Midterm test:
simulation of experimental apparatus response

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Computing Methods in Physics

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SAPIENZA
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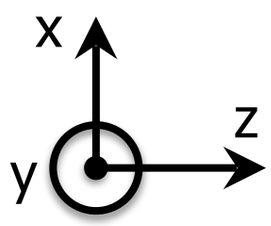
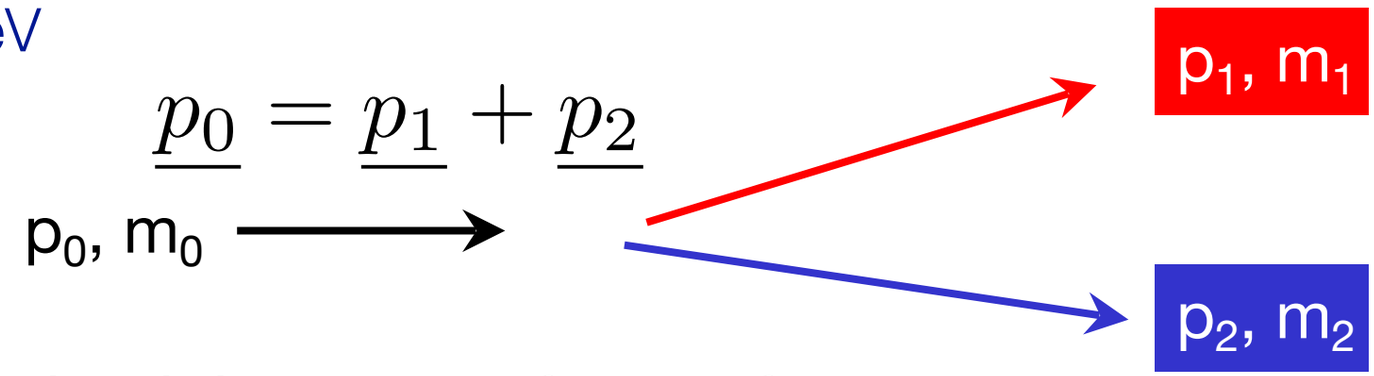
Two body decay of a particle

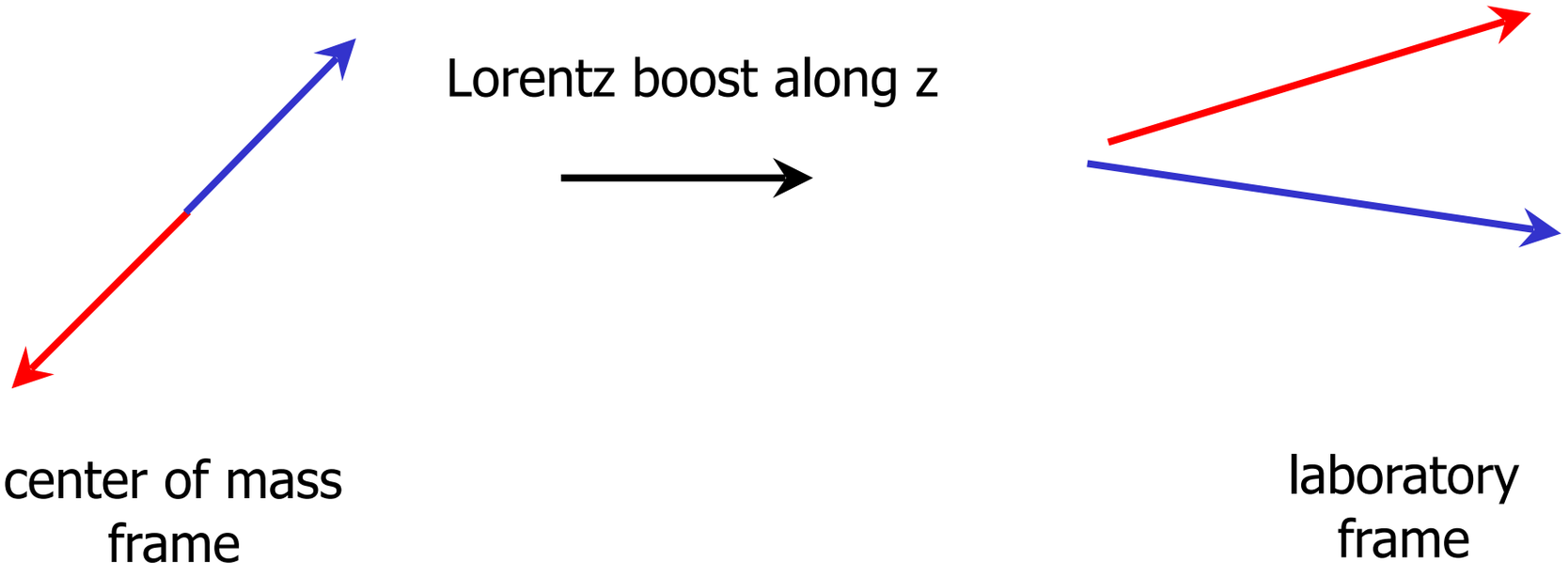
- Particle of mass m_0 and 3-momentum p_0 in the laboratory frame decays into 2 particles of mass m_1 and m_2
  - mass and momentum in GeV units
  - Use m_0 = 5.3 GeV
  - momentum p_0 along z axis with $|p_0|$ = 4 GeV
  - m_1 = 0.5 GeV , m_2 = 0.13 GeV



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

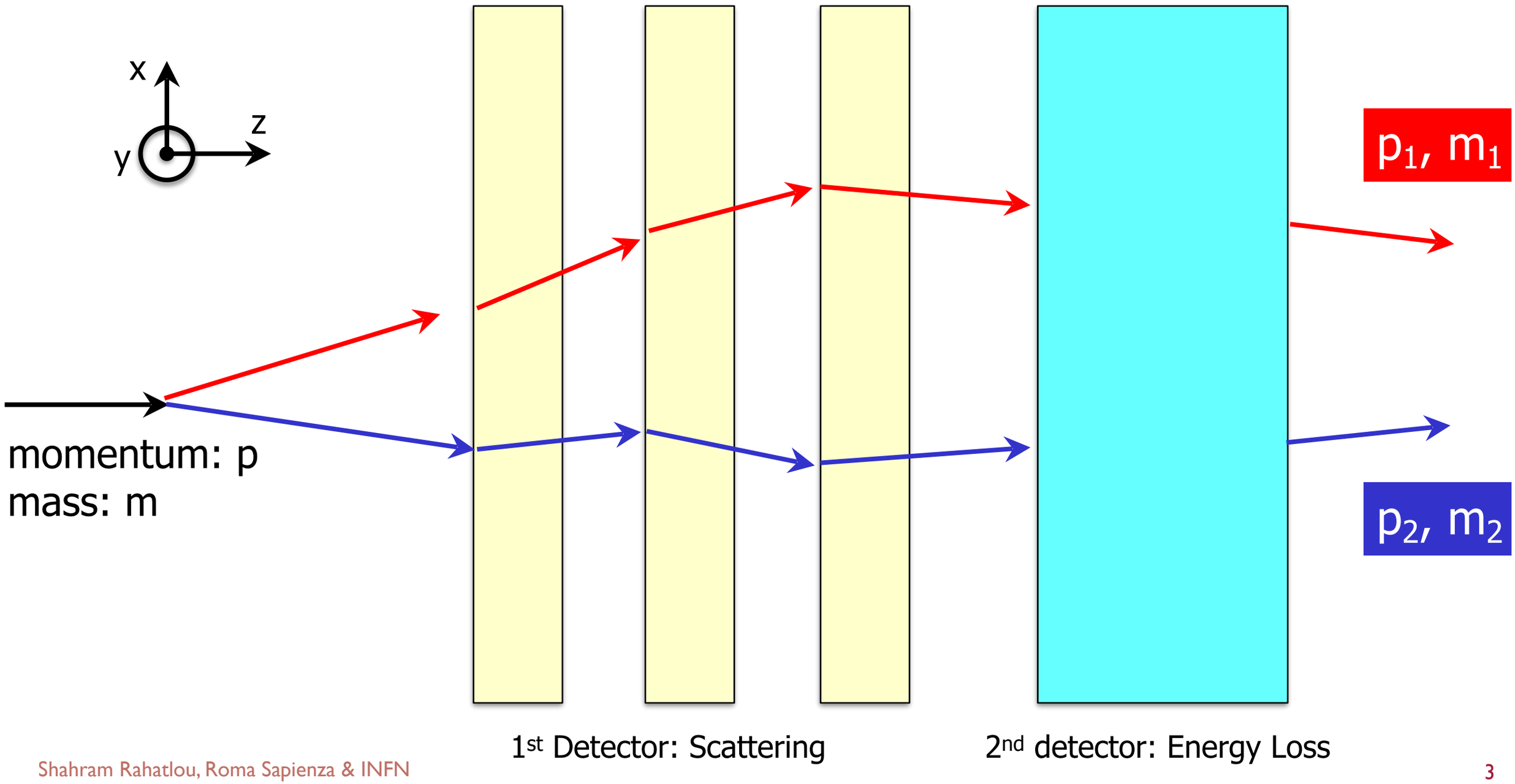


- Two particles decay back-to-back in centre of mass frame and then boosted along z axis to laboratory frame



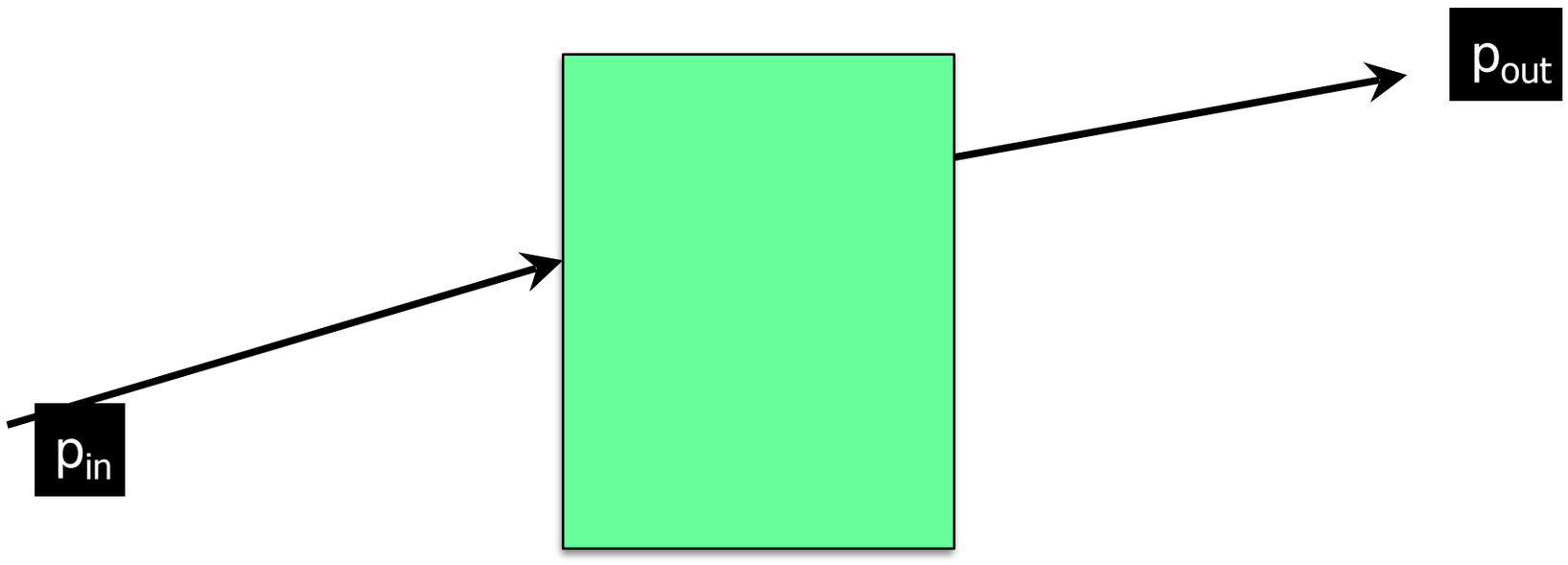
Experimental setup

- 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)



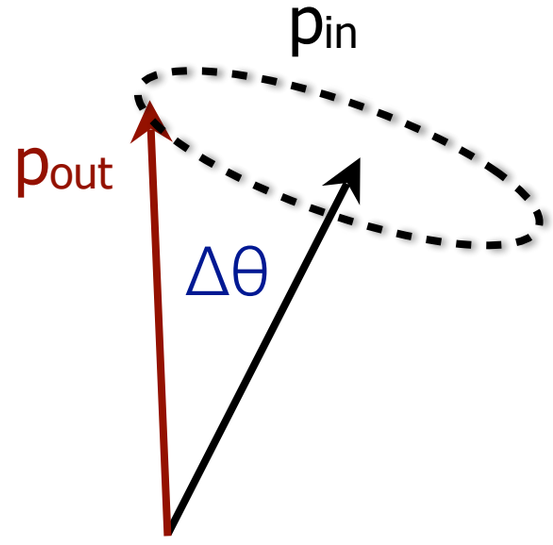
Modelling of Detector Response

- 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 Δθ



- Extract Δθ from a Gaussian distribution with mean μ and width σ
  - use μ = 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:

$$m_{inv} = \sqrt{E_{tot}^2 - p_{tot}^2}$$

$$\underline{p_{tot}} = \underline{p_1} + \underline{p_2}$$

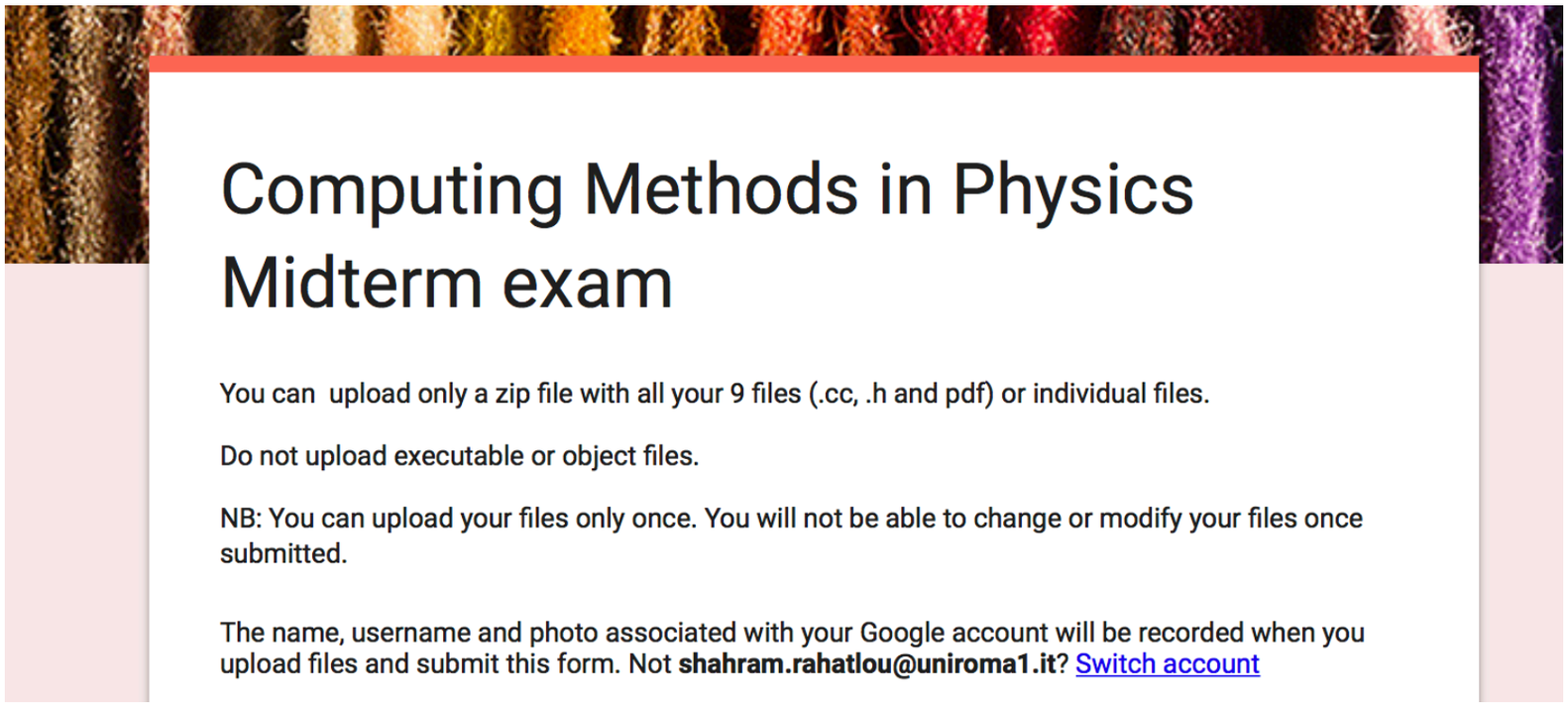
- Simulate passage of particles through one detector causing energy loss
  - compute invariant mass m_{inv} of the two particles
  - compute the response $r_j = E_j^f / E_j^i$
    for the two particles where E^f is the final energy after all 4 detectors and E^i is the initial energy after decay
- Plot 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/8kqucISvkpEmpVa83



Computing Methods in Physics
Midterm exam

You can upload only a zip file with all your 9 files (.cc, .h and pdf) or individual files.

Do not upload executable or object files.

NB: You can upload your files only once. You will not be able to change or modify your files once submitted.

The name, username and photo associated with your Google account will be recorded when you upload files and submit this form. Not **shahram.rahatlou@uniroma1.it**? Switch account

- 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 20:00 (Rome time)