Midterm test: simulation of experimental apparatus response

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Computing Methods in Physics

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SAPIENZA
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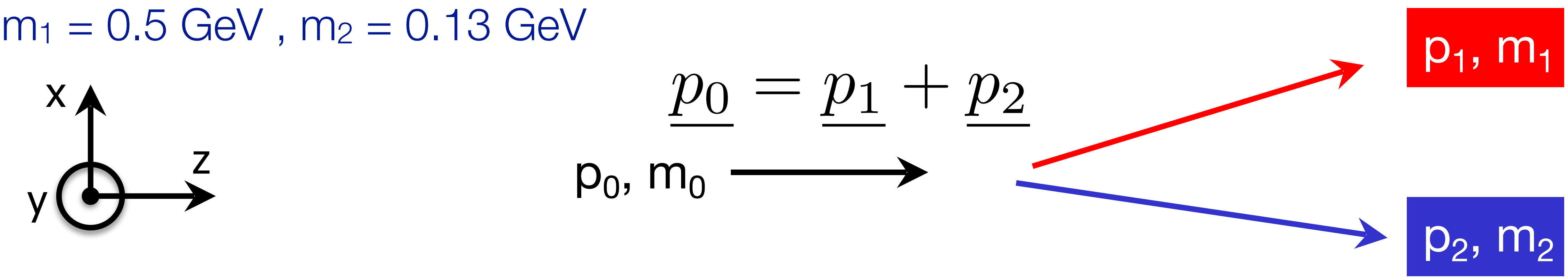
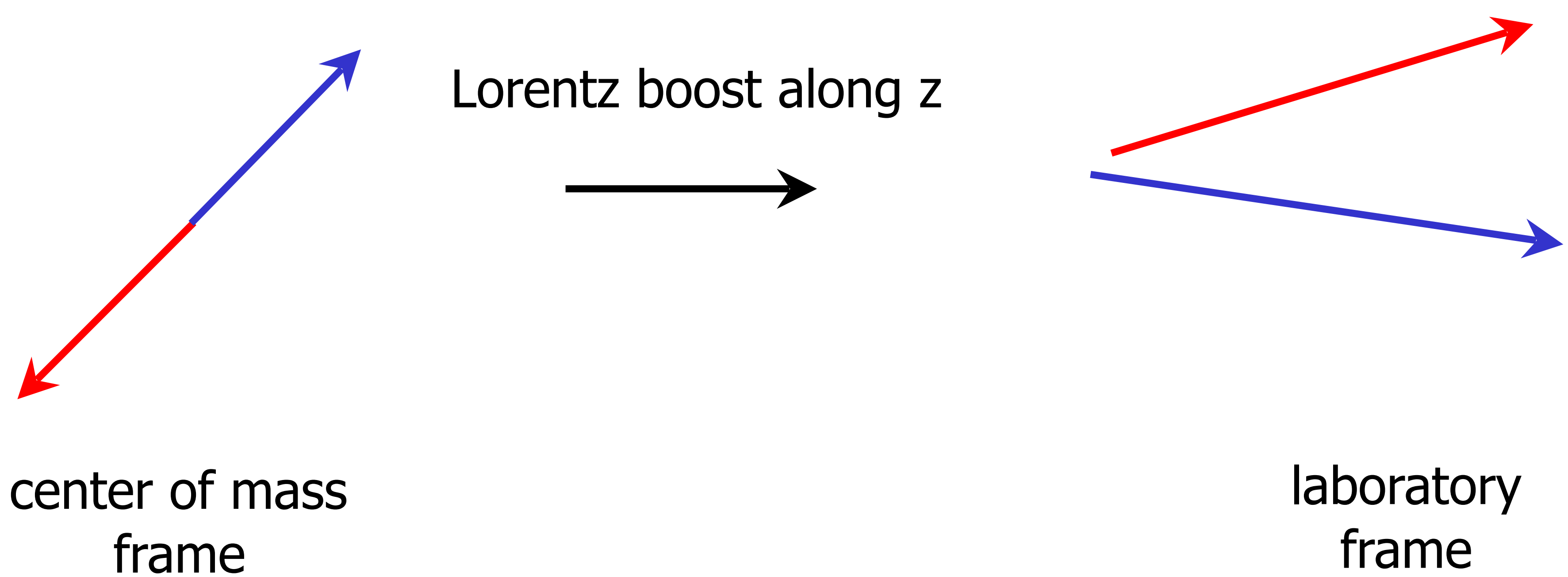
Two body decay of a particle

- Particle of mass m_0 and 3-momentum p_0 in the laboratory frame decays into 2 particles of mass m_1 and m_2
  - mass and momentum in GeV units
  - Use $m_0 = 5.3$ GeV
  - momentum p_0 along z axis with $|p_0| = 4$ GeV
  - $m_1 = 0.5$ GeV , $m_2 = 0.13$ GeV

$$\underline{p_0} = \underline{p_1} + \underline{p_2}$$

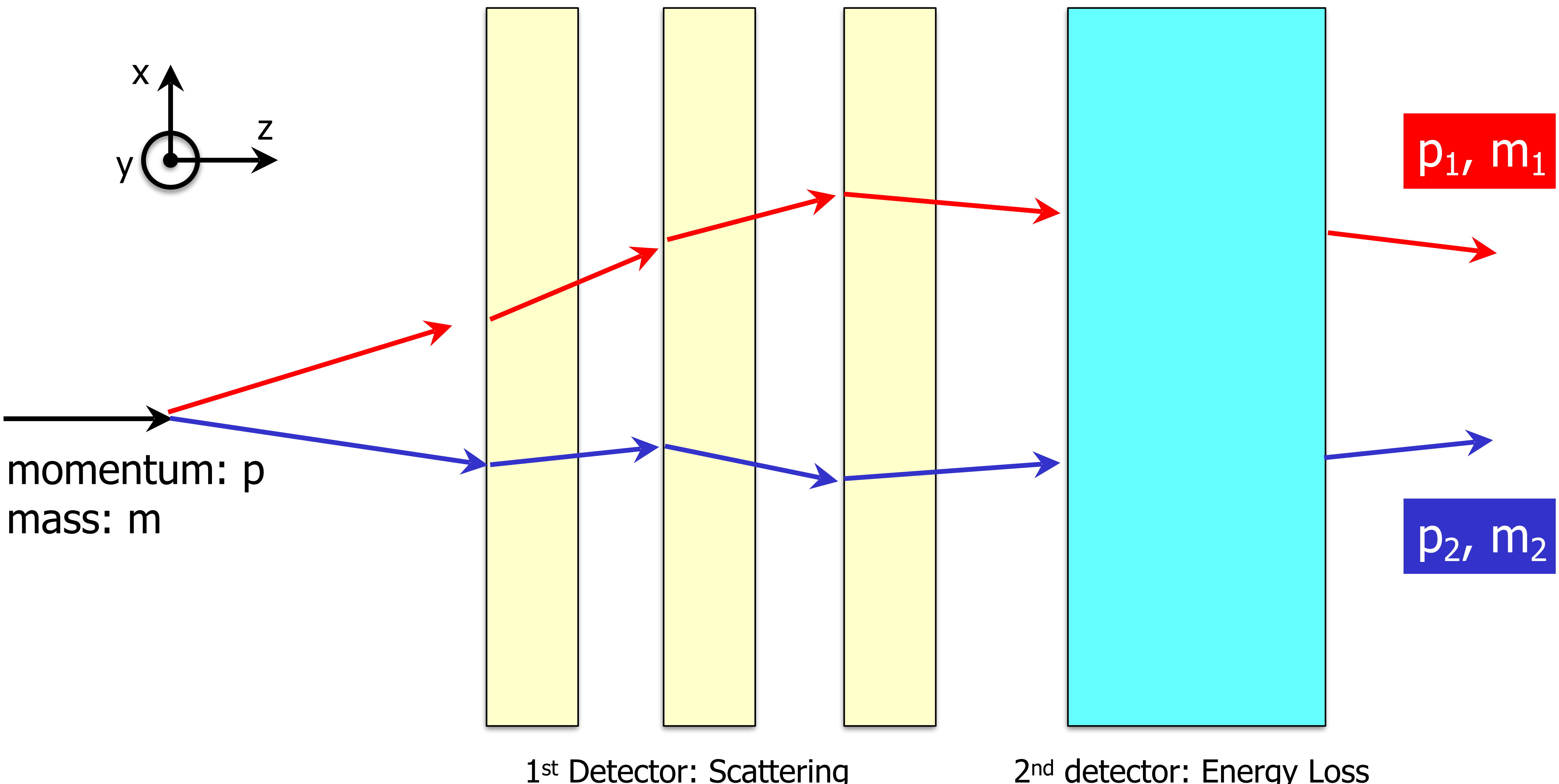


- Two particles decay back-to-back in centre of mass frame and then boosted along z axis to laboratory frame



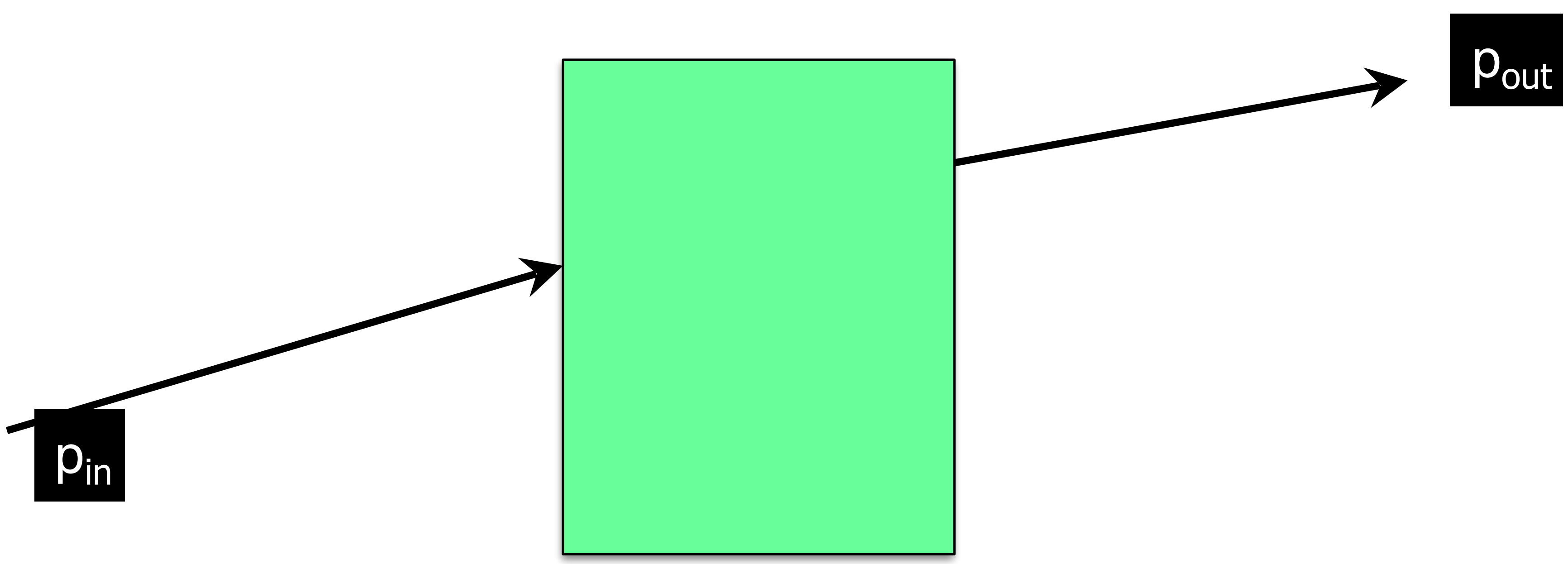
Experimental setup

- Assume decay happens before the detectors
- Passage through each detector modifies the 4-momentum of the particle
  - 1st detector modifies the direction of particles (scattering)
  - 2nd detector modifies (reduces) the energy of the particle (energy loss)



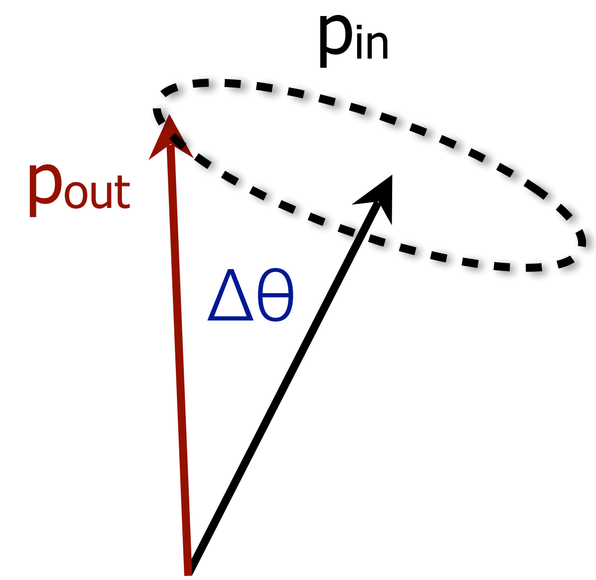
Modelling of Detector Response

- Each detector causes variation in the 4-momentum of incoming particles
  - particle comes into the detector with 4-momentum $\mathbf{p_{in}}$
  - particle leaves detector with 4-momentum $\mathbf{p_{out}}$
- Use simple Gaussian model to describe the response of each detector
  - direction and/or direction (angles) of particles smeared
  - parameters of smearing (width of Gaussian) are properties of each detector
  - parameters can be configured by user



Scattering

- Modify only the direction of the particle
  - we assume both θ and ϕ of the momentum are modified by $\Delta\theta$



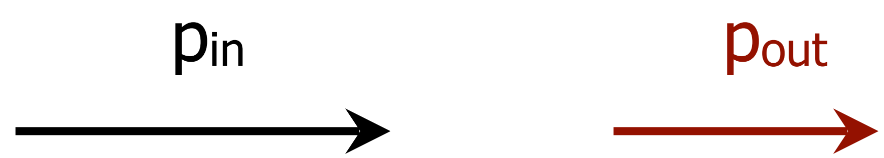
- Extract $\Delta\theta$ from a Gaussian distribution with mean μ and width σ
  - use $\mu = 0$ and width $\sigma = \frac{p_{max}}{p_{in}} \Delta\theta_{max}$
  - $p_{max} = 3.5$ GeV, p_{in} is the incoming momentum and $\Delta\theta_{max} = 0.01$ rad

- Note that particles with lower momentum have a higher probability of being deflected

- Parameters p_{max} and $\Delta\theta_{max}$ must be configurable

Energy loss

- The 2nd detector can only modify (decrease) the momentum of the incoming particle



- The momentum variation is given by $p_{out} = p_{in} - \Delta P$
- Also in this case ΔP has a Gaussian distribution with
  - mean $\mu = a \cdot p_{in}$
  - width $\sigma = b \cdot p_{in}$

  with a =0.1 and b =0.02

- Note that the particle can only loose energy so $p_{out} < p_{in}$
- Parameters a and b must be configurable

Test Program

- Generate 10000 decays
  - generate decay products in centre of mass and boost to lab frame
    - make sure you conserve energy and momentum correctly
  - Use the TLorentzVector class of ROOT to handle energy and momentum and boost
- Simulate passage of particles through 3 detectors causing only scattering
  - After each detector compute the invariant mass m_{inv} of the two particles
  - Reminder: $$m_{inv} = \sqrt{E_{tot}^2 - p_{tot}^2}$$ $$\underline{p_{tot}} = \underline{p_1} + \underline{p_2}$$
- Simulate passage of particles through one detector causing energy loss
  - compute invariant mass m_{inv} of the two particles
  - compute the response $r_j = E_j^f / E_j^i$
    for the two particles where E^f is the final energy after all 4 detectors and E^i is the initial energy after decay
- Plot distribution of the the invariant mass after each detector in a TCanvas with 4 pads and store output as **`invmass.pdf`**
- Plot distribution of r_1 and r_2 and plot them in a TCanvas with 2 pads and save the output as **`response.pdf`**
- To compile and link the executable I must be able to do
  - `g++ -o /tmp/simu  simulation.cc  Generator.cc Detector.cc ScatteringDetector.cc EnergyLossDetector.cc`

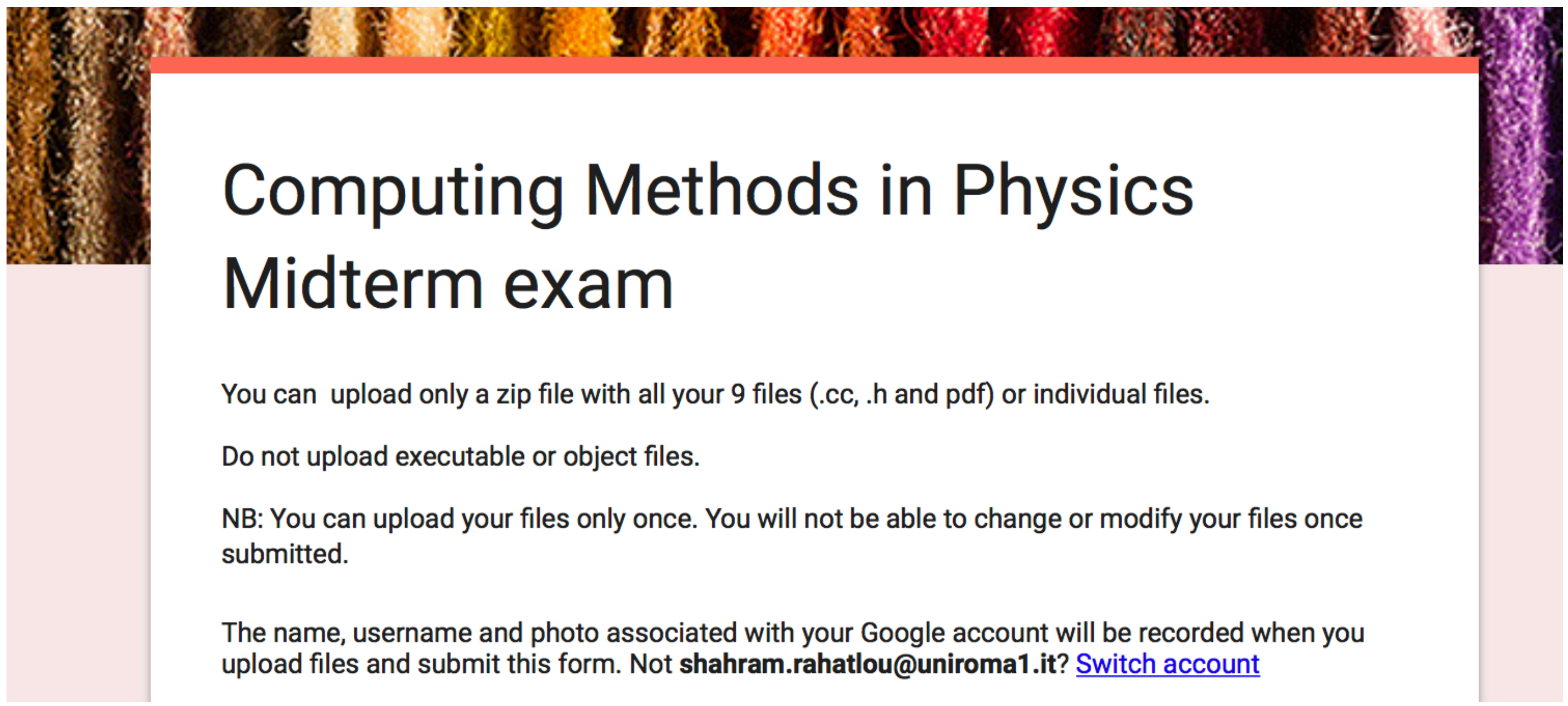
Test evaluation

- The following classes are required
  - class **`Generator`** to simulate TwoBodyDecay
  - Base class **`Detector`** and two polymorphic derived classes **`ScatteringDet`** and **`EnergyLossDet`**
    - proper choice of interface and data members will be subject of evaluation
- Write an application **`simulation.cc`** to handle
  - generation of 10000 decays
  - creation of detectors
  - computation of invariant mass and response
  - filling of histograms
  - saving plots in pdf
- A total of maximum 11 files can be provided for evaluation
  - 4 .cc and 4 .h files for Generator, Detector, ScatteringDet and EnergyLossDet
  - 1 file for simulation.cc
  - 2 pdf files invmass.pdf and response.pdf

– You can archive them as a single zip file or provide individual files

Submitting your test

- To send your project
  - Log into https://mail.uniroma1.it with your Sapienza credentials
  - visit https://goo.gl/forms/8kquclSvkpEmpVa83



- Sapienza credentials are necessary to submit your test
- You can submit only once
  - no possibility of changing or modifying your files after submission
- Submission will be open until Thursday 17:00 (Rome time)