Project 3: Beam induced hits in the CRV

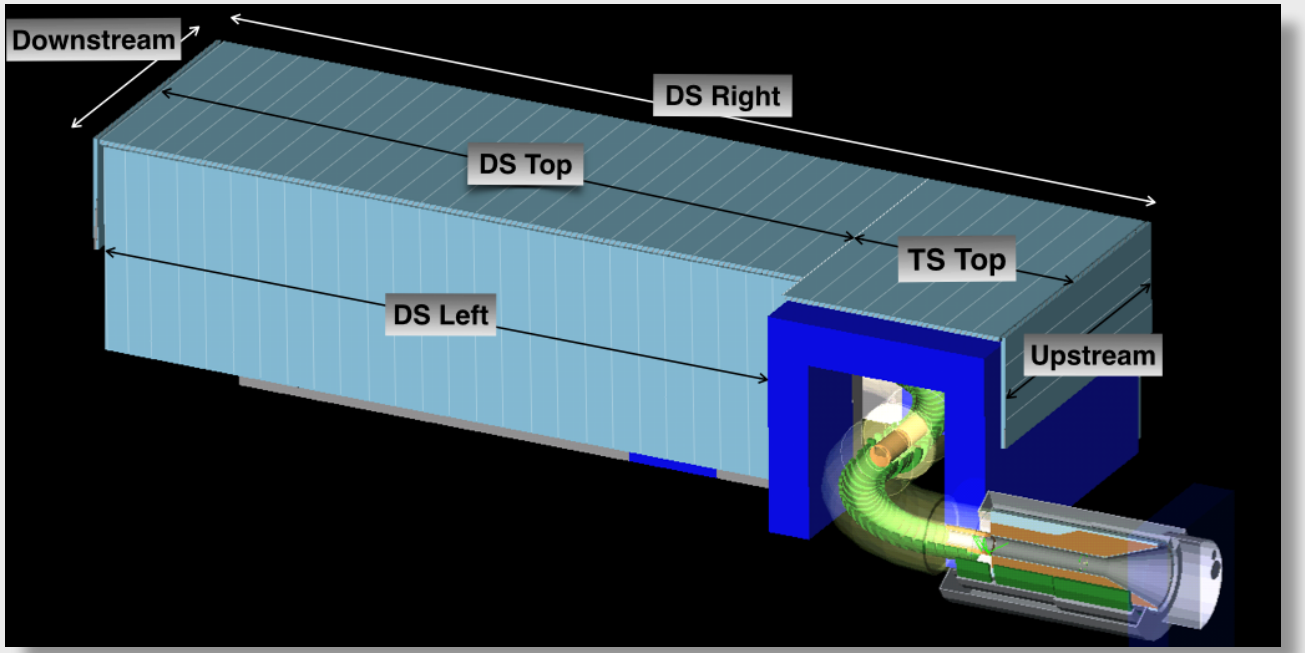
Yuri Oksuzian

Mu2e Computing Review

3/4/15

Cosmic Ray Veto (CRV)

- Mu2e expects 1 signal-like event per day induced by cosmic rays
- CRV consists of 4-layer scintillator counters, covering 300 m^2
  - Require coincident hits in 3 out of 4 layers for a valid cosmic ray muon
  - Veto 125 ns after the coincidence
- CRV has to operate in high beam induced background environment
- Cosmic Ray Veto(CRV) requirements:
  - Reject 99.99% of cosmic rays
  - Produce less than 10% dead-time

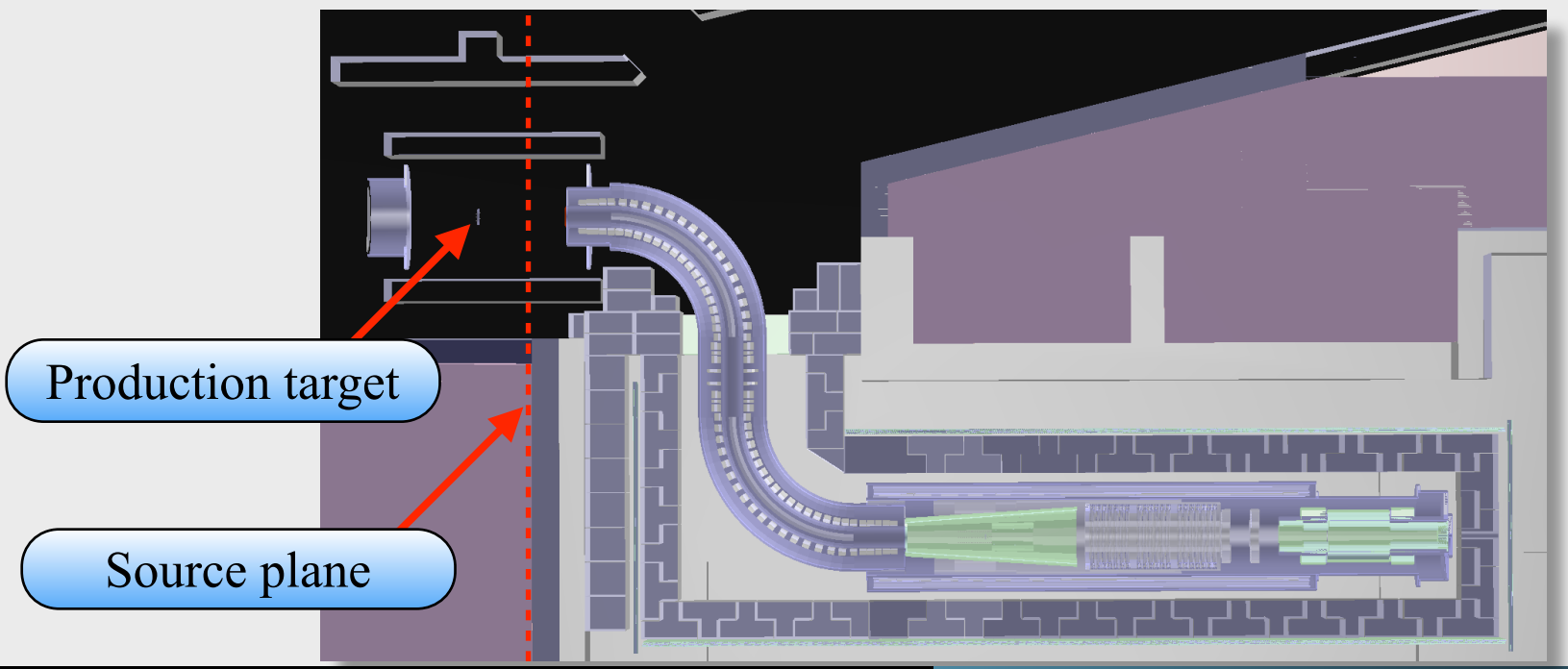


CRV: Beam induced background sources

- Neutron and gamma fluxes cause problems to CRV operations
  - Produce hits at the CRV, faking cosmic ray muons and hence increasing total Mu2e dead-time
  - Neutrons damage the CRV electronic components
- Largest source of neutrons originate from PS after beam flash
  - This source is prompt
  - CRV plans to “blind” SiPMs just after the beam flash
- Neutrons get thermalized, captured and produce delayed gammas
  - Other sources of gammas: neutron inelastic, DIO in MBS stops
- Source of delayed neutrons originate from μ-captures on collimators, beam-line and stopping target

CRV: Beam induced background estimate

- Currently, G4beamline is used to estimate the dead-time produced by beam induced background in the CRV
- Stage 1: Simulate POT and record all particles on the source plane
- Stage 2: Resample from the source plane
- The result of stage 2: neutron and gamma fluxes at the CRV
- For each geometry design iteration, we simulate 1E6 (1E9) POT on the 1st (2nd) stage
  - Each stage requires 1,000 10-hour sections



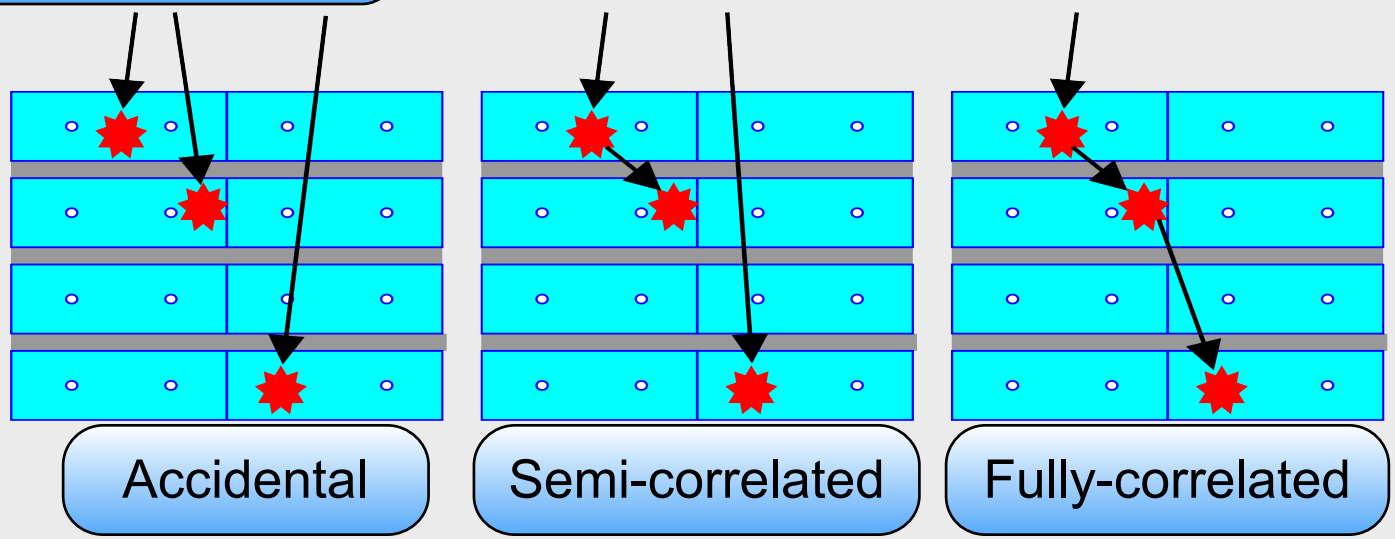
Dead-time estimation

Estimate the neutron/gamma fluxes at the CRV

Estimate the neutron/gamma efficiency to produce n-fold coincidence above 0.5 MeV

Produce n-fold hit rates at the CRV

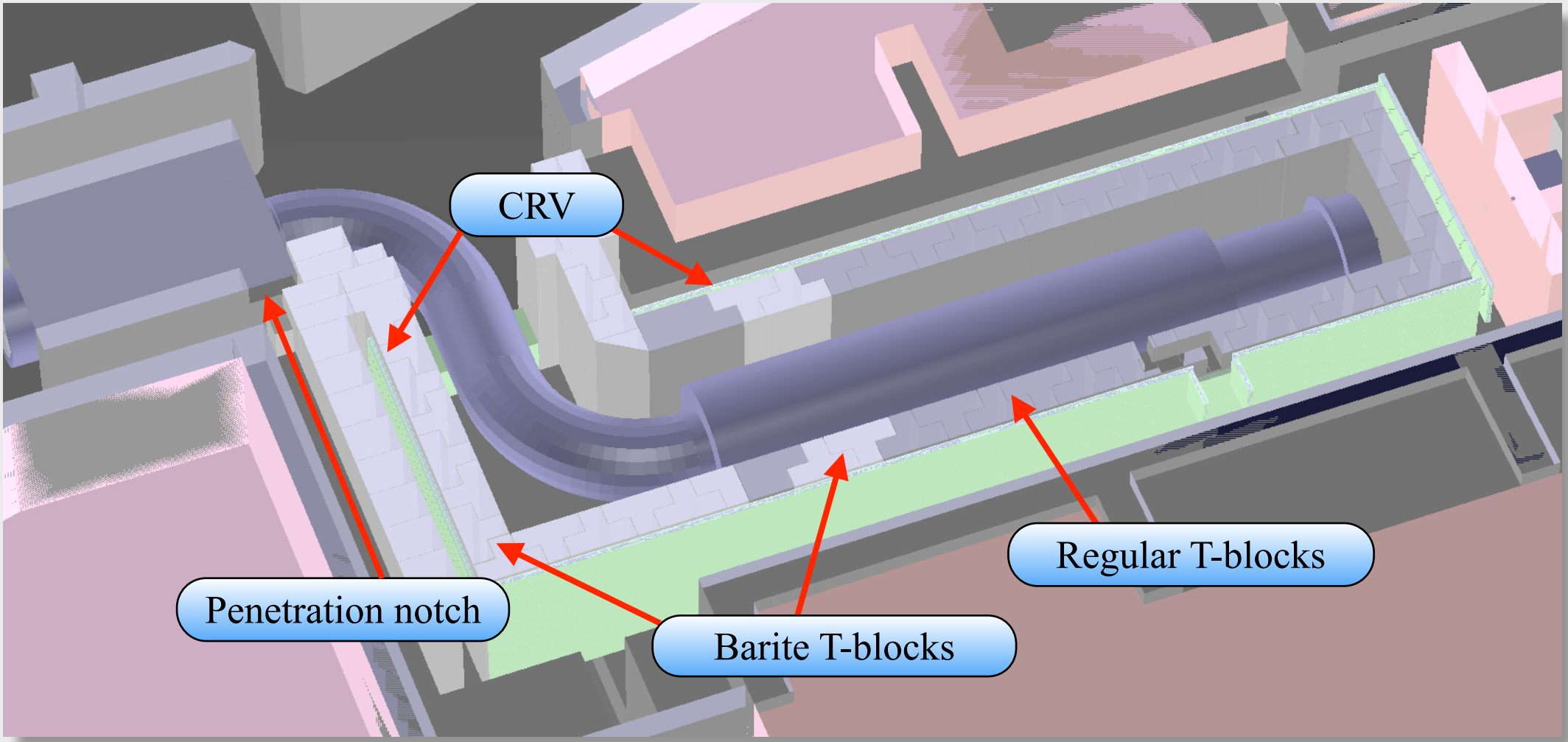
Calculate the dead-time



- Total dead-time is estimated to be 4%
- The number is sensitive to hit time resolution, effective energy threshold…

Current state of Offline framework

- Plan to estimate CRV dead-time in the Offline framework
  - Simulation of light production, propagation, SiPM response, digitization and reconstruction have been recently implemented
  - Shielding geometry has been recently updated



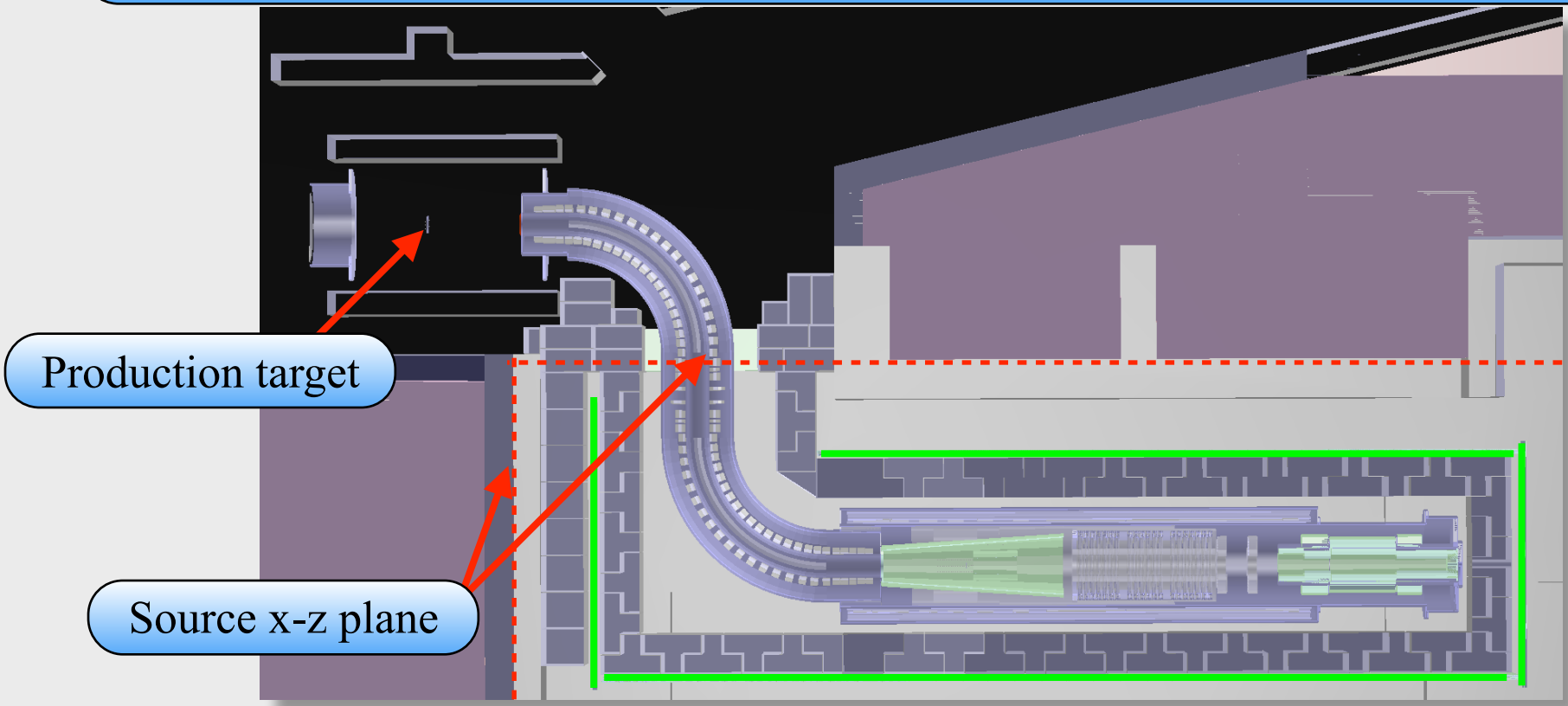
Future plans

In progress

1: Use multi-stage simulation approach in Offline

- 1: Simulate POT and record all the products at the x-z plane (similar to g4bl)
- 2: Resample from the x-z plane
- 3: Simulate particles from the stopping target
- 4: Mix (2) and (3) to form micro-bunches

Note: Steps (1) and (3) will be done in Andrei's "general" purpose simulation



Future plans

In progress

1: Use multi-stage simulation approach in Offline

- 1: Simulate POT and record all the products at the x-z plane (similar to g4bl)
- 2: Resample from the x-z plane
- 3: Simulate particles from the stopping target
- 4: Mix (2) and (3) to form micro-bunches

Note: Steps (1) and (3) will be done in Andrei's "general" purpose simulation

Done

2: Produce time wrapped micro-bunches

- Smear out the products from each POT with proton pulse shape
- Include the particles hitting the CRV from previous micro-bunches
- "Blind" SiPMs just after the beam flash
- Produce redo SiPM hits

Future plans

In progress

3: Produce 3-out-of-4 coincidence finder algorithm

In progress

4a: Dead-time:

- Calculate number of coincidences per micro-bunch produced by beam induced background
- Veto 125 ns for each coincidence

In progress

4b: Impact on CR veto efficiency

- Overlay beam induced background with CR sample
- Estimate veto reconstruction using 3-out-of-4 finder algorithm

Further geometry refinements

- ★★ Updated CRV geometry and coverage
- ★ Support structure and infrastructure for the Tracker, Calorimeter, Solenoids, Outer Proton Absorber, Stopping Target
- ★★ Muon Beam Stop design and support
- ★★ Details and material choice for collimators
- ...

Impact on CRV dead-time	★
Impact on CRV veto efficiency	★

Most of the geometry refinements are in DS region
Can be implemented after stage 1

Summary

- Detailed estimate of the impact from beam induced background on CRV operation is a high priority for Mu2e
- The dead-time is estimated to be 4%, using G4beamline factorized simulation
- We plan to:
  - Estimate the dead-time using detailed simulation in Offline framework
  - Implement the geometry details in Offline. All major components are implemented
  - Compare results between Offline/G4beamline/MARS
  - Optimize the shielding. Reduce(enhance) the shielding if possible(needed)
  - Study the systematic effects: beam-intensity, CRV hit-time resolution, light-yield, shielding gap variations…
- Offline simulation needs, assuming total POT = 10^{10}:
  - Total CPU: 0.5M hours
  - Disk space: 5T
- Total POT = 10^{10} yields 10% uncertainty on the dead-time estimate
  - Detailed analysis of the “hot” regions will require higher statistics

Backup slides

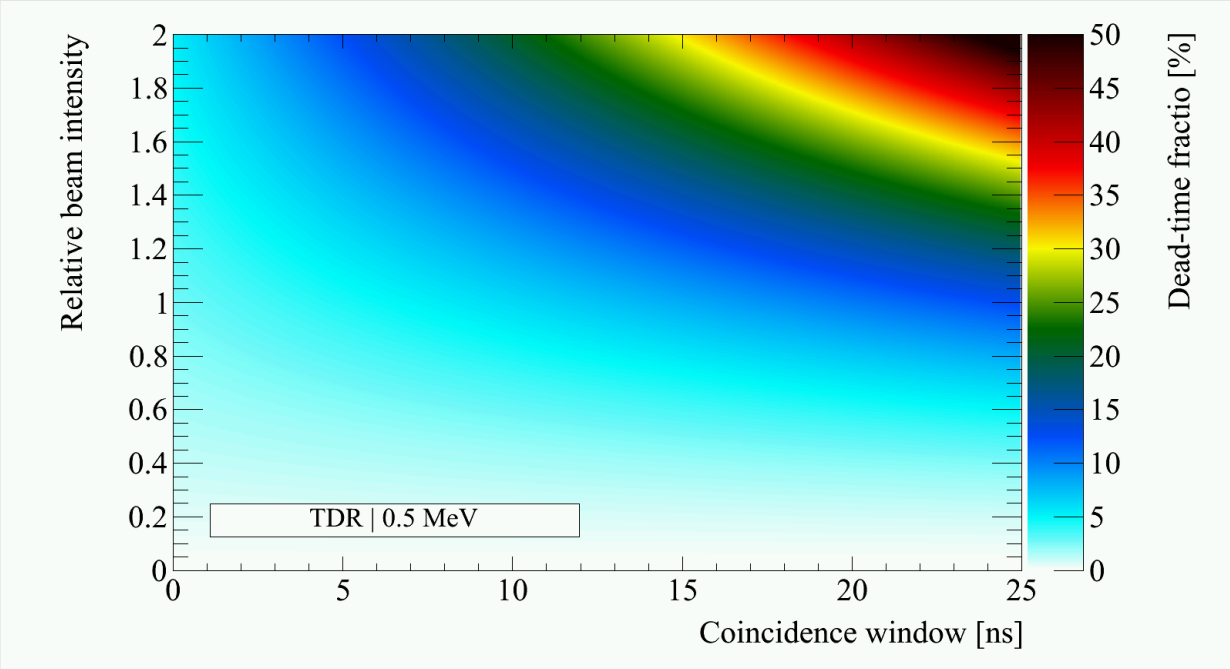
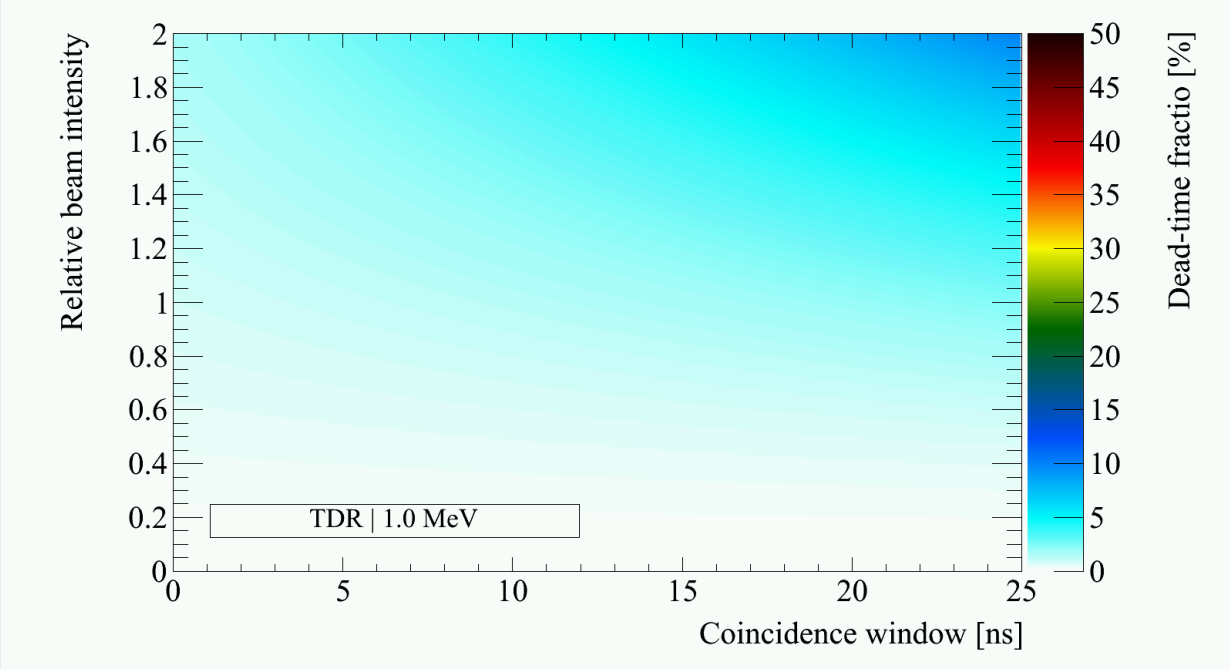
Simulation needs

- Offline simulation needs, assuming POT=10^{10}:
  - Total CPU: 0.5M hours
  - Disk space: 5T

f_v	Dead-time fraction [%]	4
N_{POT}	Total number of simulated POT	$1E^{10}$
$P_{\mu b}$	Total number of POT in micro-bunch	$3E^{7}$
Δt_v	Veto time window [ns]	125
Δt_s	Signal time window [ns]	1025

$$f_\nu = \frac{\Delta t_\nu \cdot N_{coin}}{\Delta t_s N_{POT}/N_P^{\mu b}}$$

$$N_{coin} = f_\nu N_{POT}/N_P^{\mu b} \Delta t_s/\Delta t_\nu = 109$$

$\delta N_{coin} = \sqrt{109} = 10.4$ $f_\nu = 4 \pm 0.4$	$\delta N_{coin} = \sqrt{27} = 5$ $f_\nu = 1 \pm 0.2$

Dead-time table