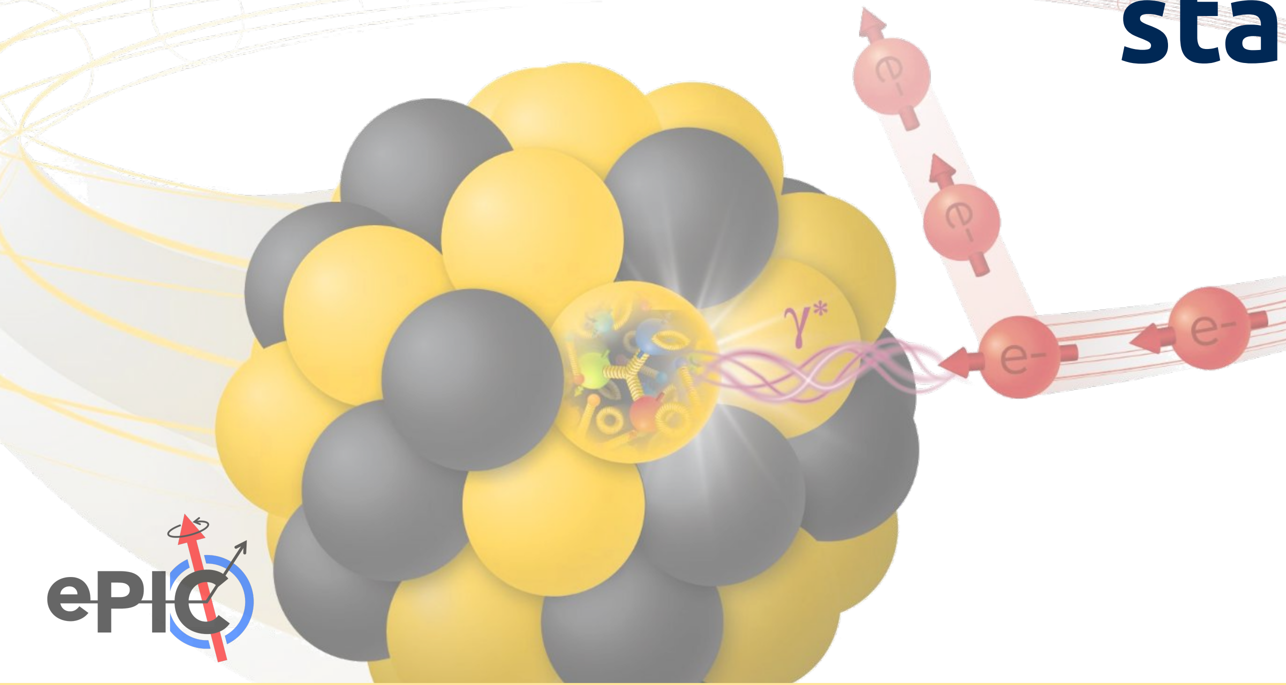
Separation of 3 upsilon states in ePIC



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LBNL EIC Meeting
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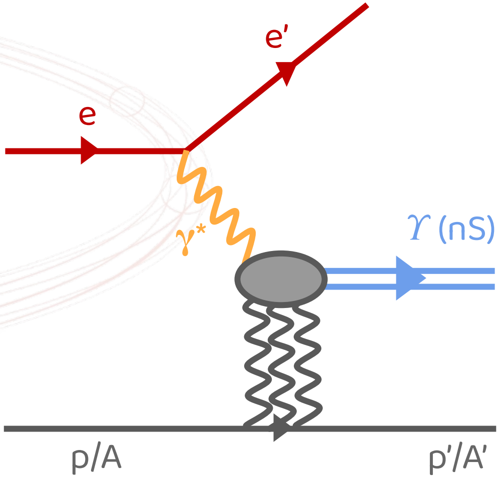
UC DAVIS
UNIVERSITY OF CALIFORNIA
BERKELEY LAB

Introduction

- **Our first goal:** Invariant mass spectrum of $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$ in the electron channel by ePIC for the resolution study

- **Exclusive Vector Mesons:**
  - $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S) \rightarrow e^{+}e^{-}$

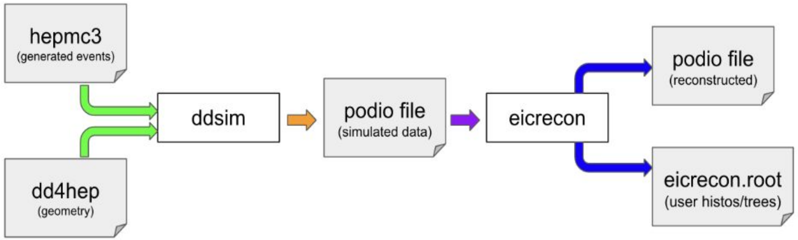
- **Current status:**
  - Initial study on Aug 2023 in eAu (18x275 GeV) collisions
  - Generating new sample with the current detector geometry
  - This presentation includes a study with simulation samples in ep (10x110 GeV) collisions (Resolving an issue with AfterBurner in the eAu sample)



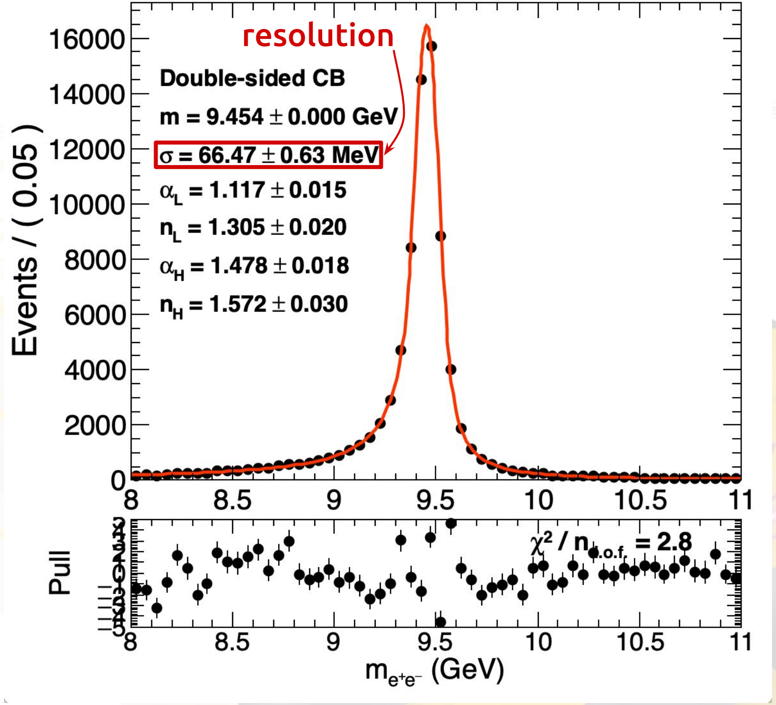
Sample Production

- **Simulation Procedure**
  1. eStarlight: generate Upsilons with the HepMC3 output
  2. afterburner under eic-shell: add beam effects
  3. npsim under eic-shell: detector (Geant4) simulation
  4. eicrecon under eic-shell: reconstruct events and tracks

- **Input Information of Sample**
  - **eAu on Aug 2023:**
    - MC Truth seeding
    - not added afterburner
    - 18x275 GeV
    - Υ(NS) to e^+e^-
    - $0 < Q^2 < 0.01$ GeV^2
  - **ep on May 2024:**
    - MC Truth seeding
    - added beam effects
    - 10x100 GeV
    - Υ(NS) to e^+e^-
    - $0 < Q^2 < 0.01$ GeV^2



Fit Model: DSCB



- Fit to a Double Sided Crystal Ball (DSCB) function
  - Double Sided Crystal Ball (DSCB) function

$$
DSCB(m;\mu,\sigma,\alpha_L,n_L,\alpha_H,n_H) = \begin{cases} e^{-0.5t^2} & \text{if } -\alpha_L < t < \alpha_H \\ e^{-0.5\alpha_L^2}\left[\frac{\alpha_L}{n_L}\left(\frac{n_L}{\alpha_L} - \alpha_L - t\right)\right]^{-n_L} & \text{if } t < -\alpha_L \\ e^{-0.5\alpha_H^2}\left[\frac{\alpha_H}{n_H}\left(\frac{n_H}{\alpha_H} - \alpha_H + t\right)\right]^{-n_H} & \text{if } t > \alpha_H \end{cases}
$$

where $t = (m - \mu)/\sigma$

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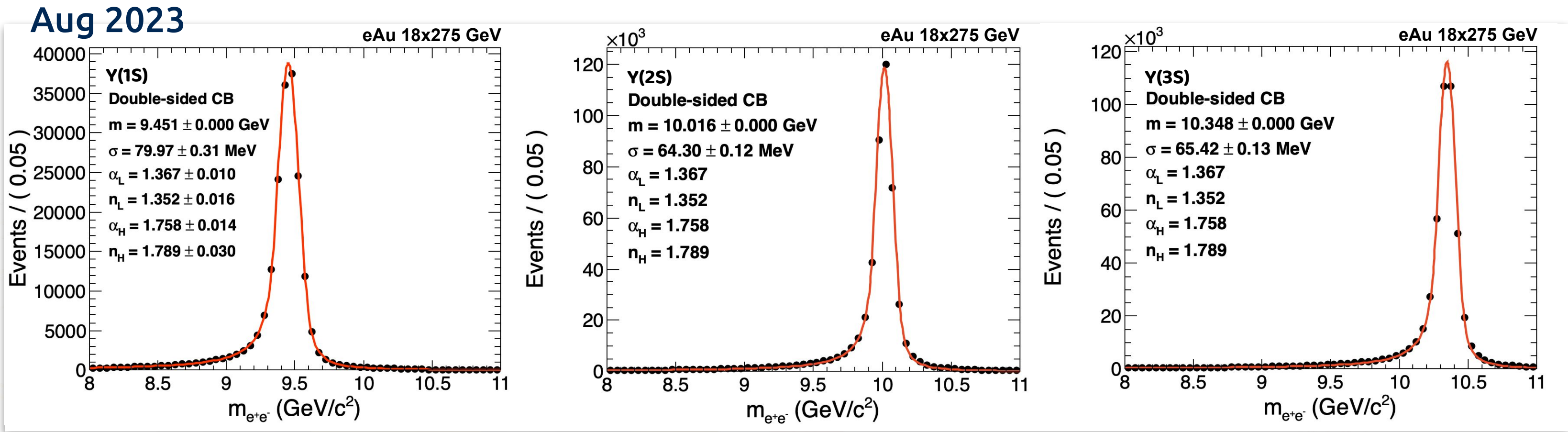
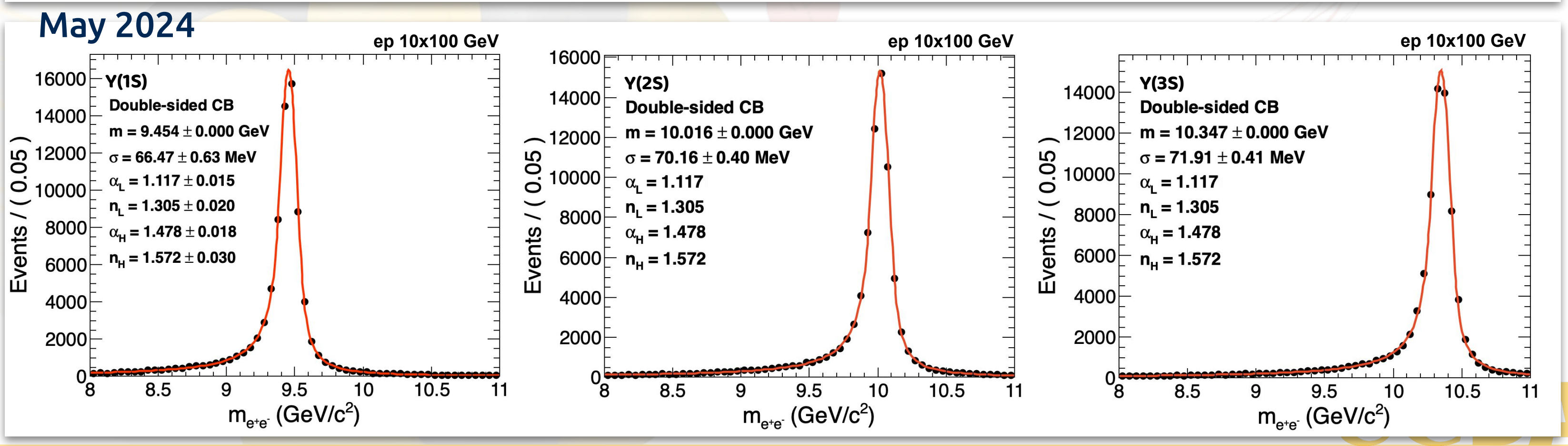
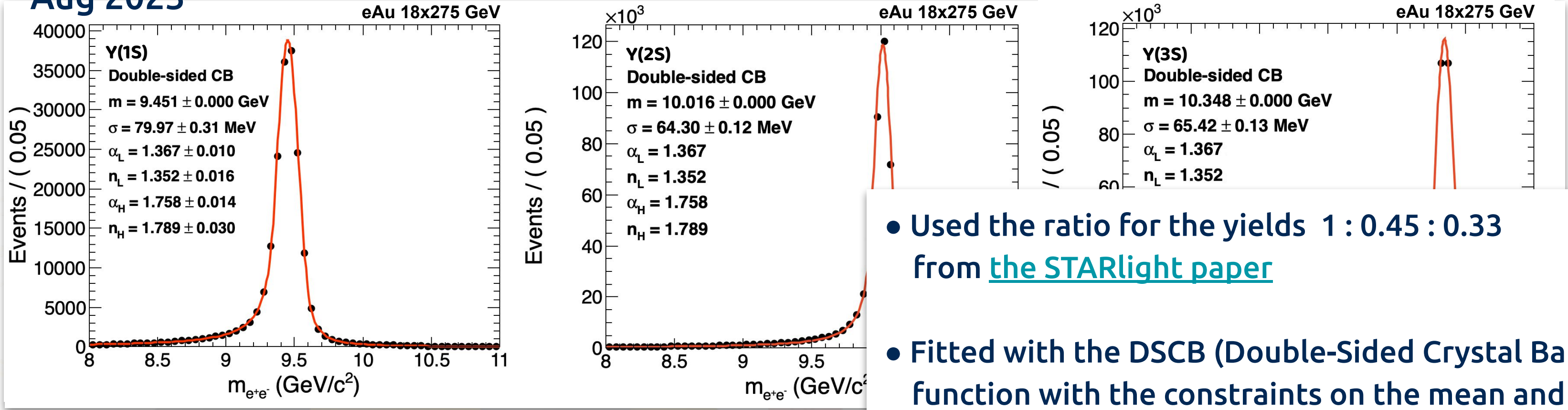


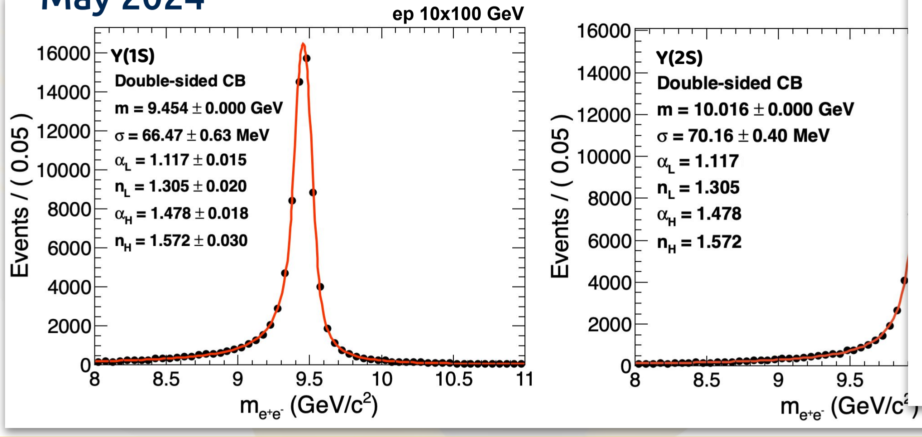


Separation of 3 upsilon states in ePIC

Aug 2023



May 2024



- Used the ratio for the yields 1 : 0.45 : 0.33 from the STARlight paper

- Fitted with the DSCB (Double-Sided Crystal Ball) function with the constraints on the mean and tail parameter values of Υ(2S) and Υ(3S).

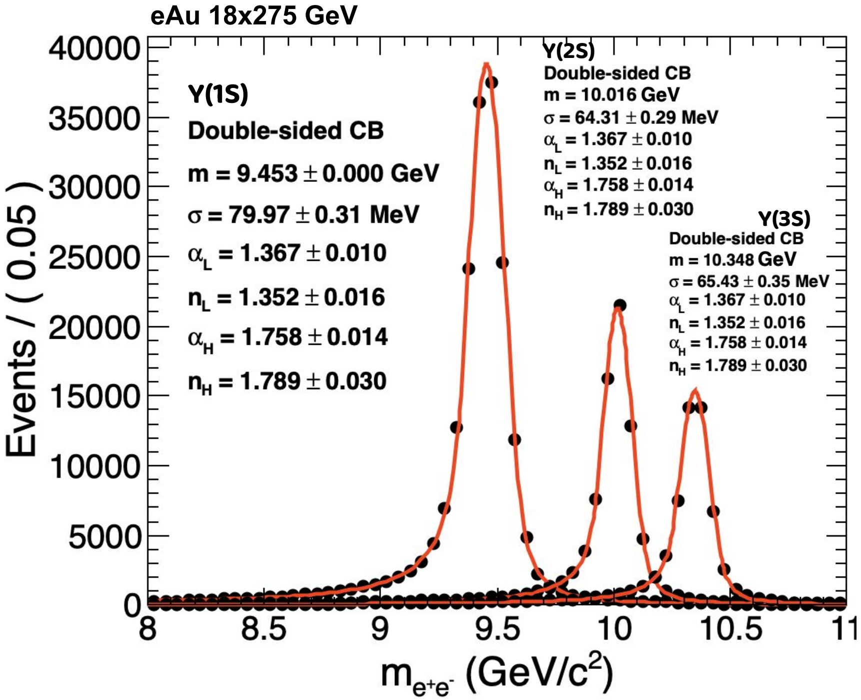
- $m_{\Upsilon nS} = m_{\Upsilon 1S} * \frac{PDGmass_{nS}}{PDGmass_{1S}}$

- Resolution of each peak:

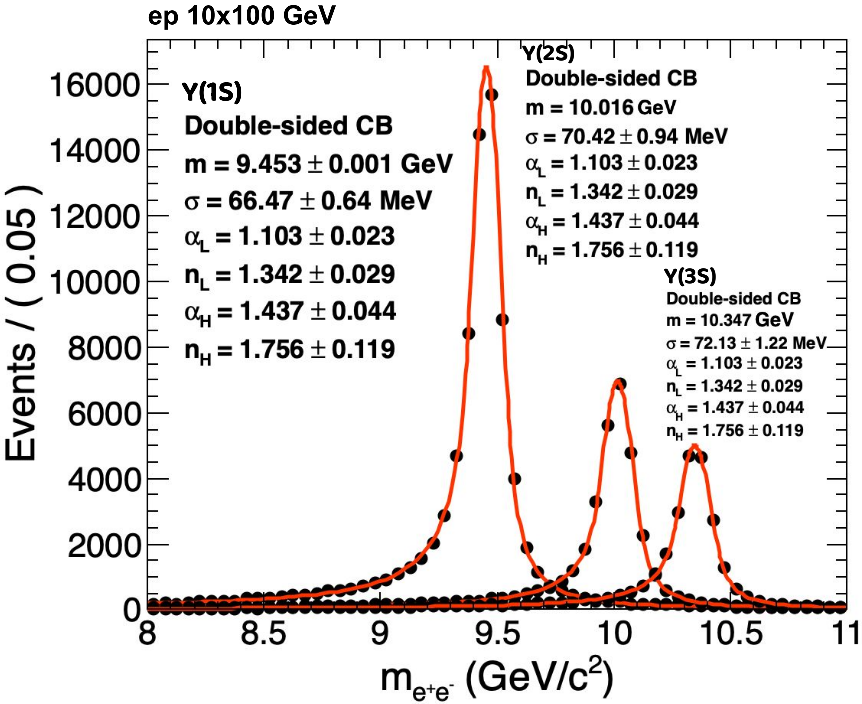
Aug 2023	May 2024
σ_{1S} = 79.97 ± 0.31 MeV	σ_{1S} = 66.47 ± 0.63 MeV
σ_{2S} = 64.30 ± 0.12 MeV	σ_{2S} = 70.16 ± 0.40 MeV
σ_{3S} = 65.42 ± 0.13 MeV	σ_{3S} = 71.91 ± 0.41 MeV

Separation of 3 upsilon states in ePIC

Aug 2023



May 2023



Summary & Outlook

- **Detector resolution study to separate $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ peaks is in progress using simulation**
  - eSTARlight (generate seeds) → AfterBurner (beam effects) → npsim (digitalization) → EICrecon (reconstruction)

- **The resolution of the three peaks was obtained using DSCB fits in the region of $0 < Q^2 < 0.01$ GeV^2 with the truth seeding**
  - **Aug 2023**
    σ_{1S} = 79.97 ± 0.31 MeV
    σ_{2S} = 64.30 ± 0.12 MeV
    σ_{3S} = 65.42 ± 0.13 MeV
  - **May 2024**
    σ_{1S} = 66.47 ± 0.63 MeV
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- **Next steps:**
  - Obtain sample in eAu collisions with beam spreads using AfterBurner
  - Detector resolution study using realistic seeding and in different region of the detector (barrel vs end cap)

Backup Slides

AfterBurner Issue with Ion Energy

Resolved!:)

- **Seems that AfterBurner can't read ion energy properly?**

↓ AfterBurner Instruction

Beam energy settings

- The input file events must have two beam particles (marked by status code 4)
- Beam particle energies should correspond to one of EIC beam energy setups:
  - ep [GeV]: 275x18, 275x10, 100x10, 100x5, 41x5
  - eAu [GeV]: 110x18, 110x10, 110x5, 41x5

↓ Ran AfterBurner using the eAu, 10x110 input (not working)

```
jug_xl> srmyoo@login38:/global/u2/s/srmyoo/EIC/estarlight_install$ abconv slight_eAu_Upsilon_10x110.hepmc -o eAu_Upsilon_10x110_ab_output
Afterburner is ENABLED
10x110 is not a valid energy combination!!
Valid (ep) Combinations are 18x275, 10x275, 10x100, 5x100, and 5x41
Valid (eA) Combinations are 18x110, 10x110, 5x110, and 5x41
terminate called after throwing an instance of 'std::invalid_argument'
  what():  Ion beams energy combination
Aborted
```

?

⇒ **The issue can be bypassed by -p 2 option!**
Default (-p 0) doesn't provide eAu energies (confirmed by Kolja)

AfterBurner Issue with Ion Energy

Resolved!:)

- **Running it with an option *-p 2***

↓ AfterBurner Instruction about the preset option

- Using `-p/--preset` flag one can select a profile:
  - 0: IP6 High Divergence (higher luminosity) - default,
  - 1: IP6 High Acceptance
  - 2: IP6 eAu
  - 3: IP8 High Divergence (higher luminosity) - default,
  - 4: IP8 High Acceptance
  - 5: IP8 eAu

Detector Simulation Issue with Ion Energy

- Another problem with the sample in eA collisions:
  - After adding beam effects using AfterBurner, the speed of the detector simulation is so slow.. (10 events ~ 1 hour and 10 mins)

    → splited the file into 1000 containing 100 events each

    → timeout in the reconstruction step