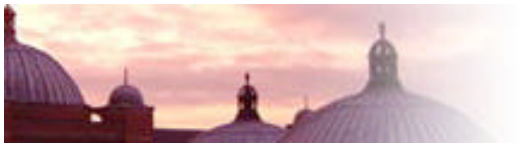


Institute of Physics
High Energy Particle Physics Group

Heavy Ion Physics at the NA57 CERN Experiment

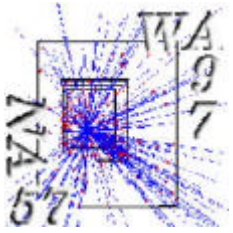
Particle Physics 2004

Parallel Session Presentation

6th – 7th April 2004

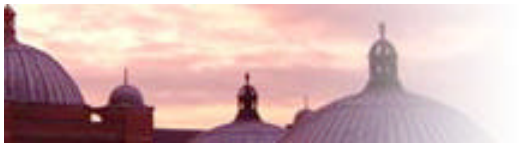
Stephen A. Bull

(The University of Birmingham)



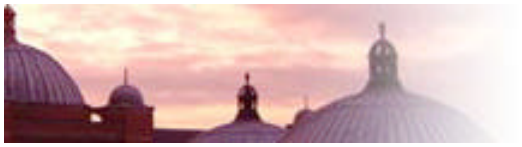
Institute of Physics

THE UNIVERSITY OF BIRMINGHAM



Contents and Introduction

- The Quark-Gluon Plasma and Heavy Ion Physics
  - Motivation
  - Why Heavy Ions?
  - Strangeness Enhancement: Signature of a QGP
- The NA57 Experiment
- My Work
  - Extracting 'cleaned' Λ and $\bar{\Lambda}$ signals
  - Strangeness Enhancement in Λs at 40 A GeV/c?
- The future for Heavy Ion Physics
- Summary

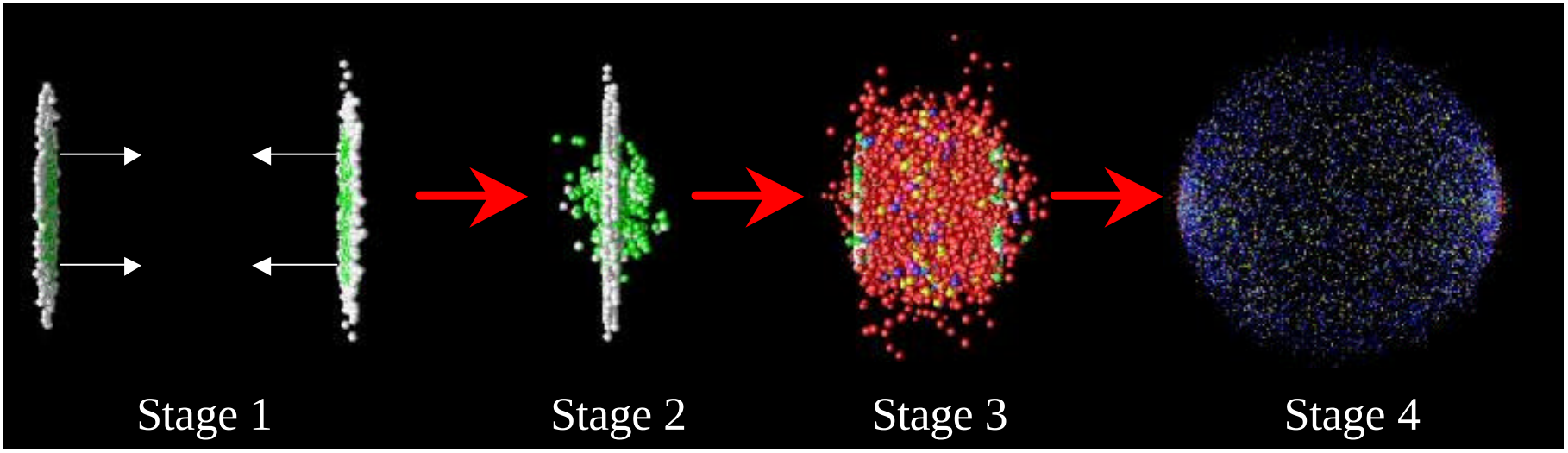


Physics Motivation

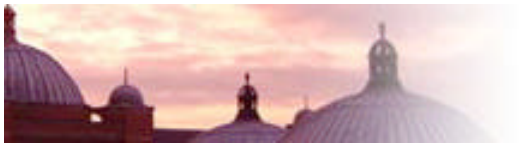
- Hadronic matter can be subdivided into:
  - Baryons (qqq) } bound together
  - Mesons ($q\bar{q}$) } by gluons
- Under normal conditions it is not possible to observe 'free' quarks, antiquarks and gluons
- However under extreme conditions, similar to that which existed ~10μs after the universe began, hadronic matter undergoes a phase transition into a Quark-Gluon Plasma: the state of deconfined strongly interacting matter. Furthermore quarks reduce to their bare masses
  - → A further test of QCD

Heavy Ion Collisions

- Why collide heavy ions?
  - So as to pack enough energy into a large enough volume to create a macroscopic ultra-hot (10^{12}K) fireball within which matter enters the QGP phase



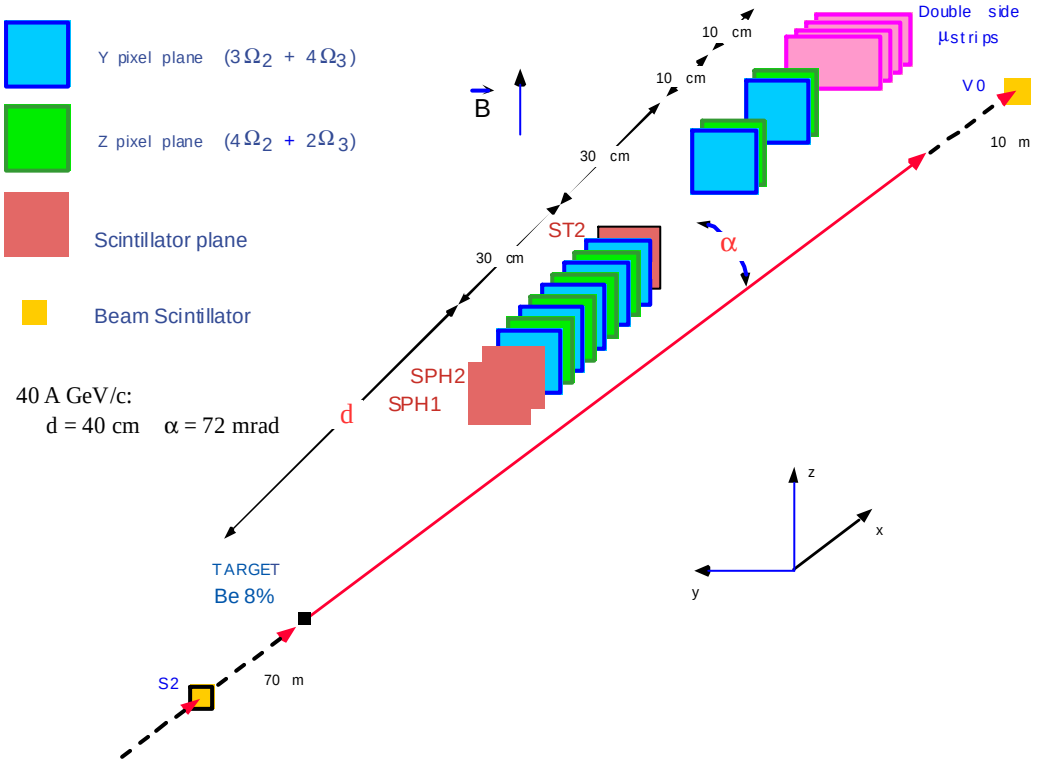
A typical Heavy Ion Collision



Observing the QGP

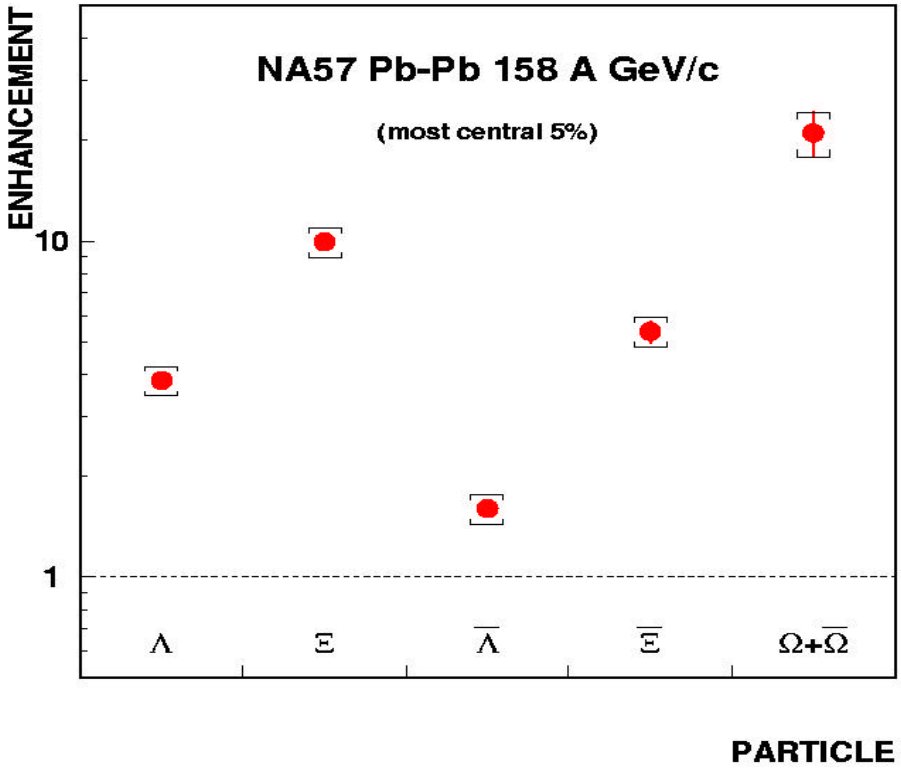
- It is not possible to observe a QGP directly, instead we look for a signature
- One such signature is Strangeness Enhancement
- In a QGP $s\bar{s}$ pairs can be readily produced by the thermal gluon fusion process:
  - $gg \rightarrow s\bar{s}$ (150+150 MeV required) [$T_{fireball} \sim 200MeV$]
- All strange quarks and antiquarks go on to form strange hadrons after hadronisation
- In a hadronic gas it is much more difficult to produce strange particles and antiparticles

The NA57 Experiment



- NA57 is a fixed target experiment and takes data at:
  - 158 A GeV/c
  - 40 A GeV/c
- 2 types of collision:
  - Pb–Pb
  - p–Be (reference data)
- The set up shown is for 40 A GeV/c p-Be

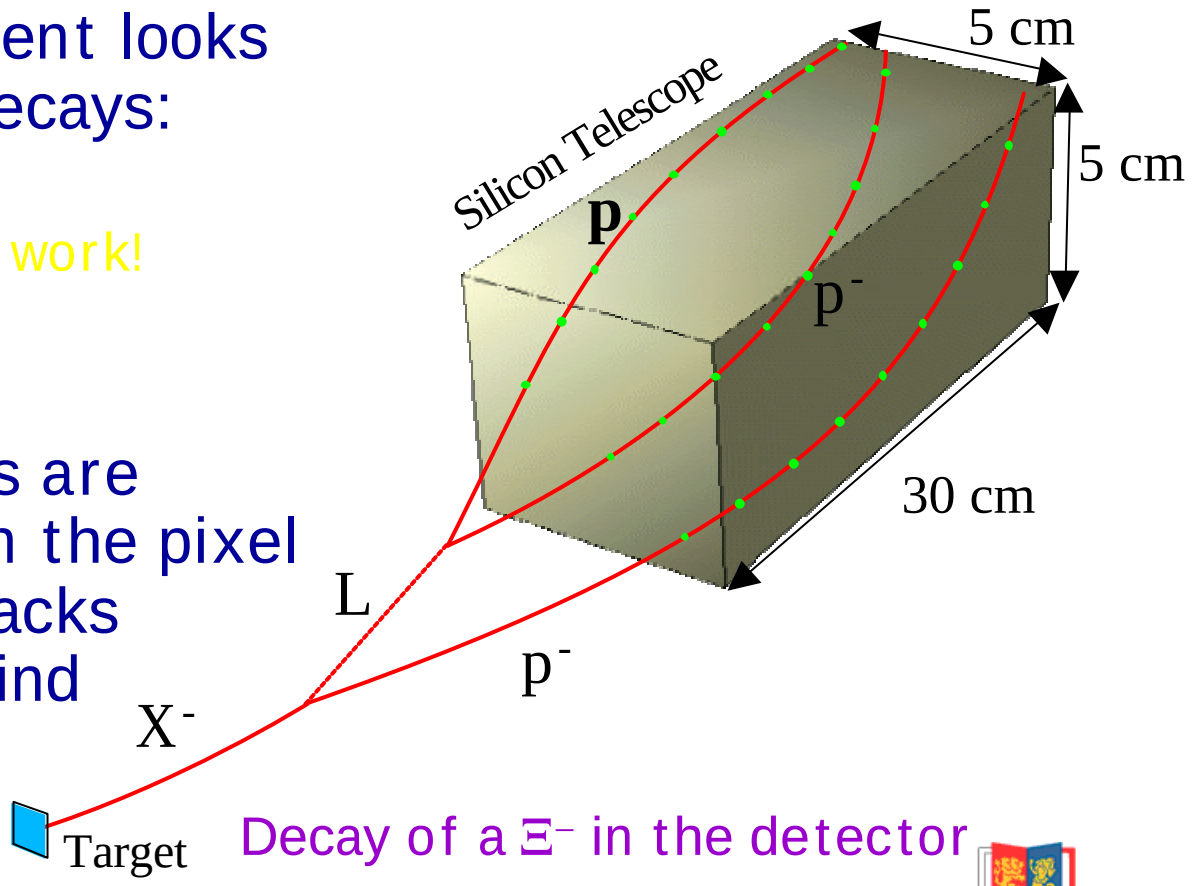
Results from NA57 at 158 A GeV/c



- The results of NA57 at 158 A GeV/c formed part of the evidence presented by CERN in Feb 2000 indicating that a QGP had been observed.
- Data at 40 A GeV/c allows us to go to lower energy densities

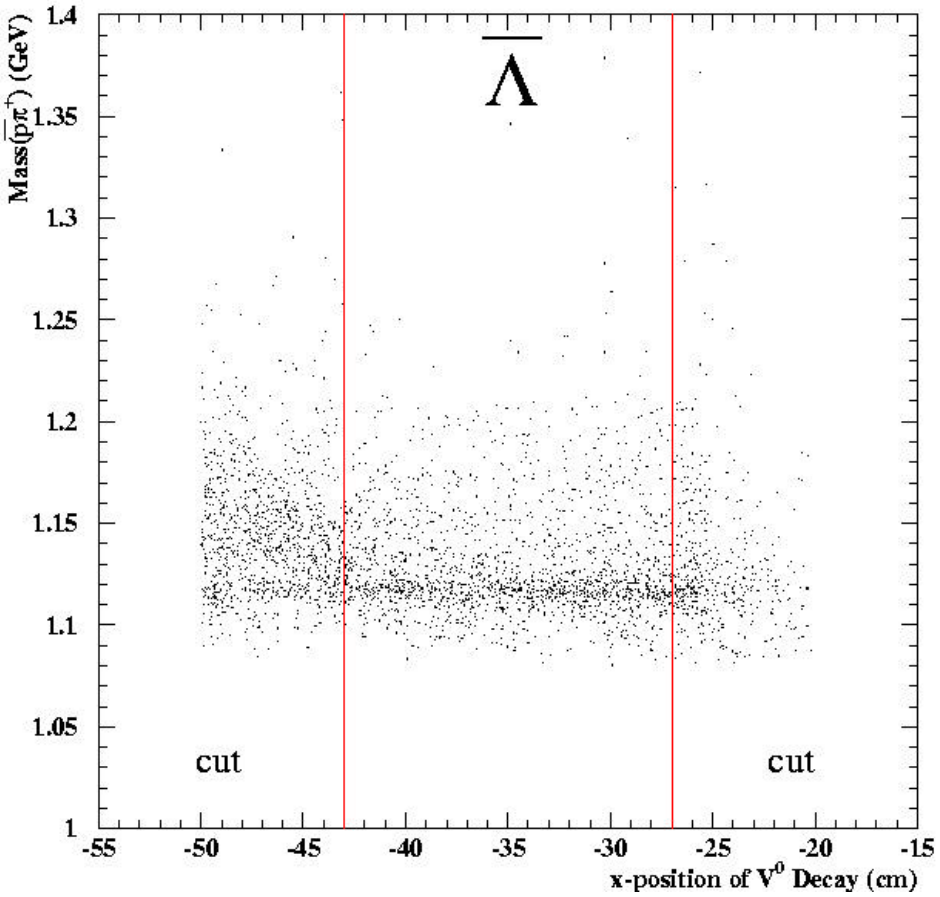
The NA57 Detector

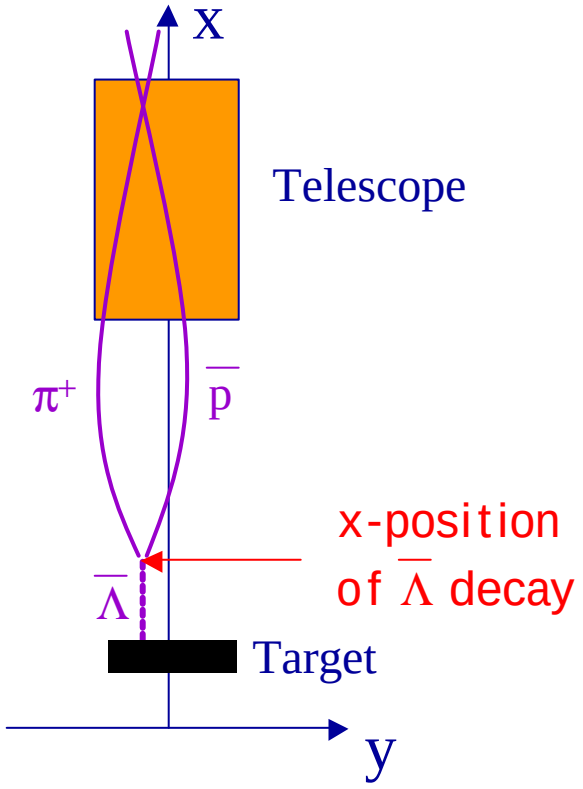
- The NA57 experiment looks for the following decays:
  - $K^0(q\bar{s}) \rightarrow \pi^+\pi^-$
  - $\Lambda\ (qqs) \rightarrow p\pi^-$ ← My work!
  - $\Xi^-\ (qss) \rightarrow \Lambda\pi^-$
  - $\Omega^-\ (sss) \rightarrow \Lambda K^-$
- The decay products are observed as 'hits' in the pixel planes and their tracks reconstructed to find the strange particle



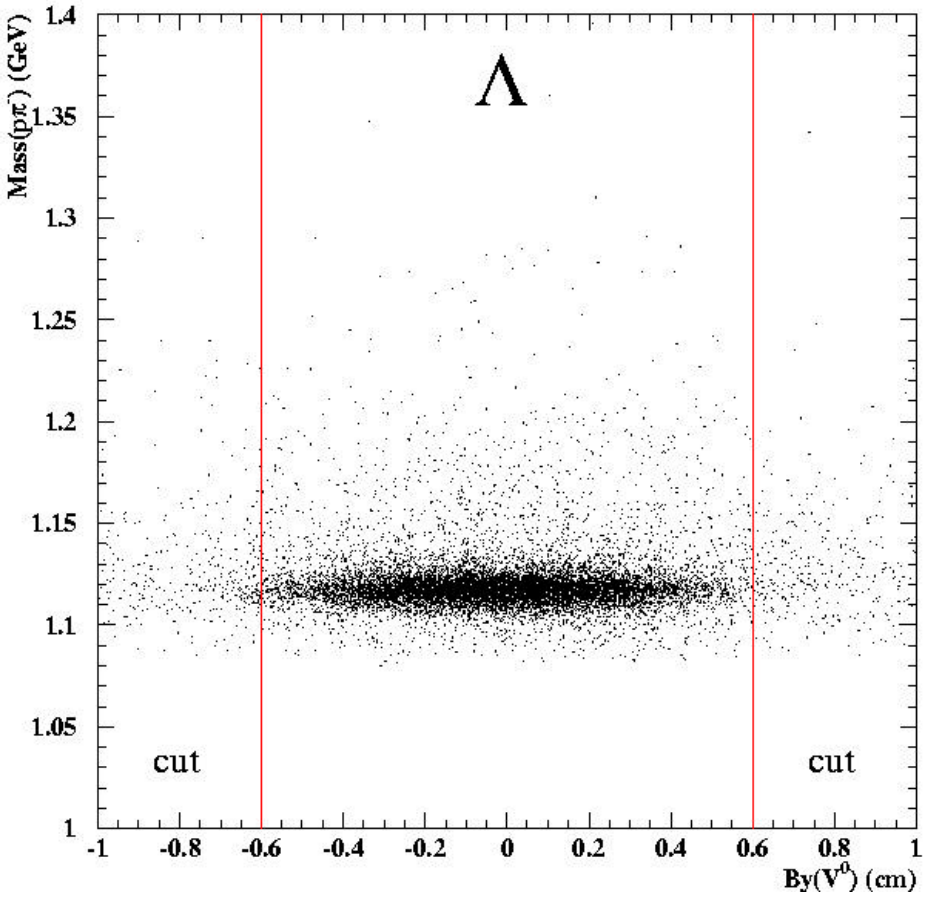
Decay of a Ξ^- in the detector

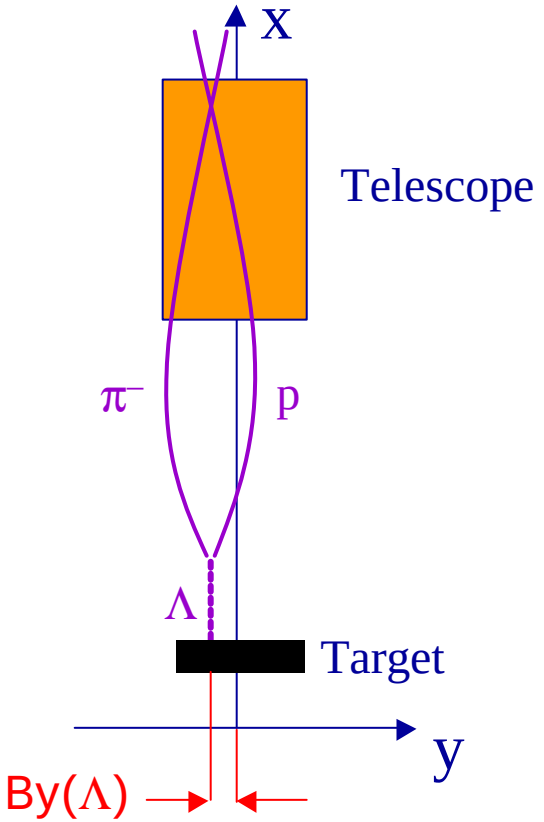
The X-Position of the $\overline{\Lambda}$ Decay



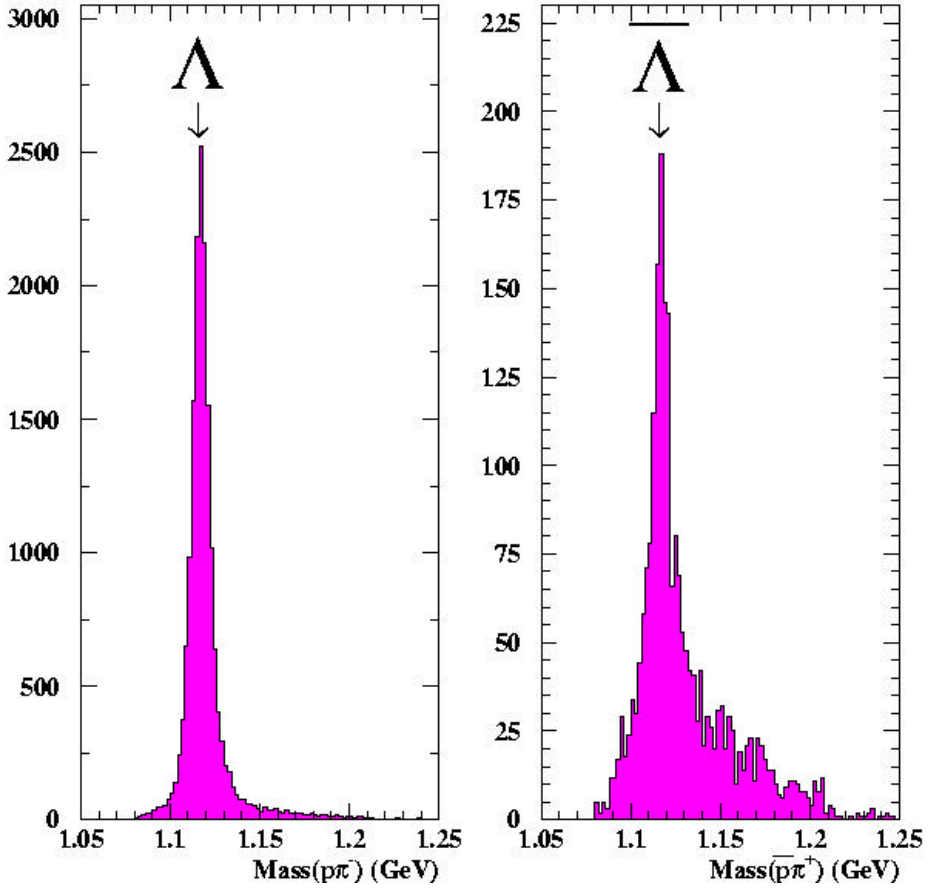


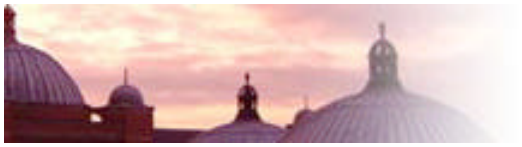
The 'By' Parameter of the Λ Decay





'Cleaned' Λ and $\overline{\Lambda}$ Signals





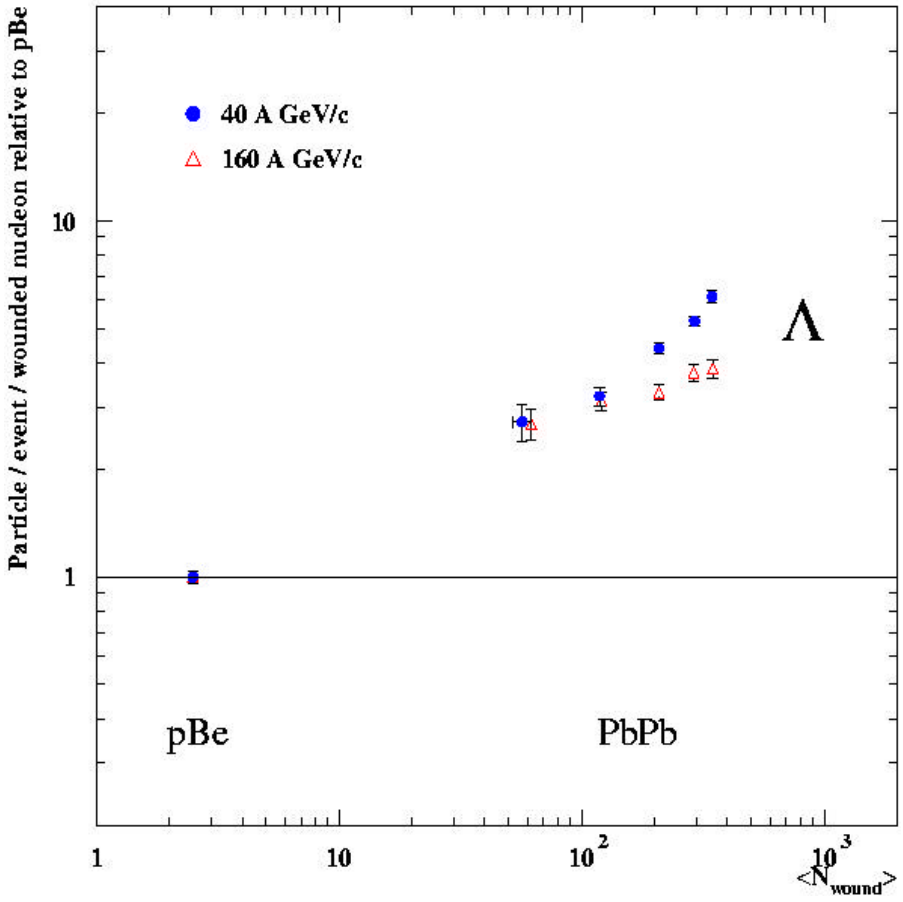
Enhancement Calculation

- An enhancement is calculated:

$$\text{Enhancement} = \frac{\left[\text{Yield} / \langle N_{\text{wound}} \rangle\right]_{\text{Pb-Pb}}}{\left[\text{Yield} / \langle N_{\text{wound}} \rangle\right]_{\text{p-Be}}}$$

- To calculate a yield a detailed analysis is performed to take into account:
  - Geometric Acceptance
  - Detector Efficiency
  - Reconstruction Efficiency
  - Selection Criteria (previous three slides)

Enhancements



- Can see a definite enhancement in Λ candidates when going from p-Be → Pb-Pb collisions
  - A QGP has been observed at 40 A GeV/c!
- Can see the 40 A GeV/c enhancement compared to 158 A GeV/c

The Future of Heavy Ions

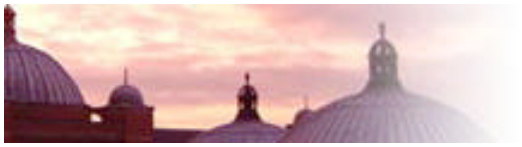
- C of M Energies
  - SPS

$\sqrt{s} = 8.7$ GeV

$\sqrt{s} = 17.3$ GeV

  - ALICE

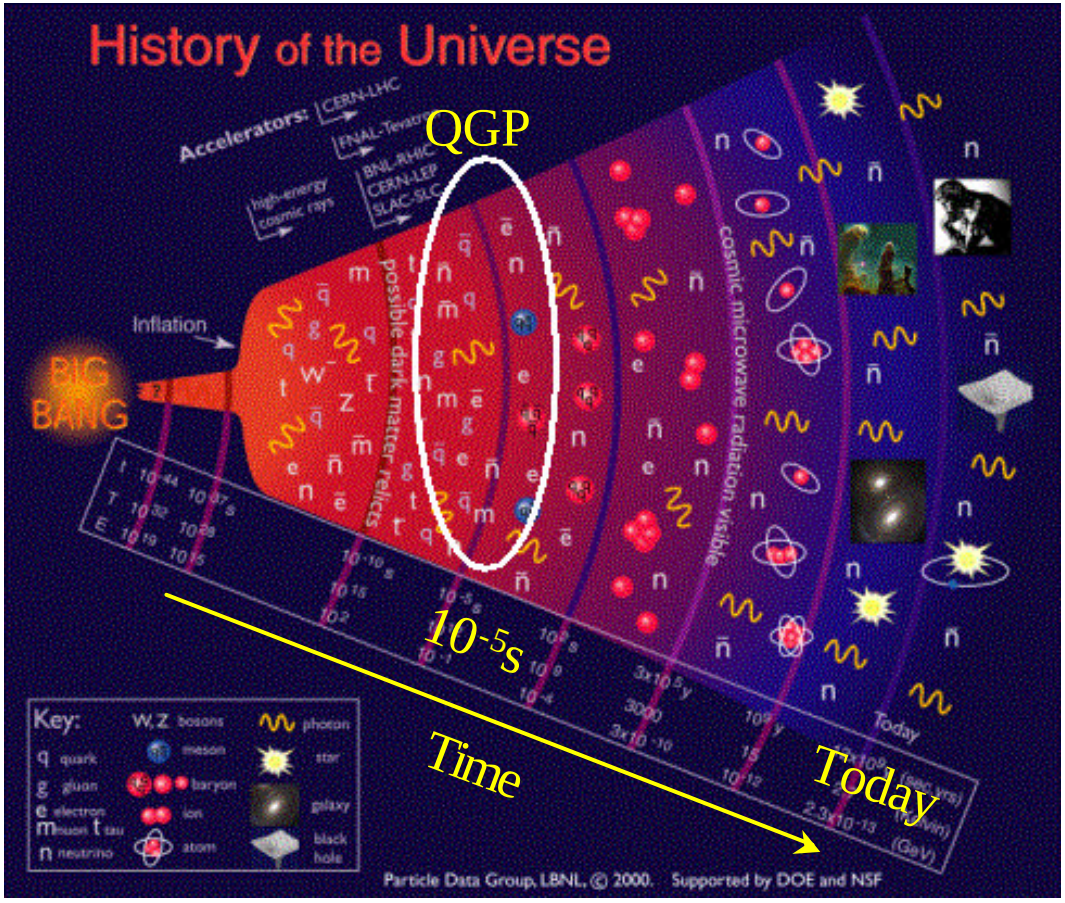
$\sqrt{s} = 5.5$ TeV



Summary

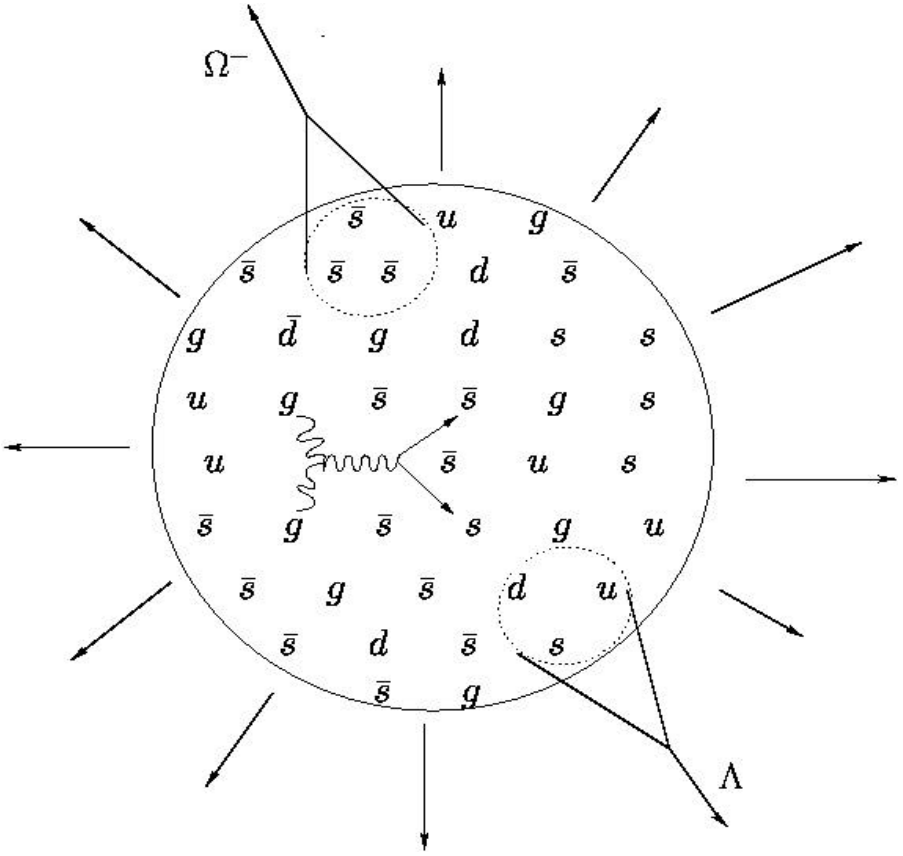
- Colliding heavy ions together allows hadronic matter to enter a new phase, known as a Quark-Gluon Plasma (QGP)
- Transition to the QGP phase has been observed by the NA57 Experiment at 158 A GeV/c
- I have studied the possible transition at 40 A GeV/c
  - Techniques have been outlined for cleaning the Λ and $\overline{\Lambda}$ signals
  - A yield has been calculated for Λ candidates in p-Be interactions
    - → Evidence to suggest a QGP has been formed in Pb-Pb collisions
- There is an ongoing and exciting future for heavy ion physics

Going Back in time …



- NA57 attempts to look back in time by recreating extreme conditions in the form of a very hot, dense fireball
- This is achieved by firing an ultra-relativistic lead beam of ions onto a lead target

Observing the QGP

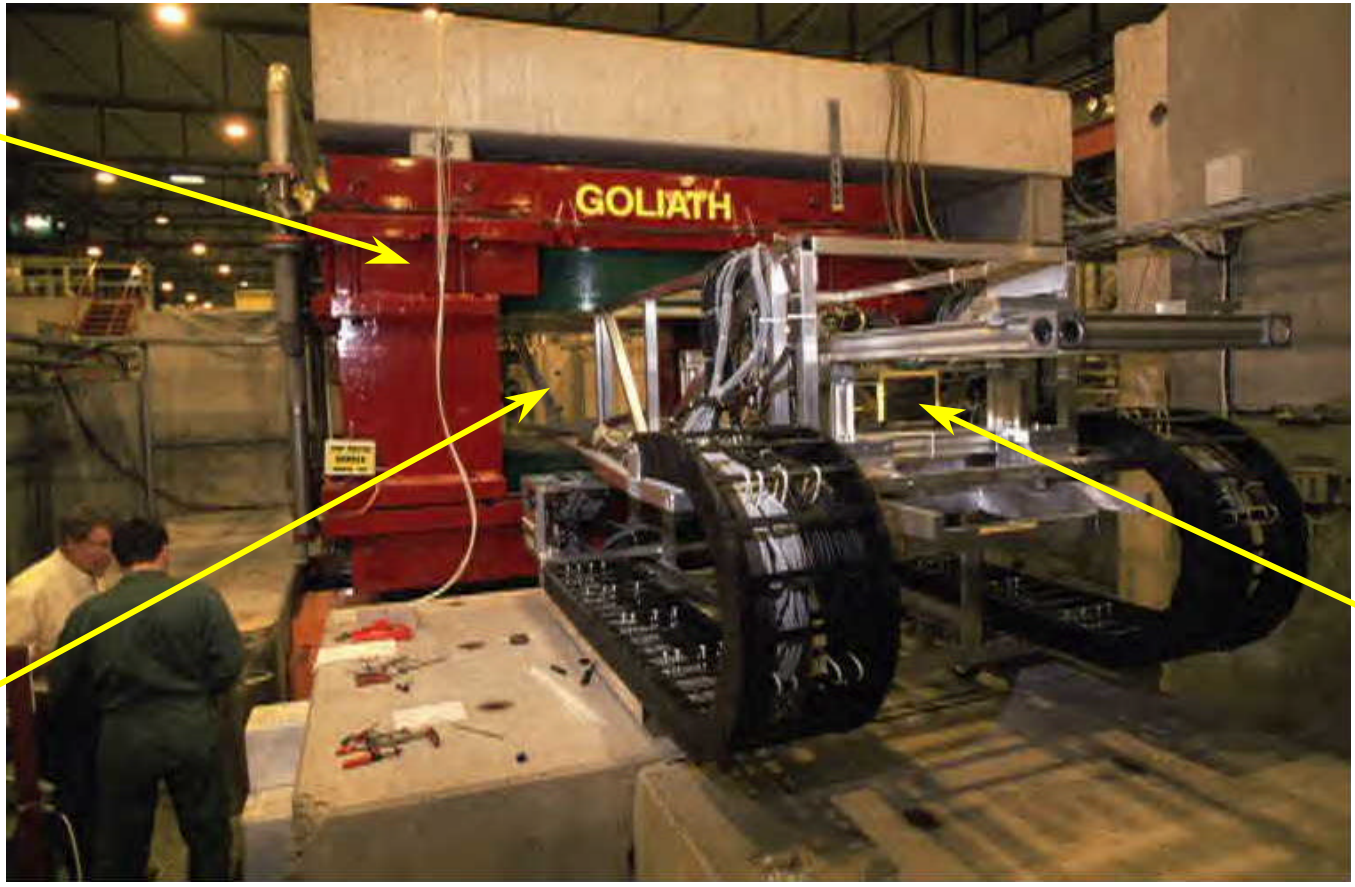


- In the ensuing hadronisation process strange particles which otherwise would only be rarely produced are observed
- An enhancement in strange particles is thus indicative of a QGP

Photo of the NA57 Experiment

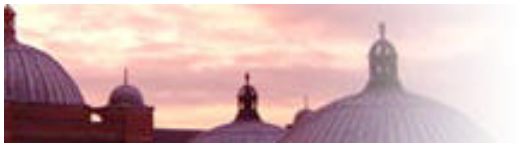
(situated in the CERN North Area)

Goliath magnet (1.4 Tesla)

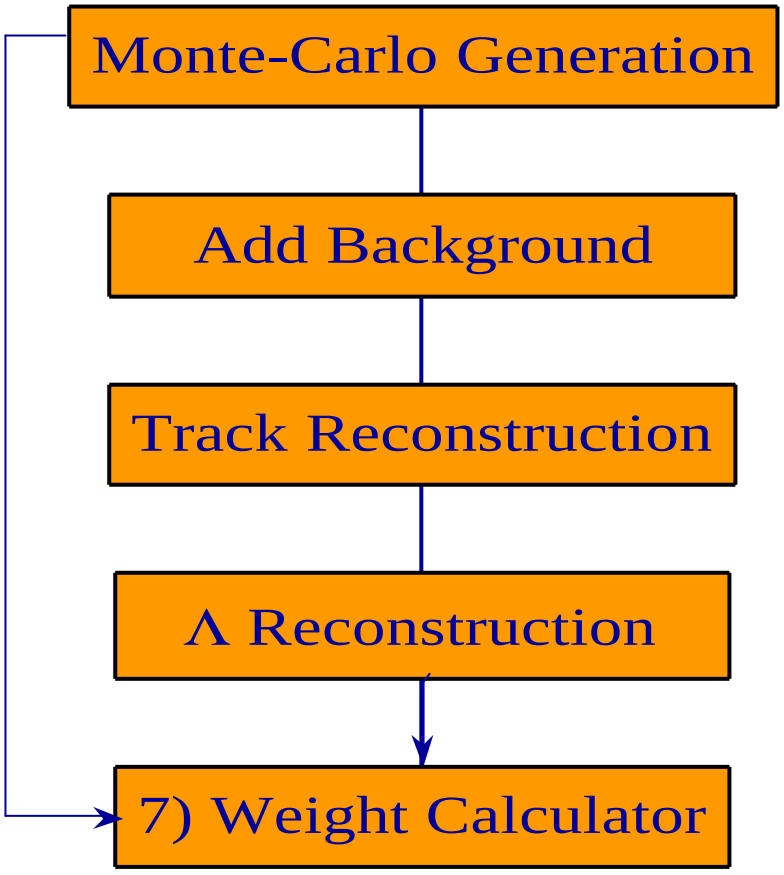


Beam pipe

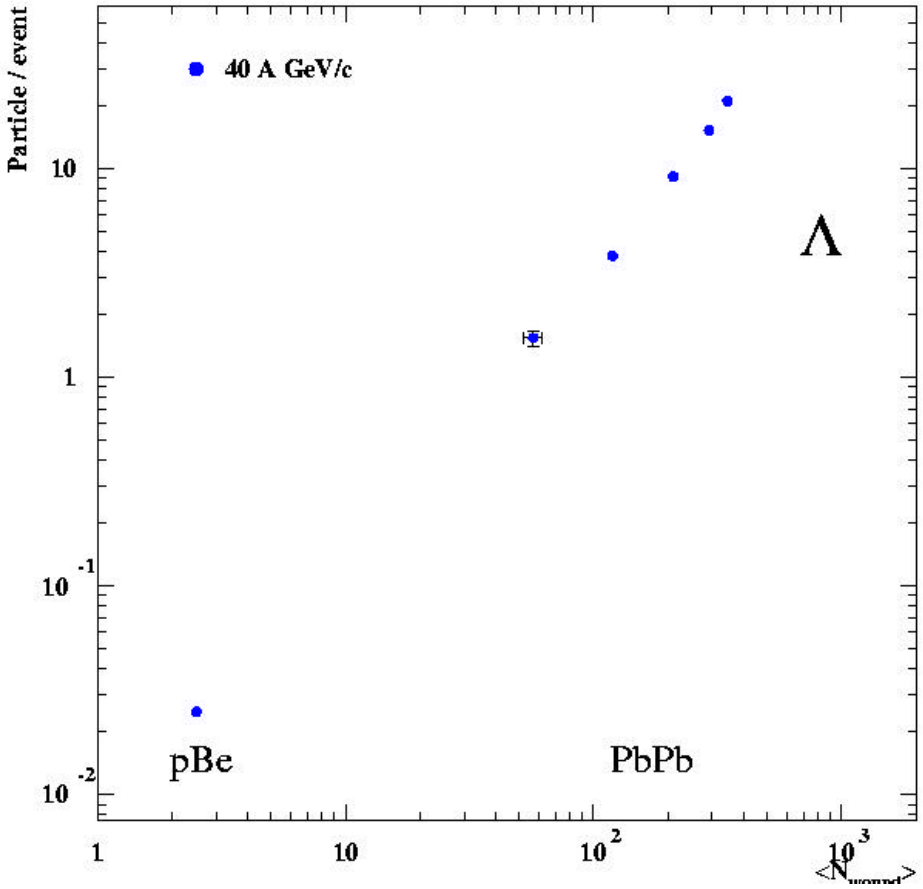
Back end of NA57 detector



Weighting


Monte-Carlo Generation
Add Background
Track Reconstruction
Λ Reconstruction
7) Weight Calculator

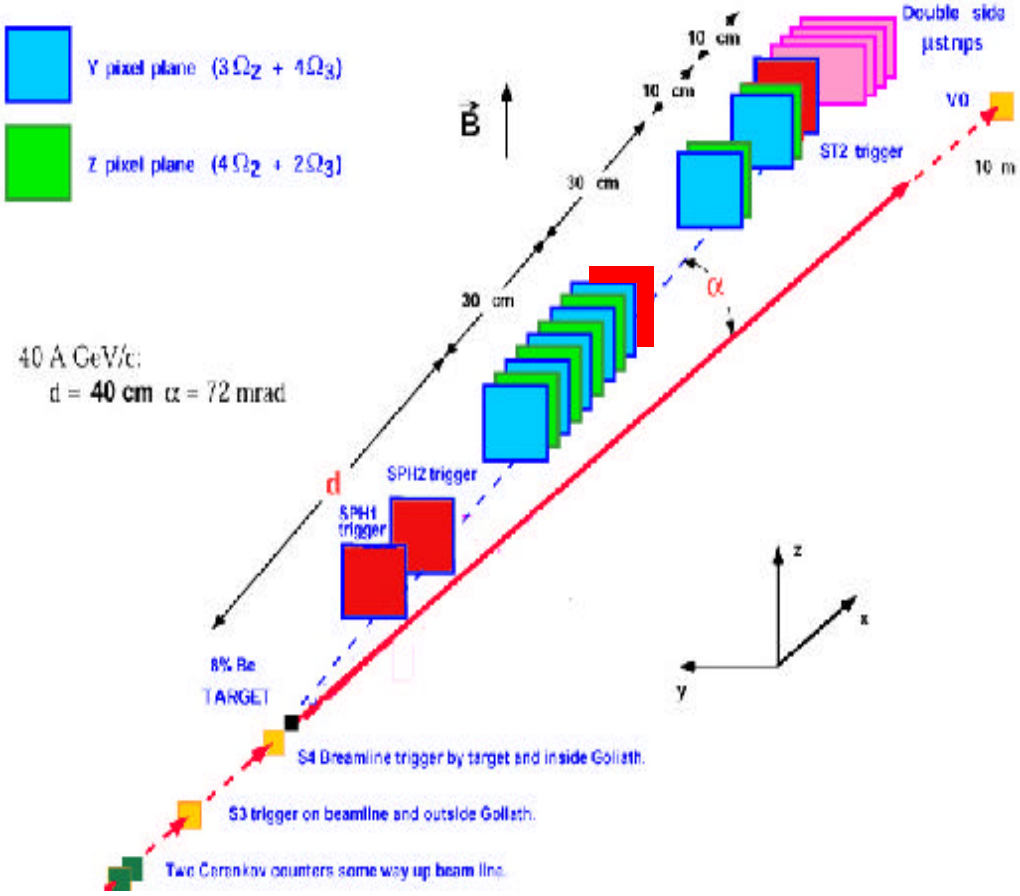
Yields



$$\text{Yield} = \frac{\sum \text{Weight}}{\text{Number of Interactions}}$$

- Once a yield has been calculated – the value can be used to calculate an enhancement

The NA57 Experiment



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