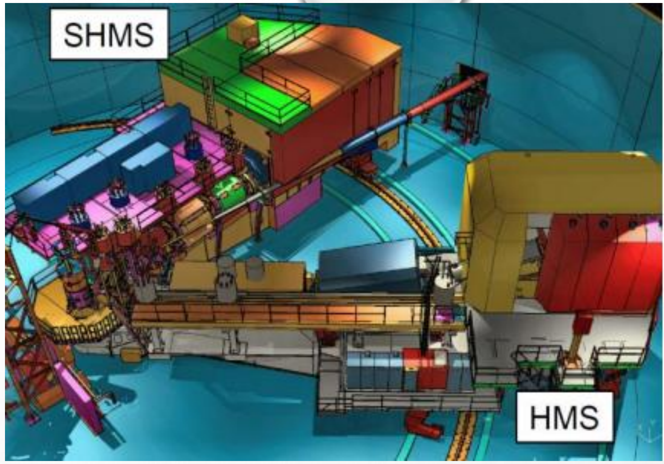
Magnetic Field

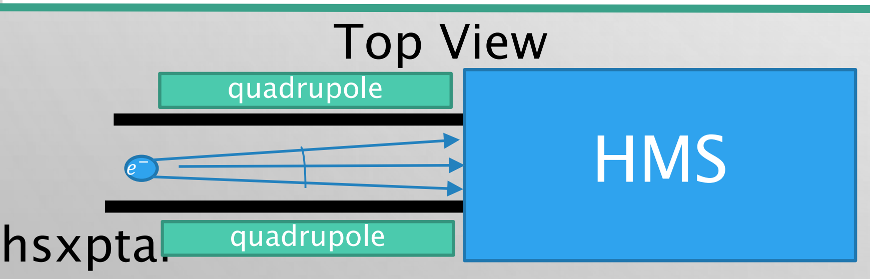


Example of a Simulated HMS Angular Distribution for Elastic Electron scattering with cuts applied

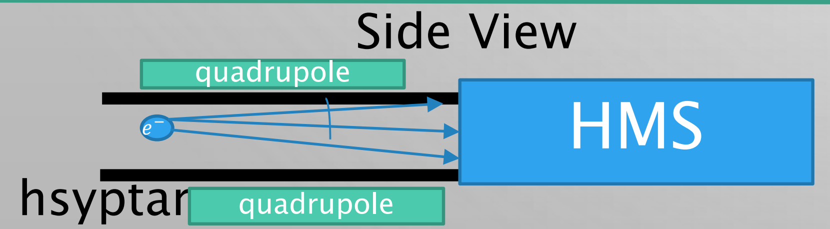


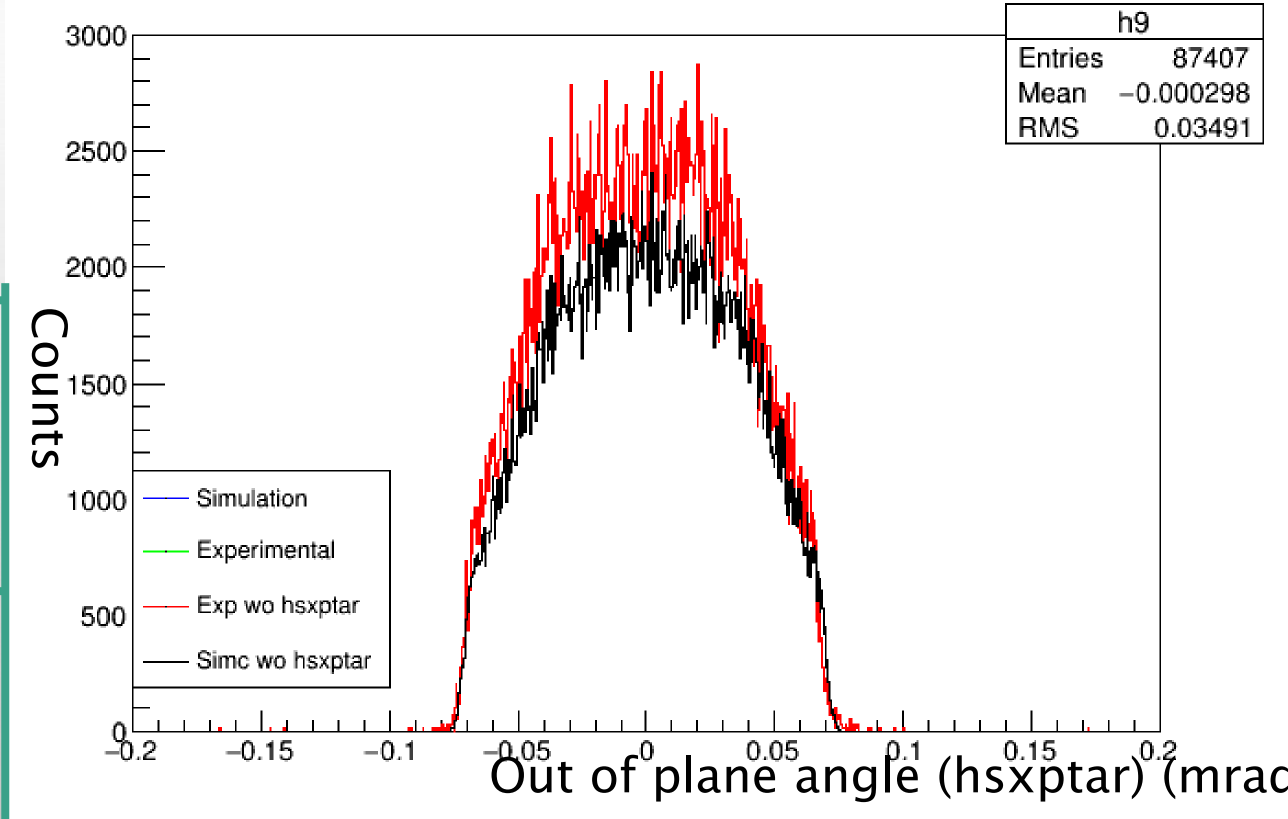




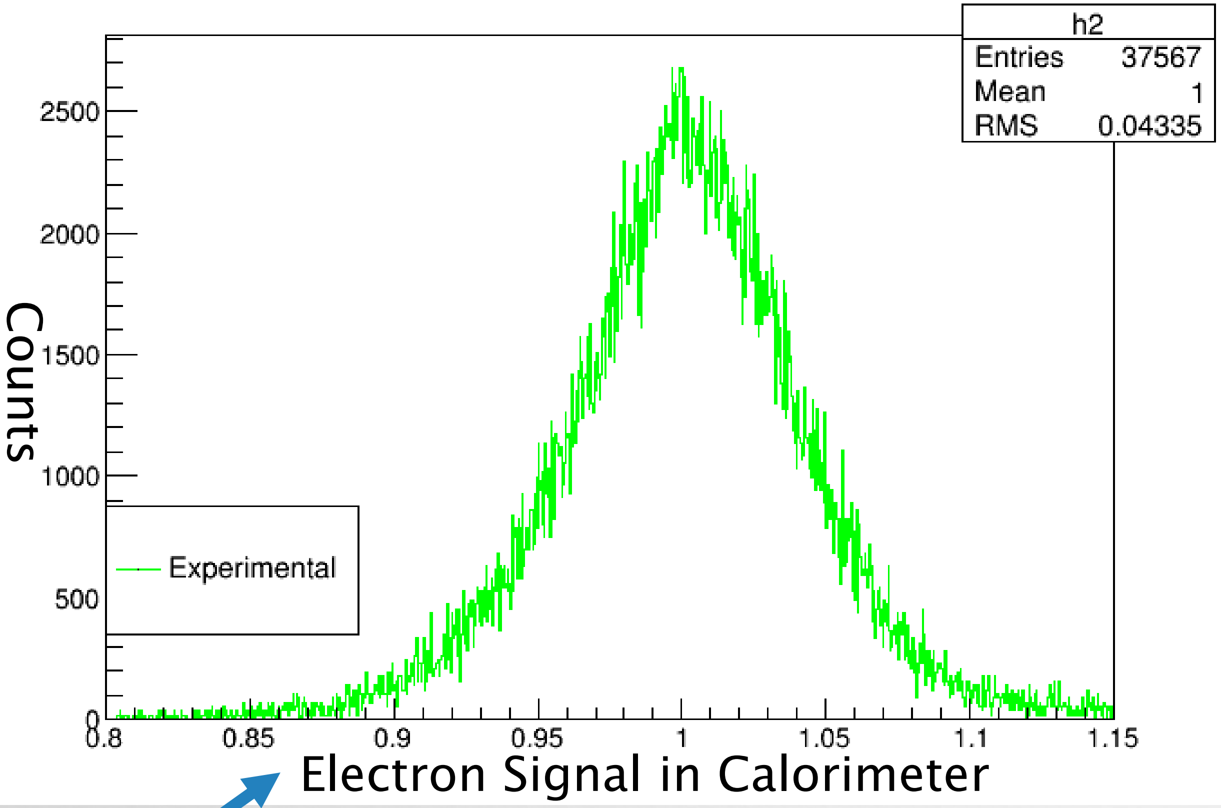


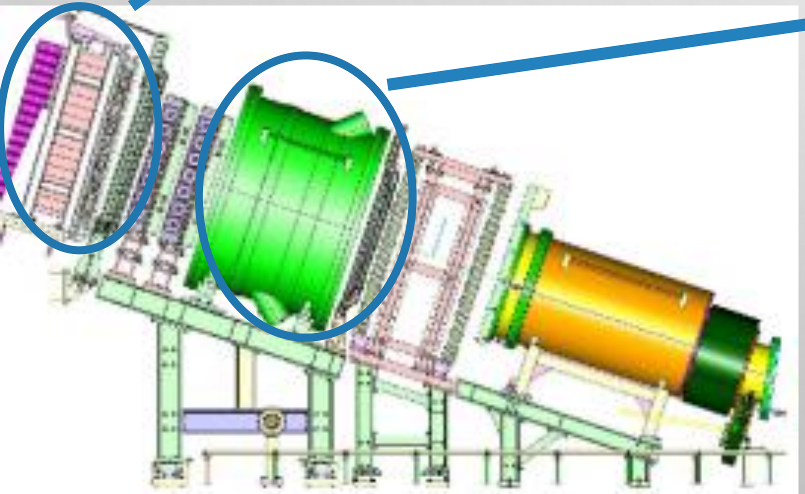
NOT TO SCALE

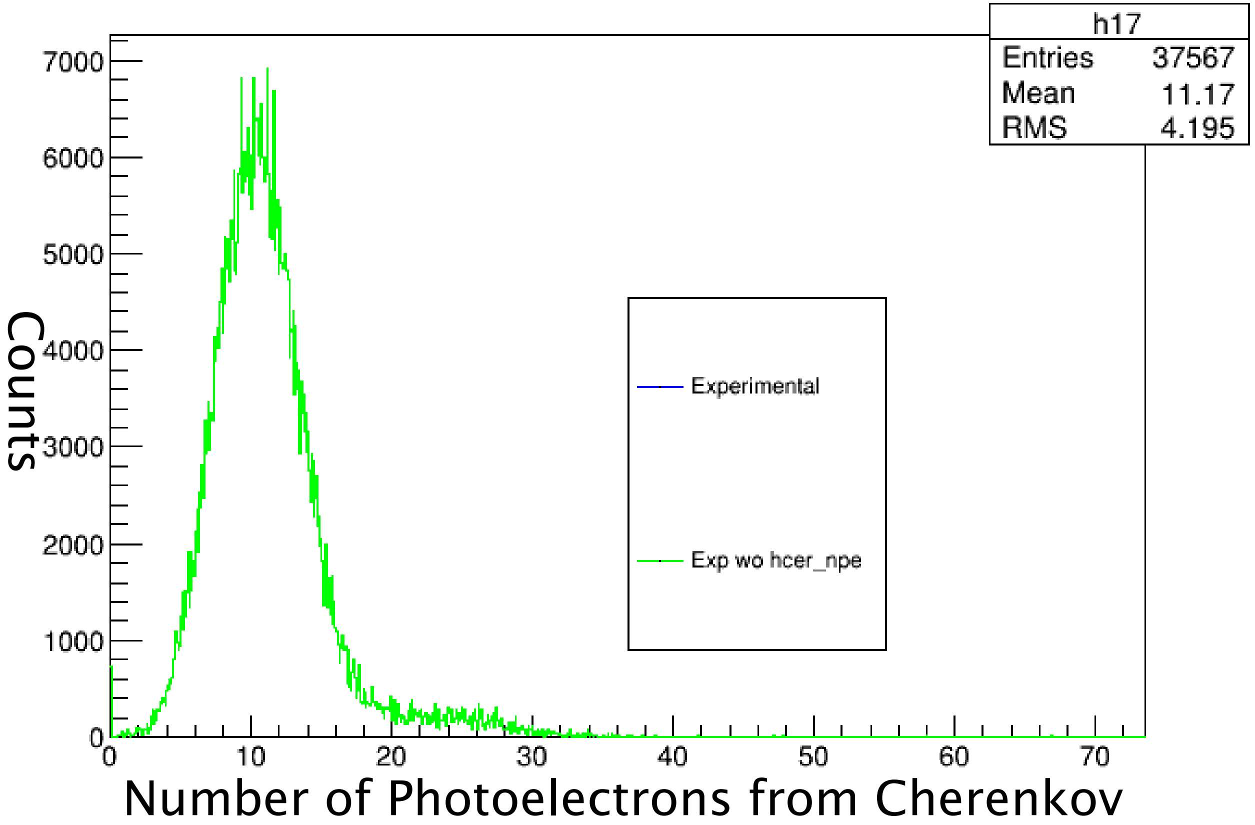




Electron Particle Identification

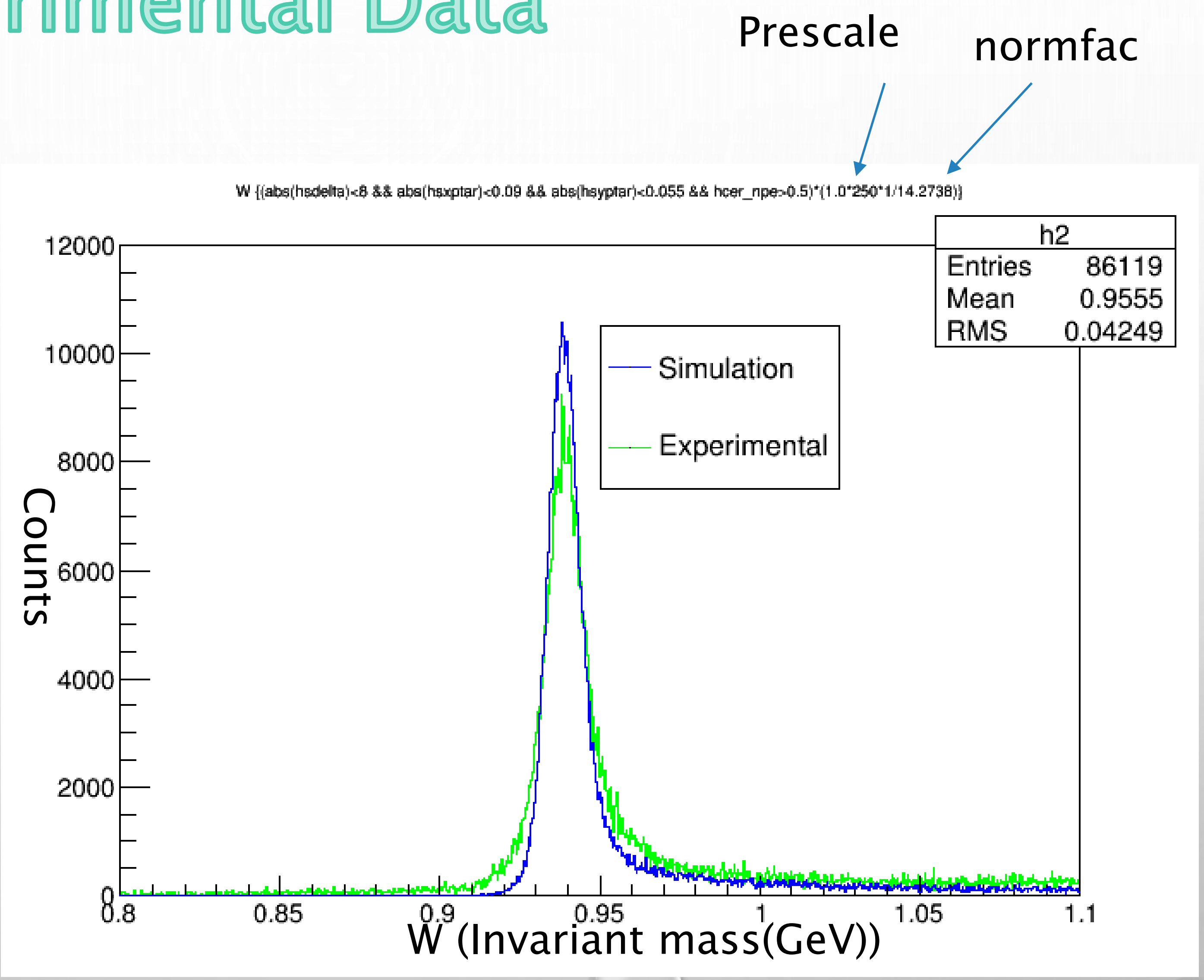






Comparing the Simulation with the Experimental Data

Kinematic Configuration	
Run	47339
Beam Energy	5246.5
e^- p	4494.4
e^- $theta$	12.0



Additional Configurations to Check the dependence on the Spectrometer Angle

Input values	
Run	47339
Beam Energy	5246.5
e^- p	4494.4
e^- *theta*	12.0

Input values	
Run	47345
Beam Energy	5246.4
e^- p	4494.2
e^- theta	14.0

Input values	
Run	47350
Beam Energy	5246.4
e^- p	3724.4
e^- *theta*	22.0

Input values	
Run	47347
Beam Energy	5246.4
e^- p	43724.4
e^- theta	19.985

Validation of the Simulation with the Experimental Data

If the simulation describes the data, the ration of the experimental and simulated yields should be one.

Uncertainty:

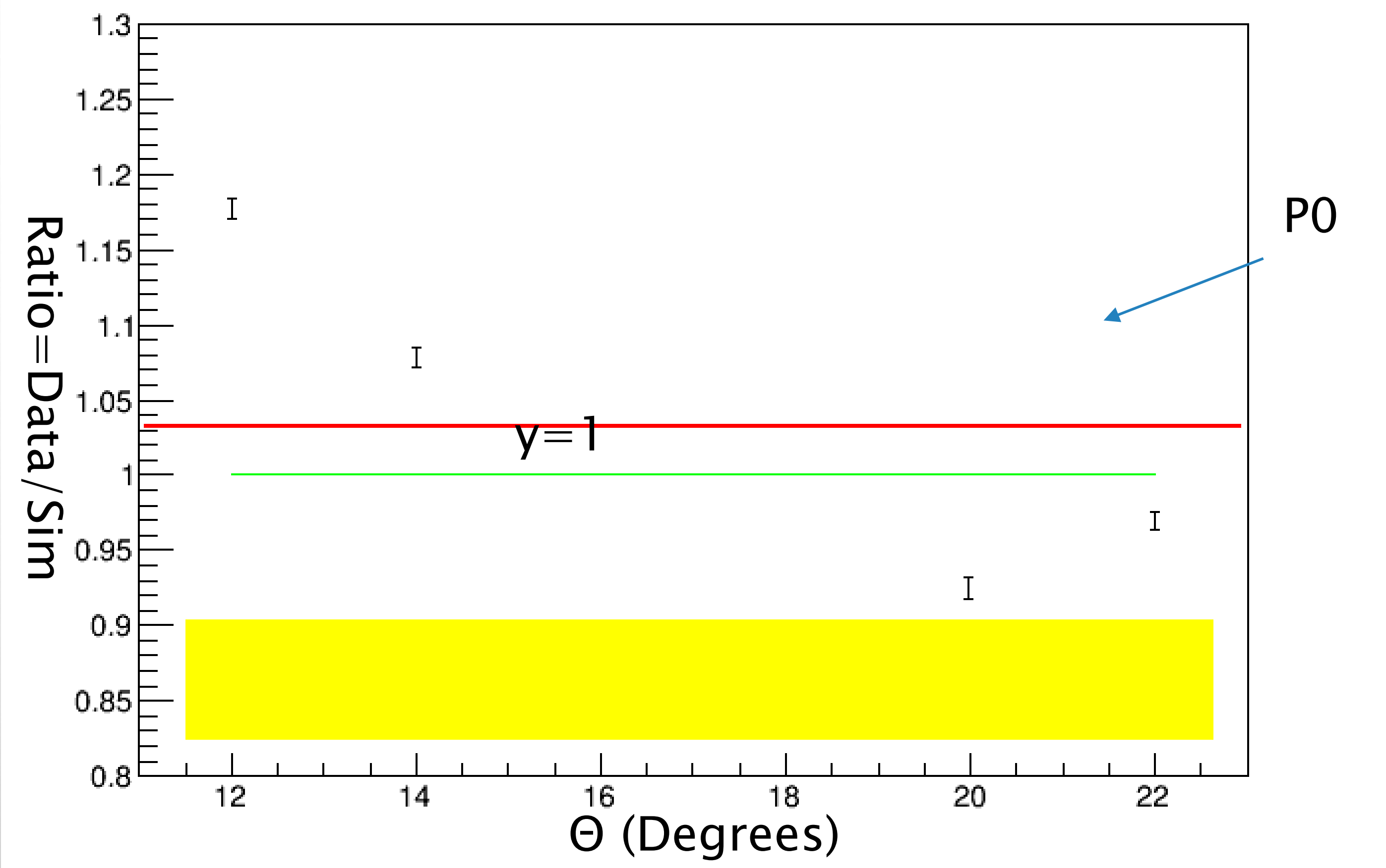
N=# of events

$$\delta y^2 = \sum_i \left(\frac{dy}{di}\right)^2 \delta i^2$$

$$\frac{\delta y}{y} = \sqrt{N}/N$$

$$\delta R = R * \sqrt{\left(\frac{\delta Yd}{Yd}\right)^2 + \left(\frac{\delta Ydmc}{Ydmc}\right)^2}$$

Experimental Y   Simulation Y



- The simulation has been Validated
- It can now be used to give an accurate prediction for Kaons

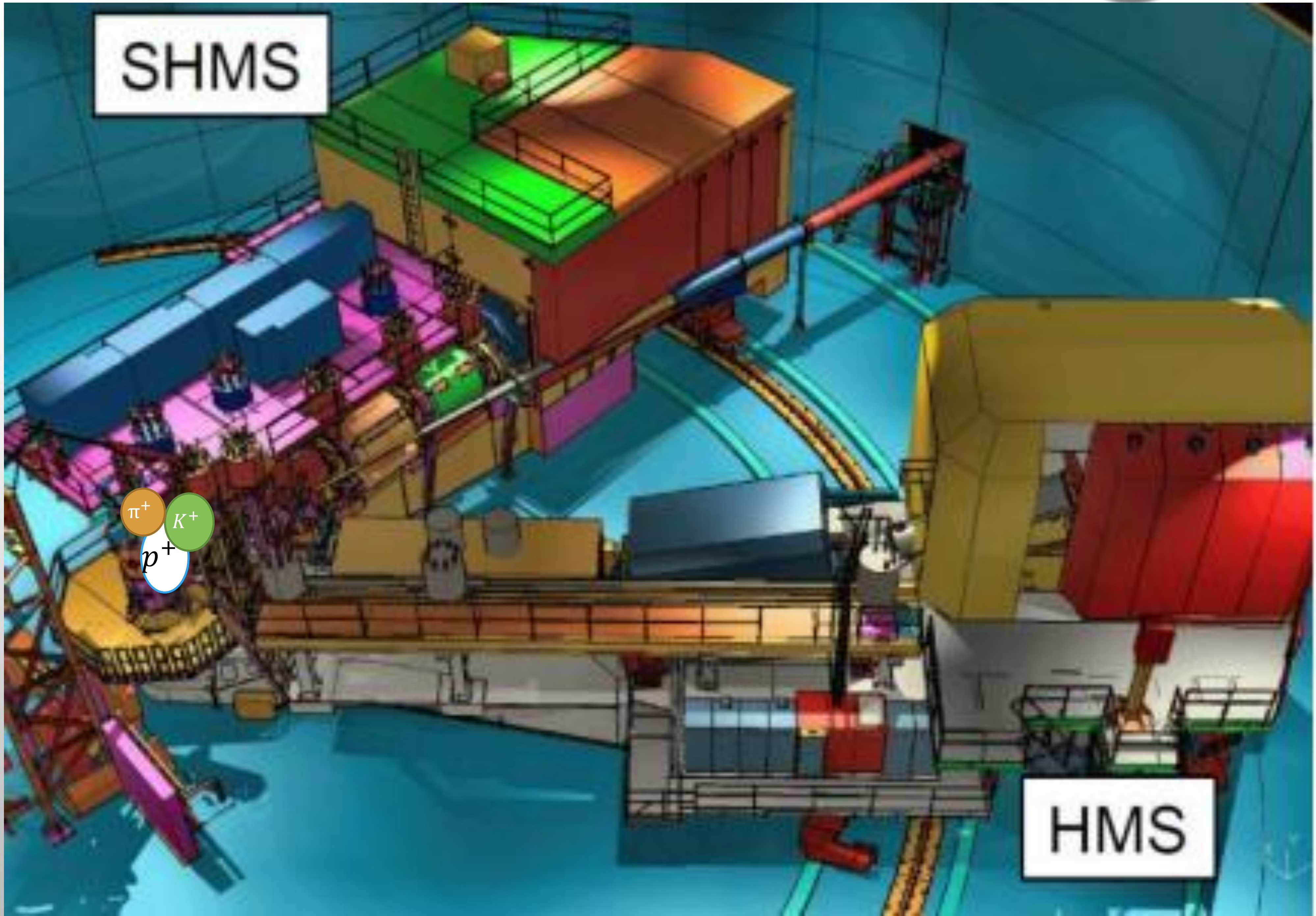
Kaon Production Analysis

- NO EXPERIMENTAL DATA COLLECTED YET
- THE EXPERIMENT TAKES PLACE NEXT YEAR
- THE GOAL IS TO DETERMINE HOW MANY FREE PIONS WE GET FROM THE KAON EXPERIMENT

Hall C

- Pions and kaons are detected in the SHMS

- Electrons are detected in the HMS

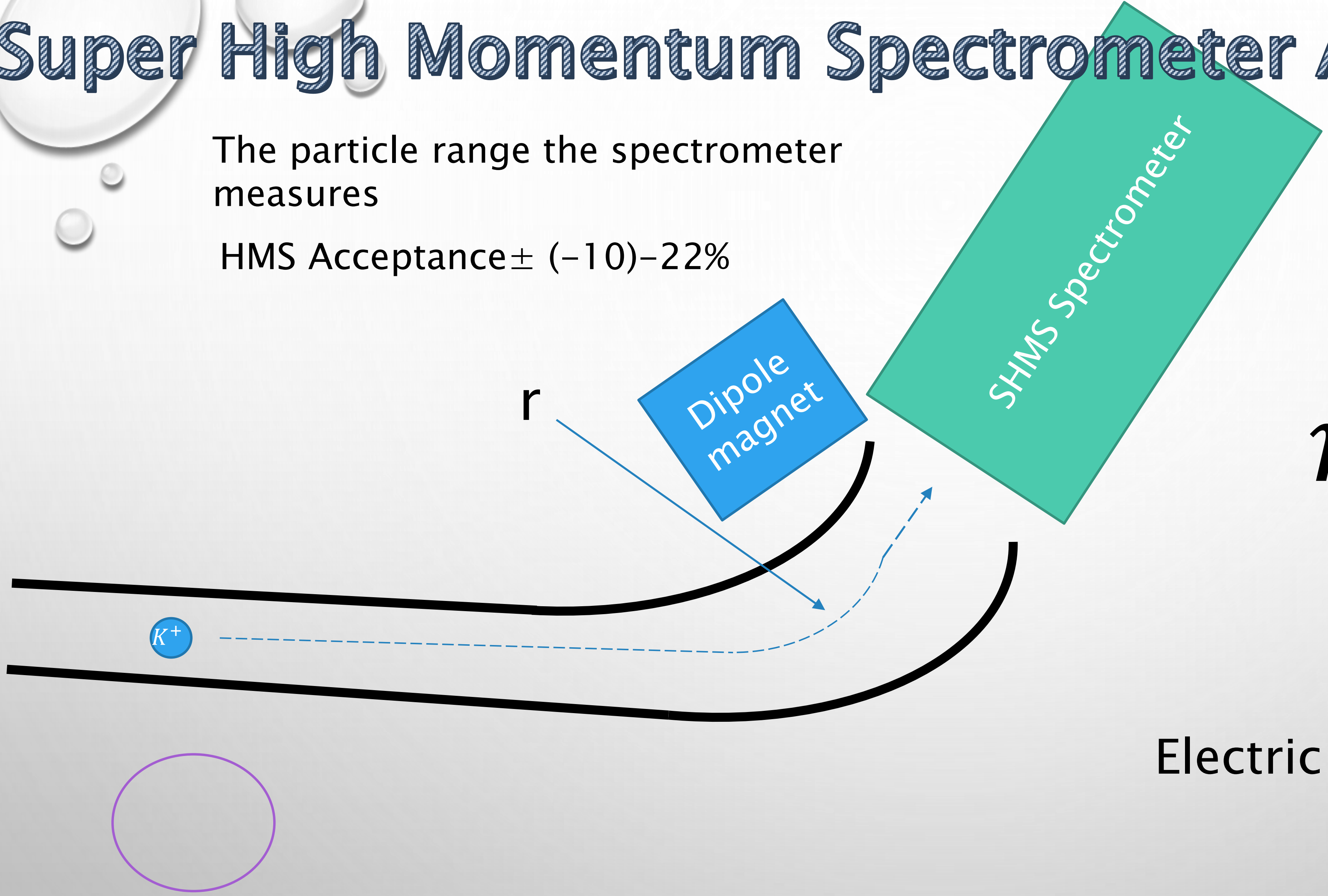


e^-

Super High Momentum Spectrometer Acceptance

The particle range the spectrometer measures

HMS Acceptance± (−10)−22%



$$r = \frac{mv}{qB}$$

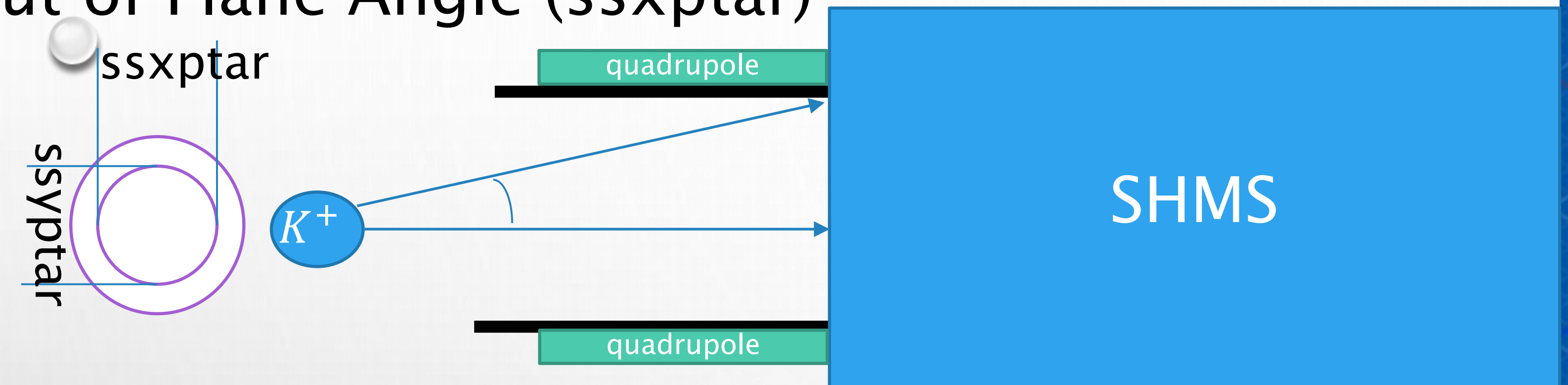
Electric Charge

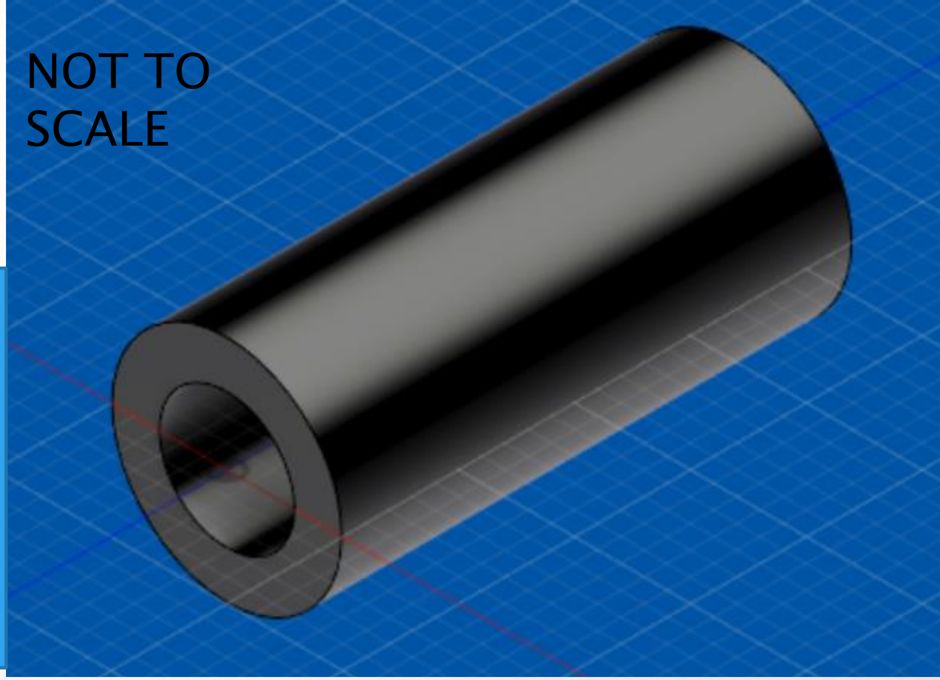
Magnetic Field

Super High Momentum Spectrometer Angular Acceptance

Out of Plane Angle (ssxptar)

Top View



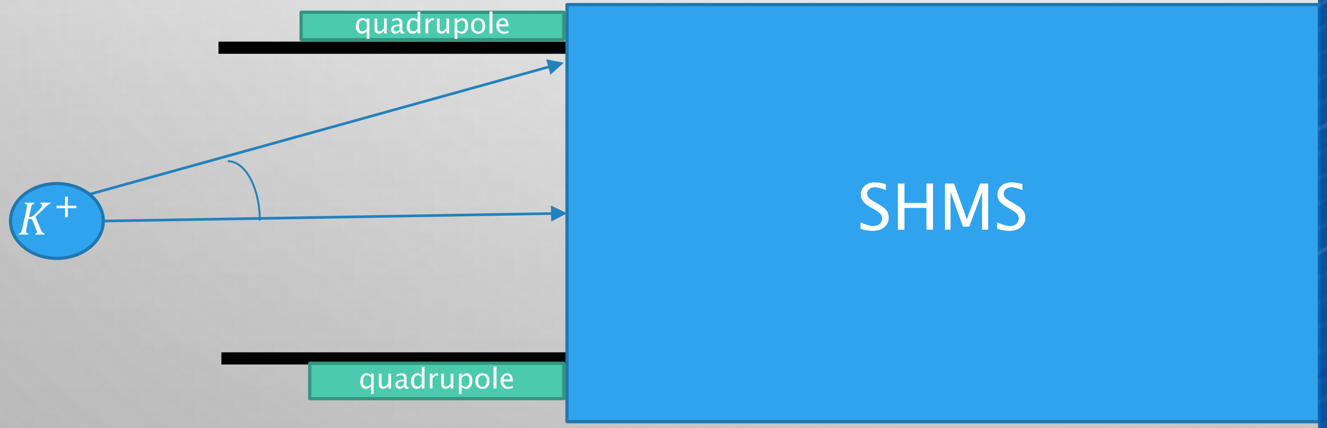


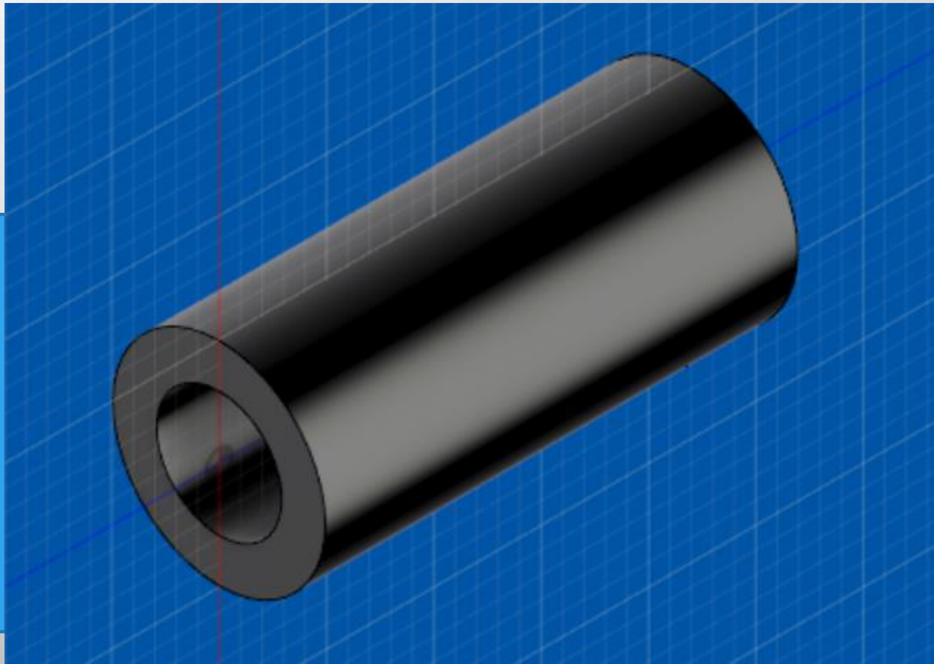
ssxptar Acceptance± .04 mrad

In Plane Angle (ssyptar)

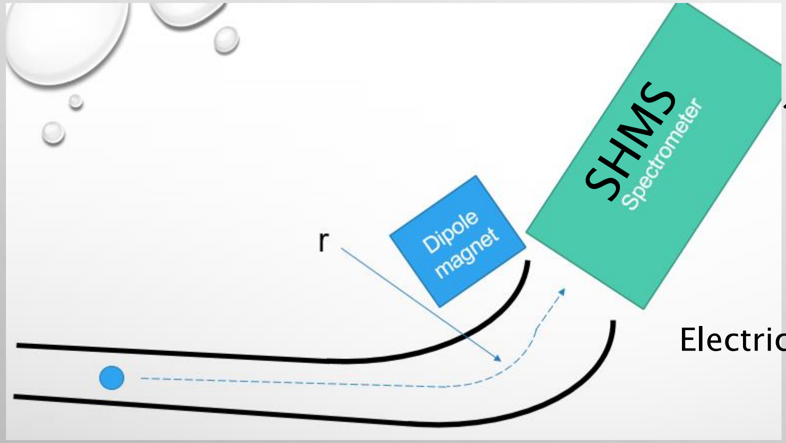
Side View

ssyptar Acceptance± .024 mrad





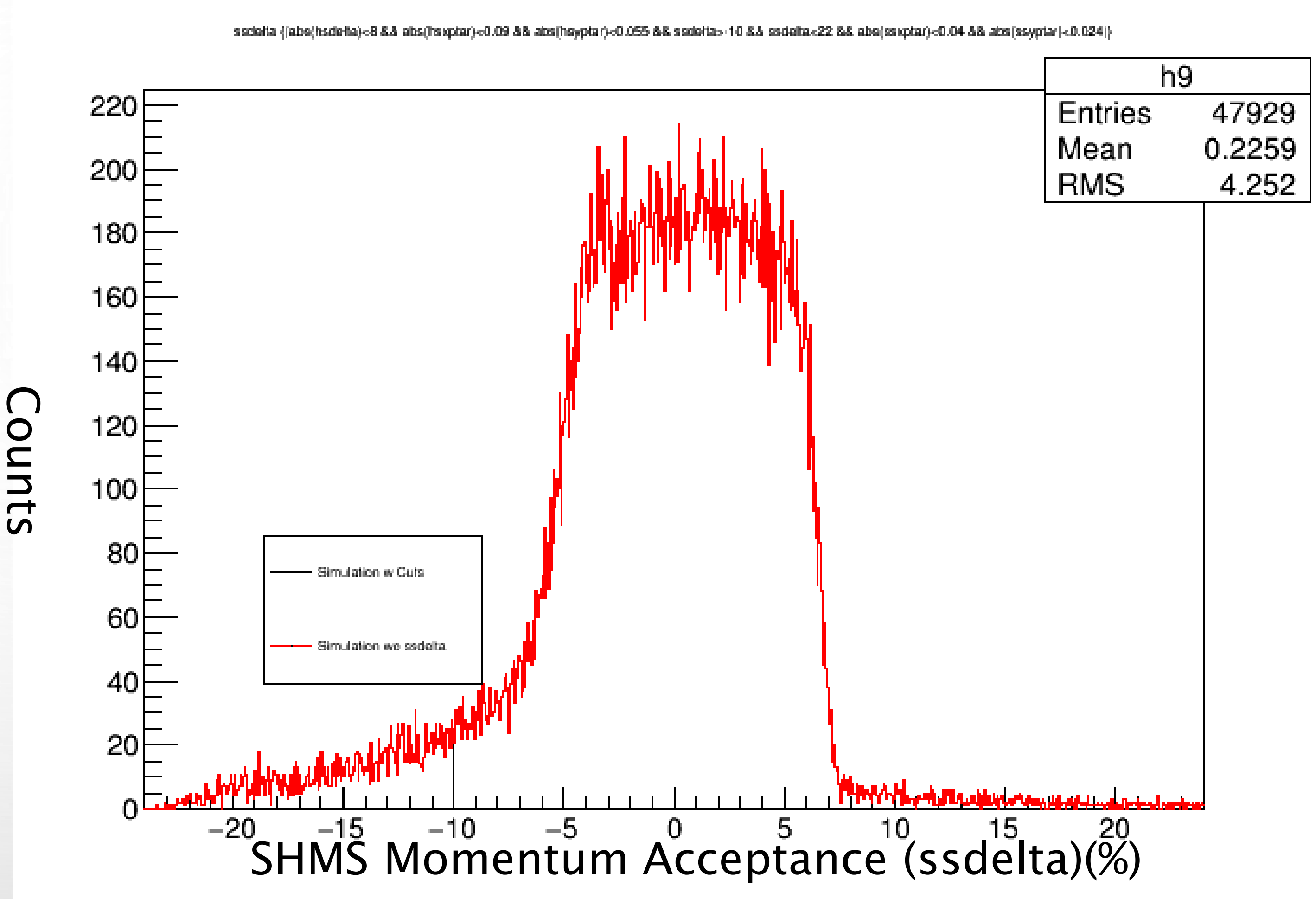
Example of a Simulated SHMS Momentum Distribution for Kaon Electro Production with Cuts Applied



$$r = \frac{mv}{qB}$$

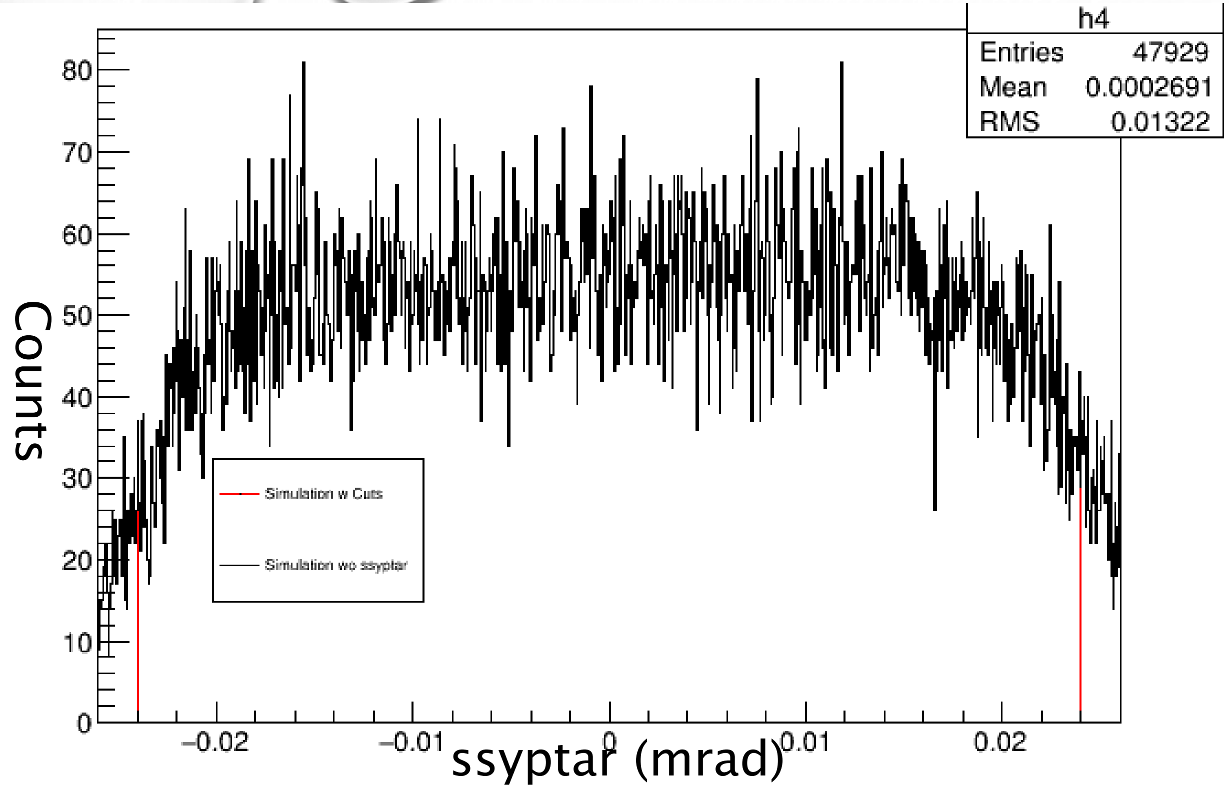
Electric Charge

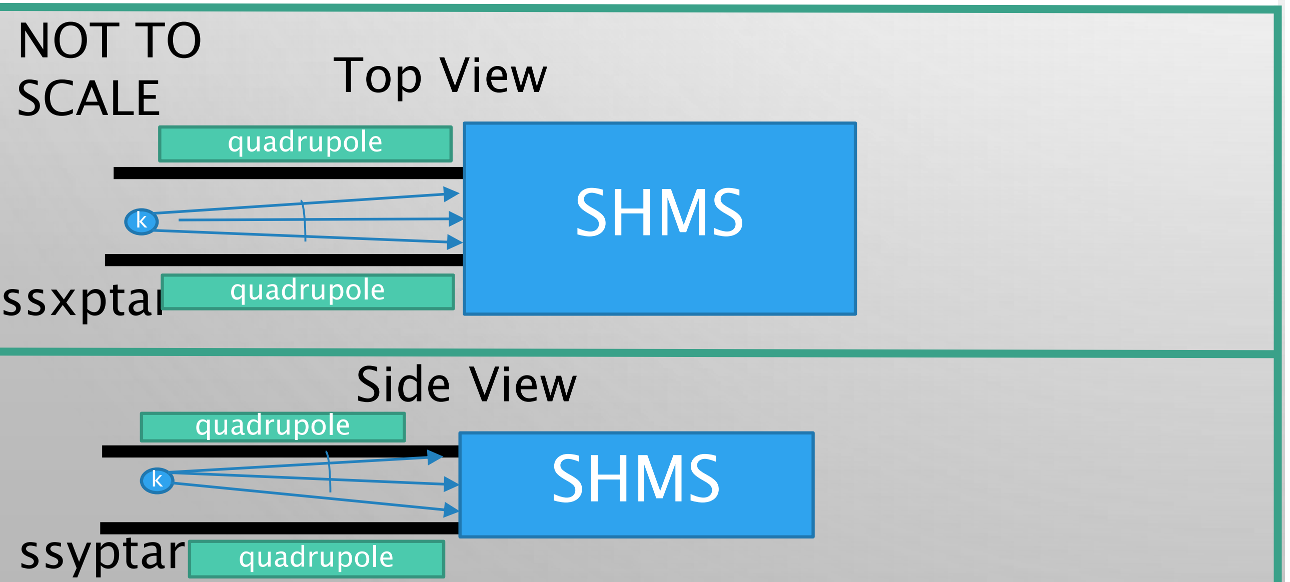
Electric Field

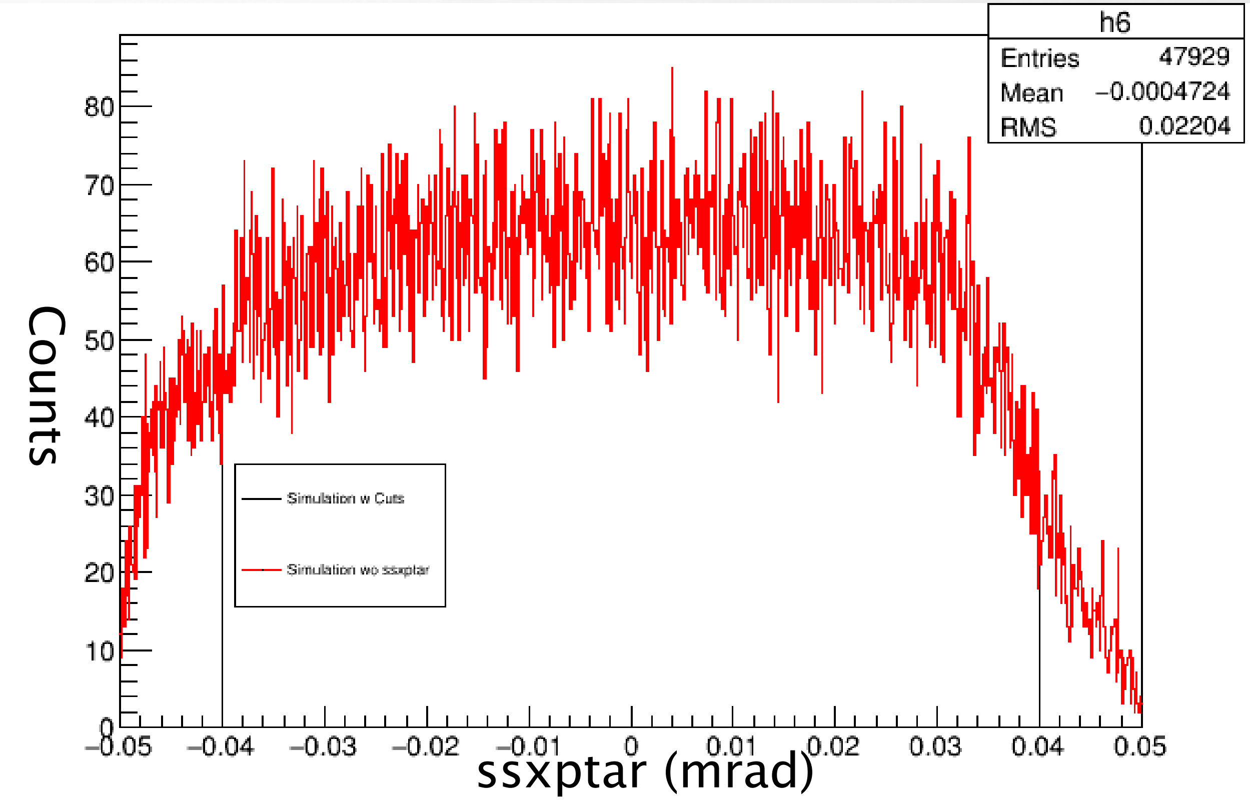


Kinematic Configuration	
Run	Q2 1.7
Beam Energy	5647
e^- p	2012
e^- theta	22.30
$ctau$	371.3
$kaon$	1

Example of a Simulated Angular Distribution for Kaon Electro Production with Cuts Applied







KAON PREDICTION

$$N_k = y\left[\frac{\#}{mc}\right] * i[\mu A] * \Delta t[s] * 10^{-3}$$

$$N_k = 4{,}381{,}020.0 \pm 2093.1$$

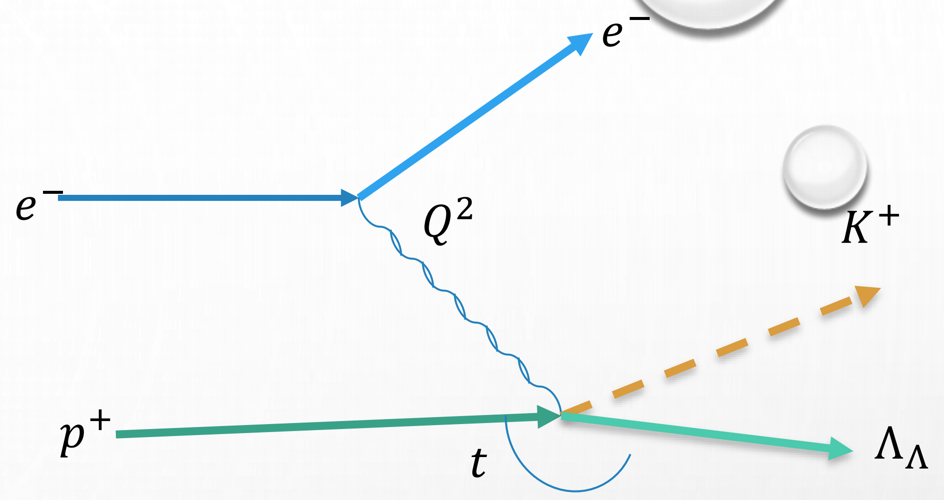
$$N_{k/s} = y\left[\frac{\#}{mc}\right] * i[\mu A] * 10^{-3}$$

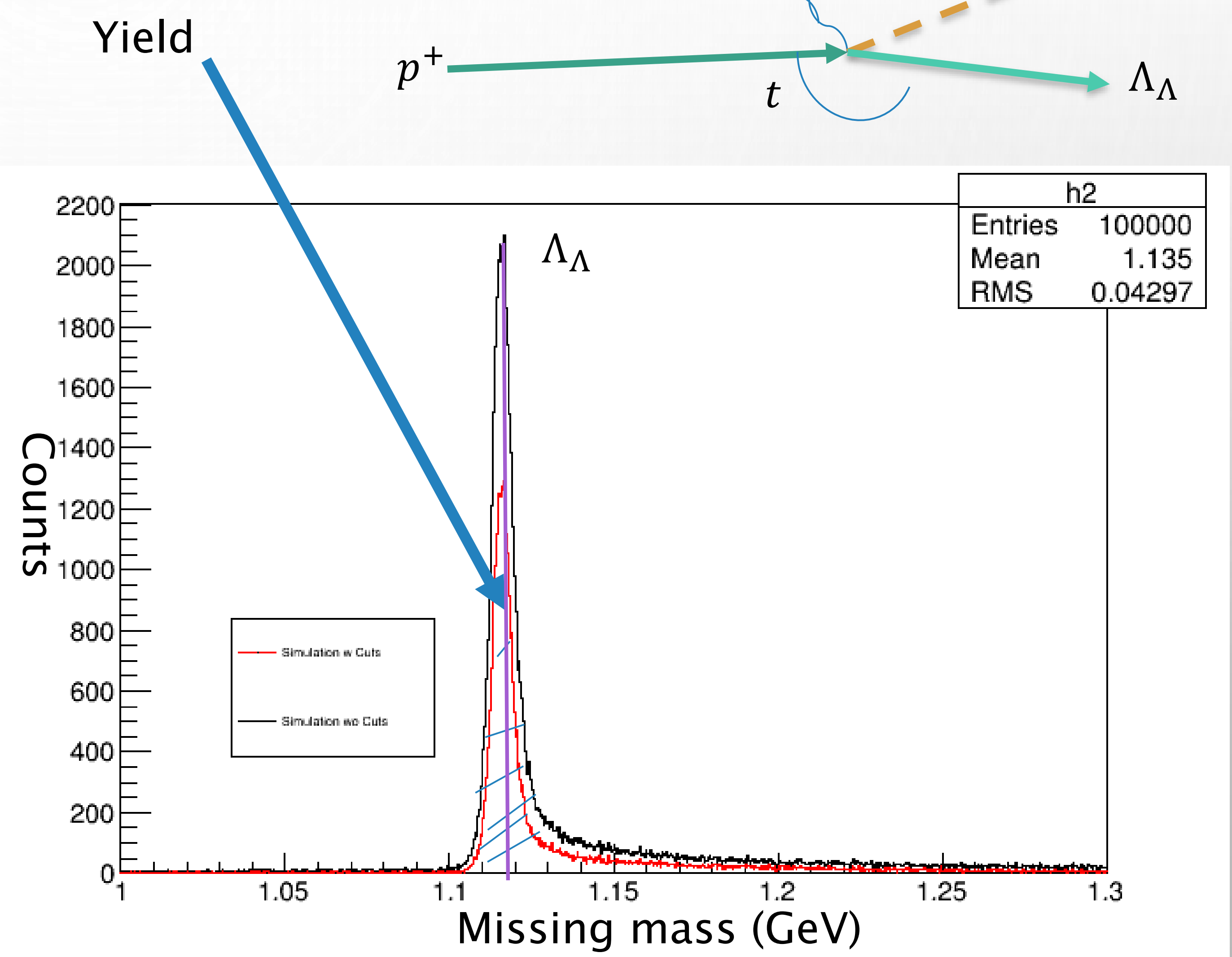
$$N_{k/s} = 39.9 \pm 0.1$$

Uncertainty:

$$\sqrt{N}$$

To verify that the simulation correctly produced the kaon electro production reaction, one can calculate the missing mass – the distribution should be centered on the Lambda mass (~1.115 GeV)





Results

Run	Kaons per second
1.7	39.9±0.1
1.7(2)	42.8 ± .1
5.5	9.2± .1
5.5(2)	11.6± .1

The experiment is set to run each trial(rows) for multiple days which will result in a lot of Kaons.

Pion Analysis

- GOAL: TO DETERMINE THE NUMBER OF PIONS DETECTED ALONG WITH KAONS IN THE EXPERIMENT WITH THE SAME SPECTROMETER CONFIGURATION.
- IF THERE ARE ENOUGH PIONS, ONE MAY USE THEM TO EXTRACT THE PION FORM FACTOR FROM THE DATA – FREE ADDITIONAL PHYSICS!

PION PROJECTIONS

Uses the same kinematic configuration as for the kaon projections, but changes the detected particle from kaon to pion. Also the recoiling particle changes too.

$$N_{\pi on} = y\left[\frac{\#}{mc}\right] * i[\mu A] * \Delta t[s] * 10^{-3}$$

$$N_{\pi on} = 278{,}263{,}944.0 \pm 16681.2$$

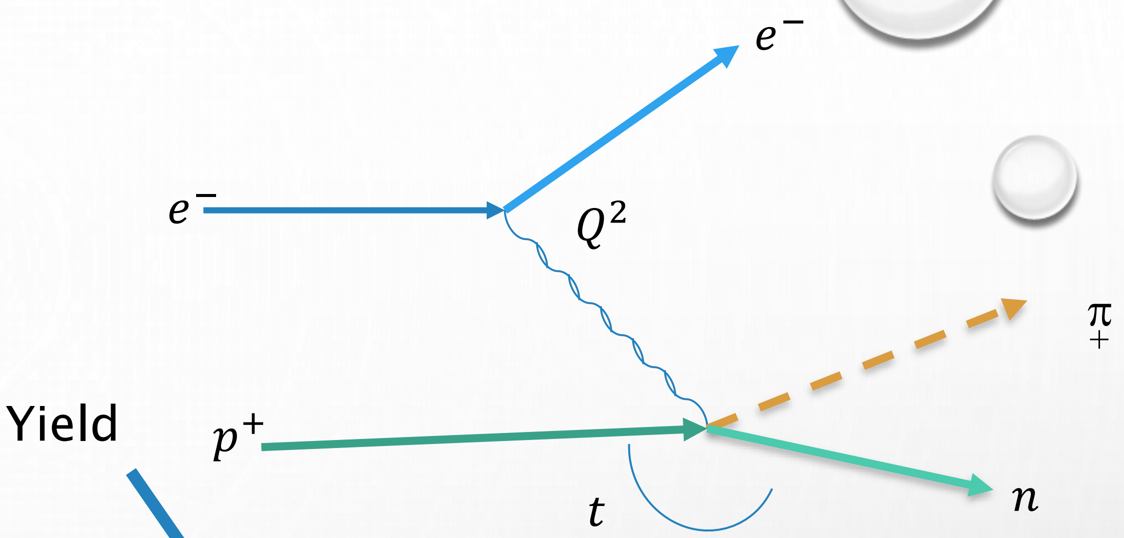
$$N_{\pi on/s} = y\left[\frac{\#}{mc}\right] * i[\mu A] * 10^{-3}$$

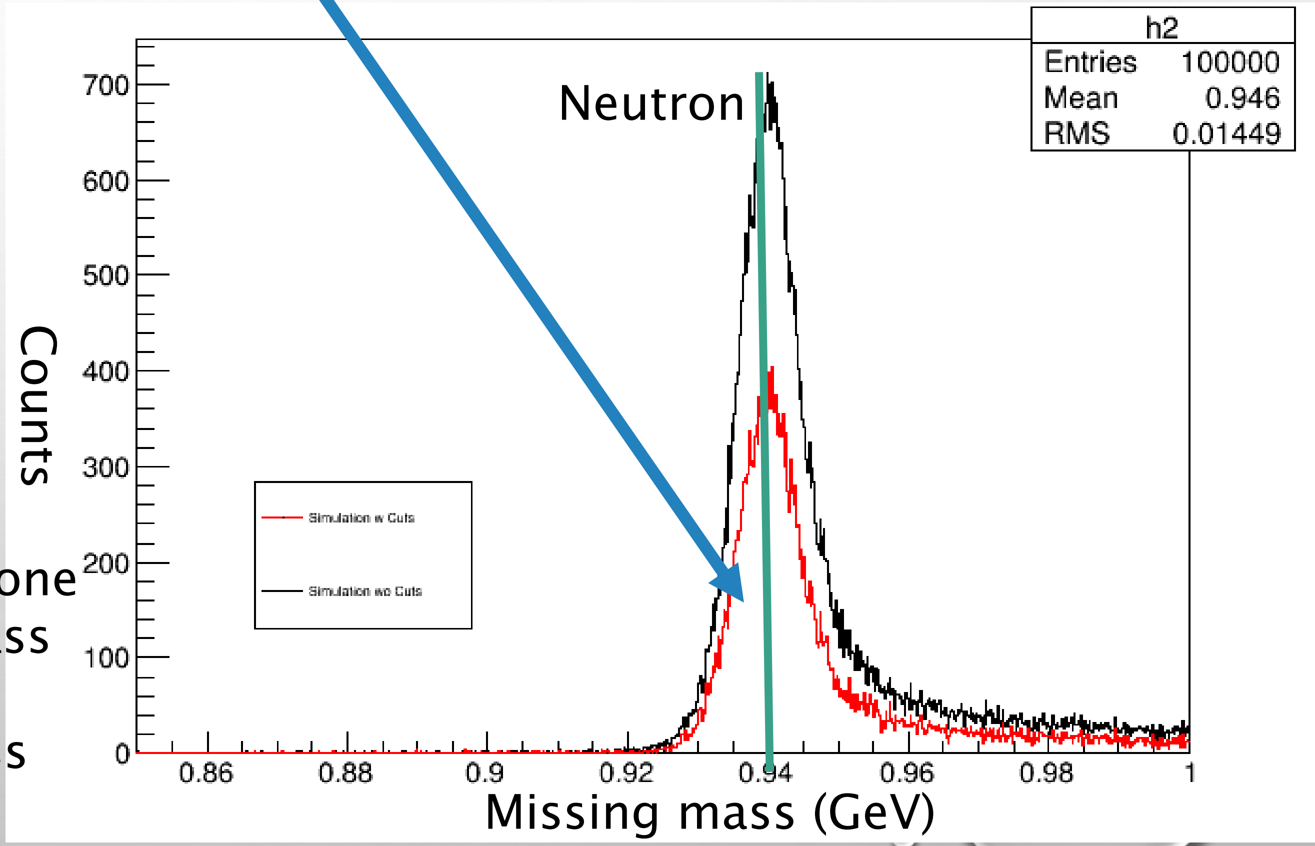
$$N_{\pi on/s} = 2534.3 \pm .1$$

Uncertainty:

$\sqrt{N}$

To verify that the simulation correctly produced the kaon electro production reaction, one can calculate the missing mass – the distribution should be centered on the neutron mass (~0.939 GeV)





Results

Run	Pions per second
1.7	2534.3 $\pm$ .1
1.7 (2)	2999.6 $\pm$ .1
5.5	2724.3$\pm$ .1
5.5(2)	2473.2 $\pm$ .1

- Large amounts of pions can be detected in the kaon experiment
- These “Free” pions can aid in the pion form factor study

Further Research

- CALCULATE THE STATISTICAL UNCERTAINTIES FOR A MEASUREMENT OF PIONS EXPECTED FOR THE SCHEDULED BEAM TIME OF THE KAON EXPERIMENT
- MAKE PROJECTIONS FOR HOW WELL ONE COULD DETERMINE THE PION FORM FACTOR BASED ON THESE “FREE” PIONS

ACKNOWLEDGEMENTS

I'D LIKE TO THANK MARCO CARMINGOTTO, DR. HORN, SALINA ALI, AND JOHAN MEJIA-OTT FOR THEIR TREMENDOUS HELP IN MY RESEARCH. WITHOUT THEIR HELP NONE OF THIS WOULD HAVE HAPPENED. I'D ALSO LIKE TO THANK MY COWORKERS SALIM ROUSTOM, DANNIE GRIGGS, AND ABBY MCSHANE FOR THEIR INPUT.