The Sensitivity Update 2020 (SU2020) Project

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SU2020: **Why** do we need it?

Latest blessed sensitivity evaluation for $\mu \rightarrow$ **e-** dates back to July 2017 (doc-db 7464-v13).

Since then many things have changed:

- run plan (Run I – LBNF 2 years shutdown – Run II)
- beam intensity profile: SDF=60% and initial reduced intensity
- reduced shielding (regular concrete) in Run I
- Hayman 2 production target: ~20% less stopped muons per POT
- Thicker Al foils in stopping target: ~5% more stopped muons
- CRV aging
- proton and deuteron yield from muon capture (ALCAP+TWIST)
- **ECAL waveforms and reconstruction software**

No blessed sensitivity evaluation for $\mu \rightarrow$ **e+** exists

SU2020: **What** do we want to do?

We want to update what has been done for CD3 for $\mu \rightarrow$ **e-** and extend the study to $\mu \rightarrow$ **e+**
This implies evaluation of:

- **Single Event Sensitivity** (SES)
- **90% CL upper limit**
- **5σ discovery reach**

And must be supported by

- Background evaluation with statistical and systematical errors
- Exaustive Documentation

Given the uncertainty on the detector upgrades for Run II we focus our effort on **Run I** (before the 2 years shut down)

When do we want a blessed update?

The need for this update is quite compelling: we need it as soon as possible to show robust numbers at the next conferences.

This is a large effort and a realistic term to have it completed can be **next collaboration meeting in October**.

<u>An other projects with different time schedule</u>:

- **MDC2020** is a different project focusing on the validation of the infrastructures to be used for first data taking. It will likely start producing new MC datasets at *fall ‘20*.

How can we reach a blessed update?

1) Organize man power, efficient communication

2) Define nominal conditions (geometry, beam intensity)

3) Freeze software version

4) Dataset preproduction and software validation

5) Dataset production (digi art files and ntuples)

6) Reconstruction (including PID)

7) Analysis: signal/background optimization

8) Full documentation

9) Blessing

Who can do that?

A common effort by many people:

- **experienced people** that worked on CD3 studies: **Pasha**
- **Experienced consulents:** Andrei, Rob, Dave, Ray
- **new people** that need guidance and training

Training of unexperienced people is an added value for the whole project. Good opportunity for everyone.

Starting from the end!
9) Blessing

Groups working on specific subtasks are requested to present their work at dedicated meetings.

Everyone is invited to read the documentation and propose improvements or modifications.

More iterations may be needed: previous blessings usually required ~1 month

8) Documentation

Groups working on specific subtasks are requested to write an exhaustive documentation covering:

- Critical description of initial assumptions (theoretical models, available experimental data, generation details, ...)
- Procedure: the description should be detailed enough to allow a medium skill analyzer to reproduce the result
- Systematic error discussion (dependence on initial assumptions)

7) Analysis

Once signal and background datasets are available we can optimize our time and momentum window to obtain the best discovery reach or the best upper limit (see doc-db 7464).

Two possible approaches we can think at the moment:

- Feldman-Cousins counting method, same as CD3 (Phys.Rev.D Vol 57, 7, 1998):
  - pros: doesn’t use signal shape (but it could)
  - cons: discretization issues

- Confidence Level Likelihood (Read, J. Phys. G: Nucl. Part. Phys. 28 (2002) 2693–2704):
  - pros: exploit signal vs background different pdfs
  - cons: sensitive to systematic errors on pdfs

6) Reconstruction

Working on

Trigger: update ECAL trigger (Sdf)

Tracker: track quality (Andy, Pasha, ...)

ECAL: time resolution, new waveforms (Bertrand,...)

CRV: aging/thresholds, time coincidence window

Particle Identification: official MVA tool

If not ready, ad hoc corrections for su2020 estimate will be used

5) Dataset production (https://github.com/Mu2e/su2020)

One folder for each dataset (more folder in case of different versions of generation):

- μ-
- μ+
- CE-
- CE+
- Comics
- Antiprotons
- Beam background
- RMC
- RPC

Final product are art files with detector digital readout and Stntuple ntuples (TrkAna is track based and not event based)

4) Dataset preproduction and validation

Different issues already observed:

- pbar forward production underestimated

- track -calo time misalignment by 2 ns: differences observed between box cuts and MVA track quality selection

- cosmic track reconstruction when track doen’t cross the stopping target

- RPC out of time produced by antiprotons

4) Man power

- Primary datasets:
  - CE (Pasha)
  - CE+ (Pasha)
  - DIO (M.Hedge, A. Edmonds)
  - RPC (L. Borrel, S.Middleton)
  - RMC (E. Diociaiuti, M.MacKenzie)
  - Pbars (G. De Felice)
  - Beam background (Pasha)
  - Cosmics generation with CRY, flux normalization with Corsika (Y. Oksuzian, B. Barton, R. Ehrlich, R. Soleti, Pasha)

Whoever is interested can join at any time.

3) Freezing the software version

CALO software development version released by Bertrand.

Validation needed: is energy and time reconstruction correct?

Work in progress… help welcome!

2) Definition of initial conditions

Run plan, beam intensity profile and concrete shielding for Run I are in some way defined now. (M. McKenzie)

Some concrete block needed to keep CRV dead time under control ? (G. Ginther)

1) Work organization

Periodic status reports at biweekly Simulation WG meetings.

Weekly thematic zoom chats for working groups are already shown to be very useful.

A mu2e slack channel has been created: #sensitivity_update_2020 has been created.

An internal wiki page has been created:
https://mu2einternalwiki.fnal.gov/wiki/SU202

This will the best place to document the initial assumptions, the works in progress and to collect the bibiliography relevant for each subitem.

Summary

A lot of work already done!
Important issues have been raised: pbar background potentially higher than expected.
Preliminary results from other channels reproduce CD3 estimates.
Sensitivity optimization will start after datasets production will be needed.

For more details ask me or follow updates at Simulation WG meetings...