NA62++

Tommaso Spadaro

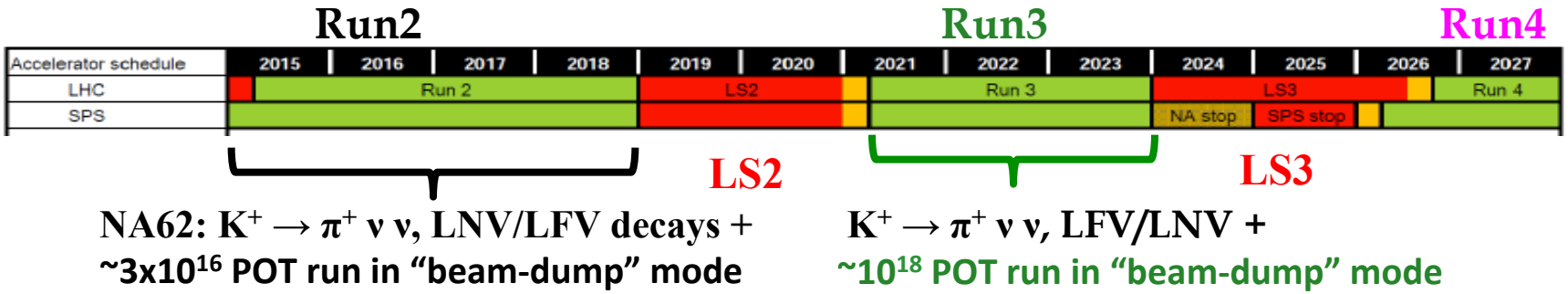
(INFN Laboratori Nazionali di Frascati)

On behalf of the NA62 collaboration

NA62++: Dump mode in Run 3

Searches for MeV-GeV mass hidden-sector candidates
A rich field to be explored with optimized setup in dump mode

In Run3 : ~10^{18} POT run in "beam-dump" mode for hidden sector



NA62++ : searches for MeV-GeV hidden-sector candidates

High-intensity 400-GeV proton beam → boost charm/beauty, other meson production

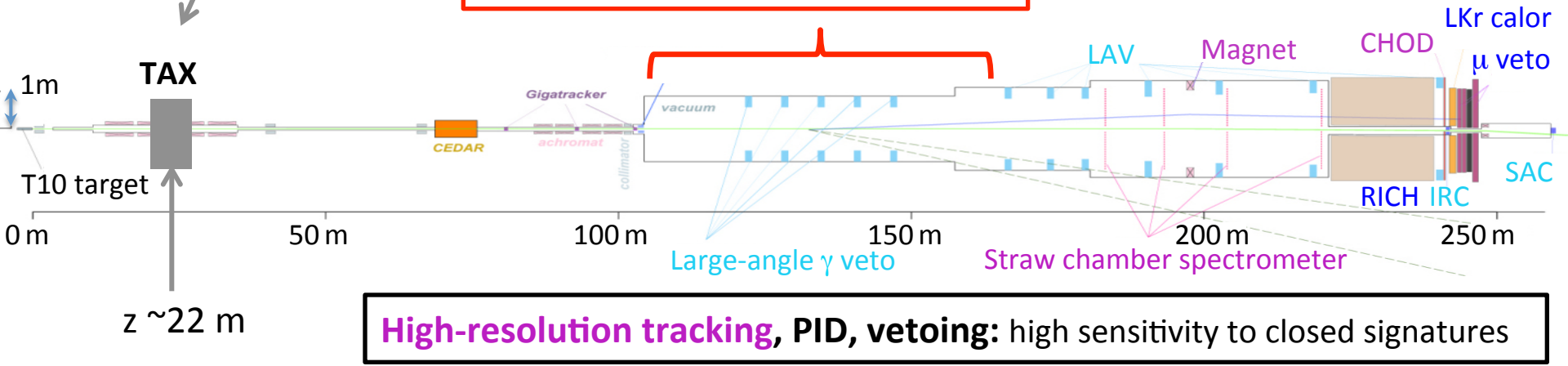
10^{18} POT / nominal year: 10^{12} POT/sec on spill, 3.5-s/16.8 s, 100 days/year, 60% run efficiency

10^{15} $D_{(s)}$, 10^{14} K, 10^{18} $\pi^0/\eta/\eta'/\Phi/\rho/\omega$ with ratios 6.4/0.68/0.07/0.03/0.94/0.95

Compact beam dump: ~11 λ_I Cu-Steel beam-defining collimator (TAX) radioprotection-compliant even if target removed

Plans to collect ~10^{18} POT run in "beam-dump" mode in Run 3

Decay volume ~ 60 m long (in vacuum):
% acceptance to long-lived states



High-resolution tracking, PID, vetoing: high sensitivity to closed signatures

Summary of activities in the past 2 years

1. **Sensitivity projections either from toy MC or from GEANT4 NA62MC, in the zero-background hypothesis**
2. **Analysis of test runs taken in Run2 in beam-dump mode, to determine the possible background level**
3. **Definition of possible minimal detector upgrades to ease background rejection**
4. **Study of possible minimal modifications/optimization of the current optics for a beam-dump run - work within the Conventional Beam WG of the PBC**

The beam dump mode in 2017-18

Trigger configuration based on the CHOD hodoscope:

- **"Q1" condition: at least one hit in a CHOD tile**
- **"Q2" condition: at least two hits in CHOD tiles mutually in time**

The trigger rates are reduced by a factor of ~100 wrt when running in kaon mode:

- **Q1 rate: ~250 kHz**
- **Q2 rate: ~ 8 kHz**

Rates dominated by muons from decays of π's and K's generated in the TAX or produced in the residual material in the T10 target region

Analysis of test runs in beam dump mode

A total of ~3 x 10^{16} POT taken in 2 days of data in beam dump configuration:

- **T10 target lifted, upstream TAX collimator used to dump the beam**
- **Beam intensity ~ 1.1 10^{12} protons per second for a ~3.5 s spill**

In summary, the conclusions are:

1. **When selecting events with a decay vertex to two charged particles, different data analyses proved complete background rejection**
2. **This sample might be already competitive for the search of ALP decays to two photons: the analysis is in progress**

Extrapolated 0-background sensitivity curves included in PBC-BSM report

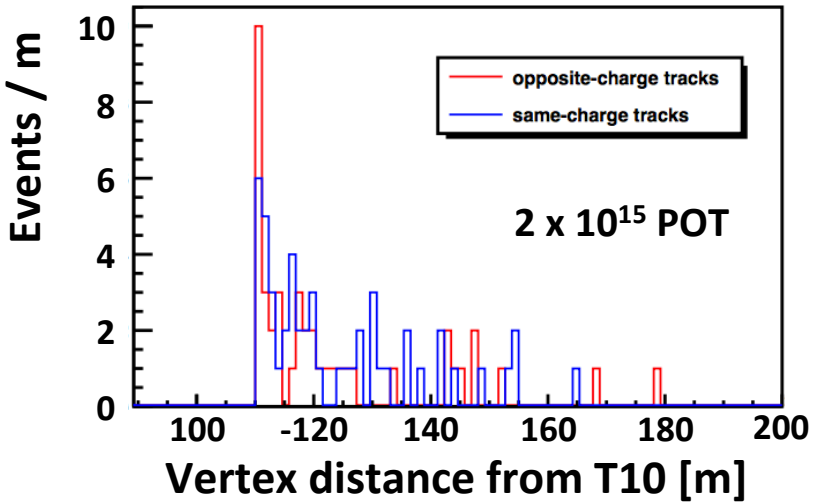
Further studies with 3 x 10^{16} ongoing

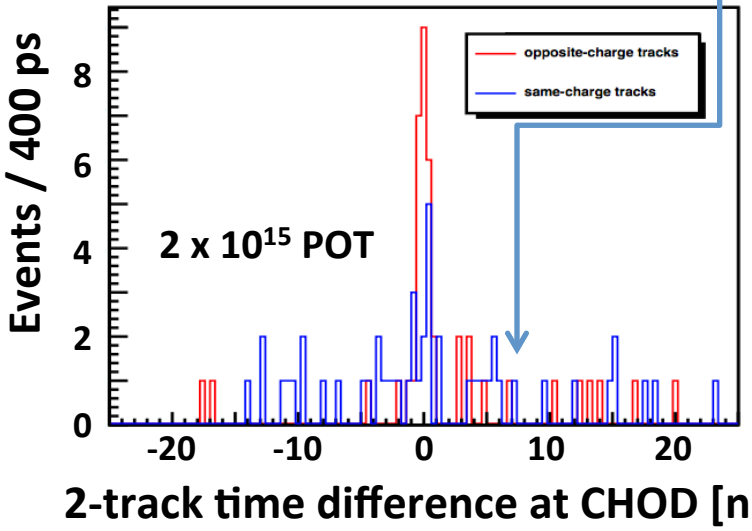
Background composition

After selecting two-track vertices of good quality with 110 < z < 180 m:

Combinatorial background, flat in time

Products of muon interaction, in time and concentrated upstream

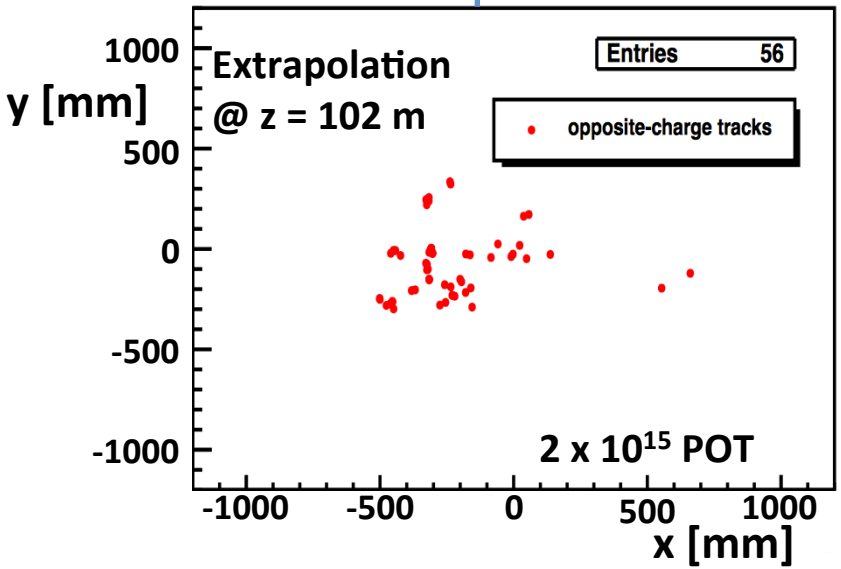


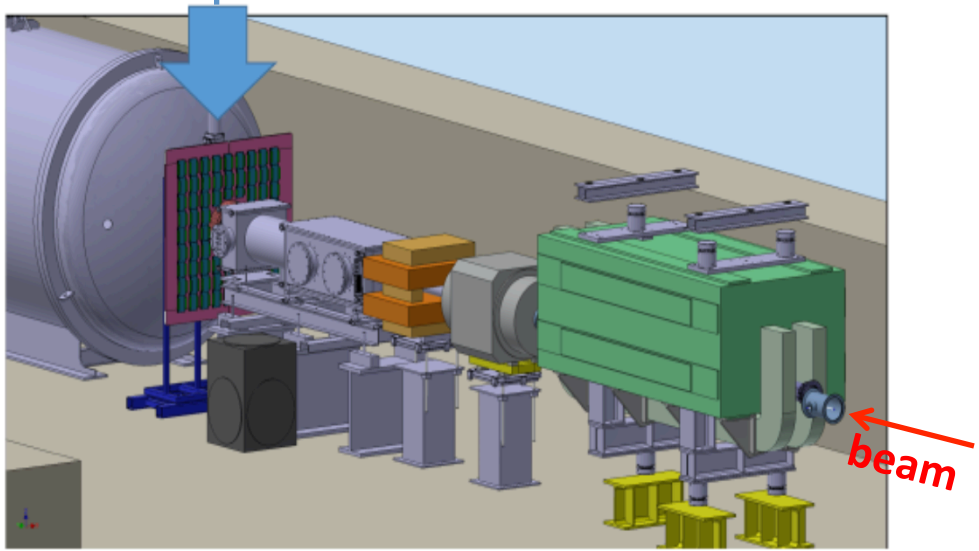


All background events can be rejected after applying all veto conditions

Background source

Background tracks stem from a region not instrumented, upstream of the decay volume





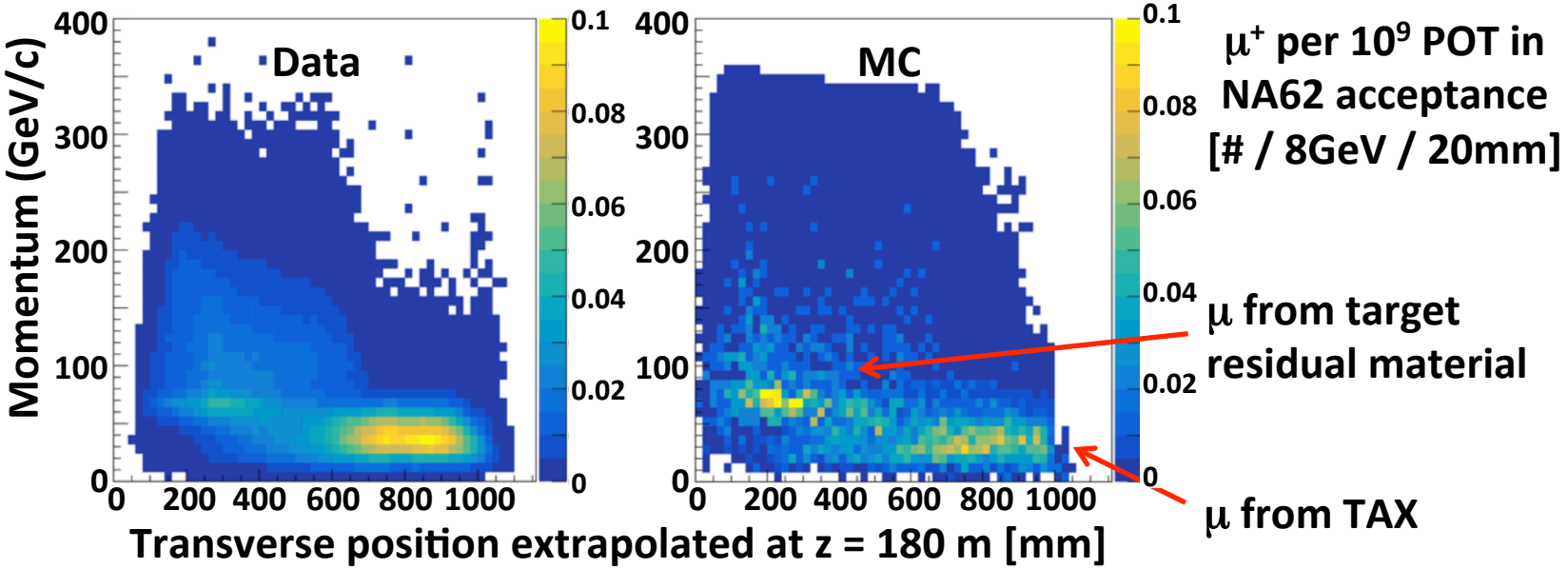
Can be instrumented with a scintillator hodoscope with σ_T < ~ 1 ns and inefficiency to MIPs ~ 10^{-4}, to provide full background rejection at 10^{18} POT

Prototype work ongoing

Beam dump setup optimization

A GEANT4-based MC simulation of the K12 beam line has been performed

- **For details, see the talk by Johannes Bernhard tomorrow**
- **Re-sampling used in different scoring planes, to increase the MC yield**
- **MC benchmarked vs data (Q1 trigger, beam dump), MC to be corrected by x5**



Setup optimization: beam spot

The present optics minimizes the beam waist at T10: $\sigma_{x,y}$ ~ 400 μm, corresponding to ~5 mm at TAX01

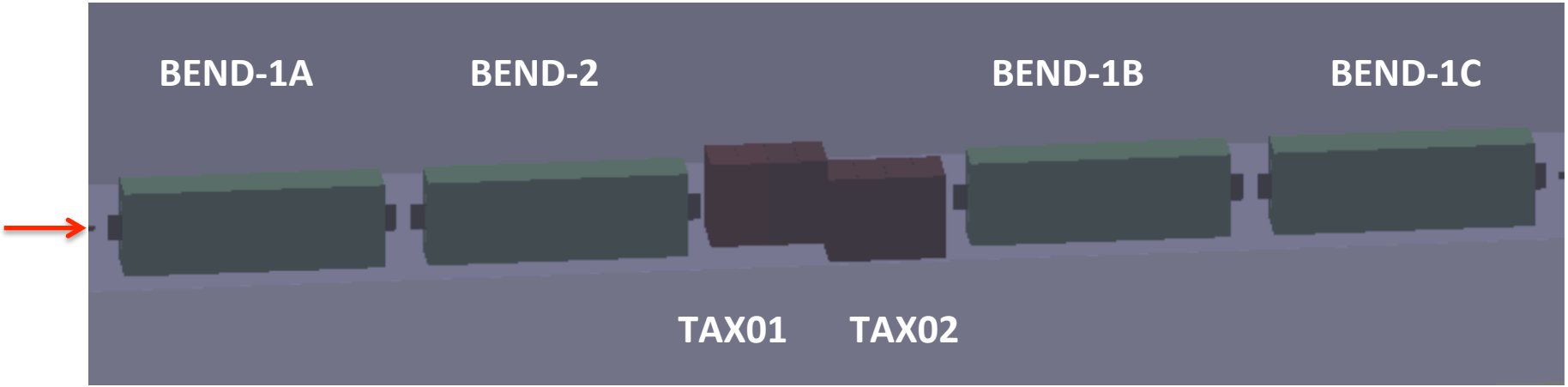
Tuning the currents of the last 4 quadrupoles of P42 and the first 6 of K12 allows a new setup optimized for TAX01: $\sigma_{x,y}$ ~ 1.2 mm, down by x4

The same optimal point might be used to allow the proton beam to pass through the TAX holes with loss <1%, allowing in principle for a dump further downstream

The option of dumping ~20 m downstream the TAX has been thoroughly studied, at the moment is seen to involve larger background

Setup optimization: reduction of halo muons

The present TAX is placed within a system of 4 dipoles with 0 net deflection



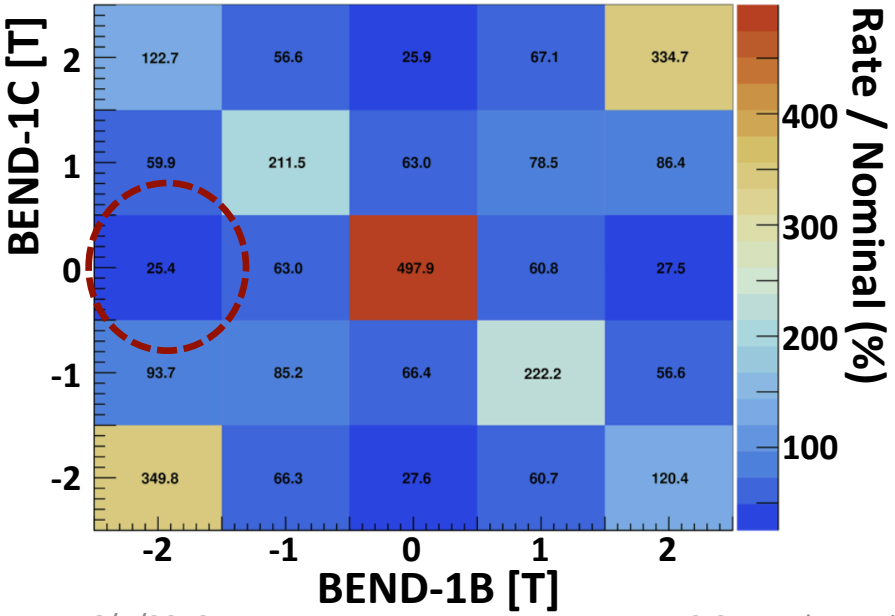
In absence of beam downstream TAX01:

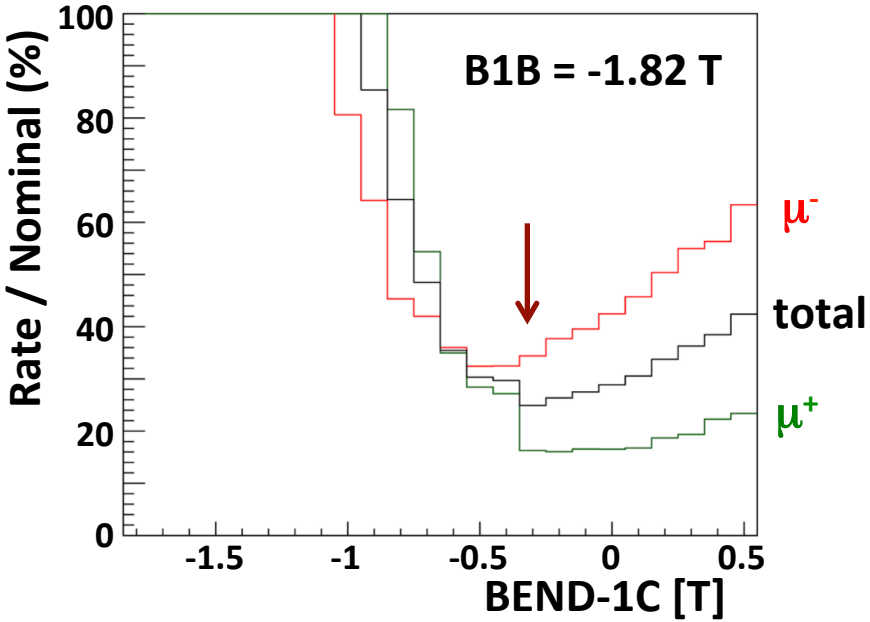
- **should use full bending power of BEND-1B,C**
- **no need to vertically offset the beam → switch off BEND-1A, BEND-2**
- **use their power supplies so that both BEND-1B and 1C can be set up to +-1.82 T**

Setup optimization: reduction of halo muons

Two scenarios have been considered:

1. **Lowest expected total muon rate in the MUV3 acceptance, for BEND-1B = -1.82 T and BEND-1C = -0.3 T: rate ~ 1/4 of the nominal**

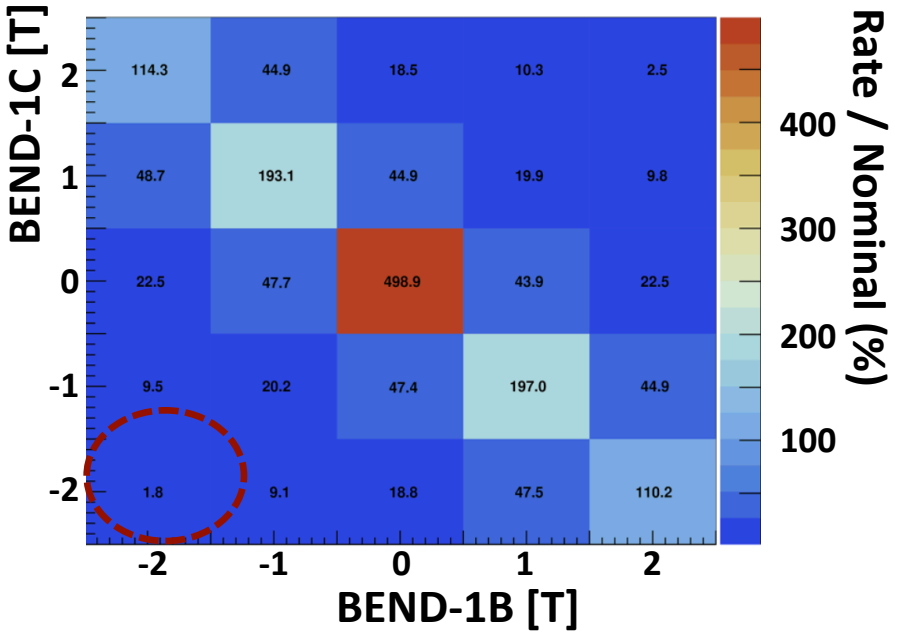


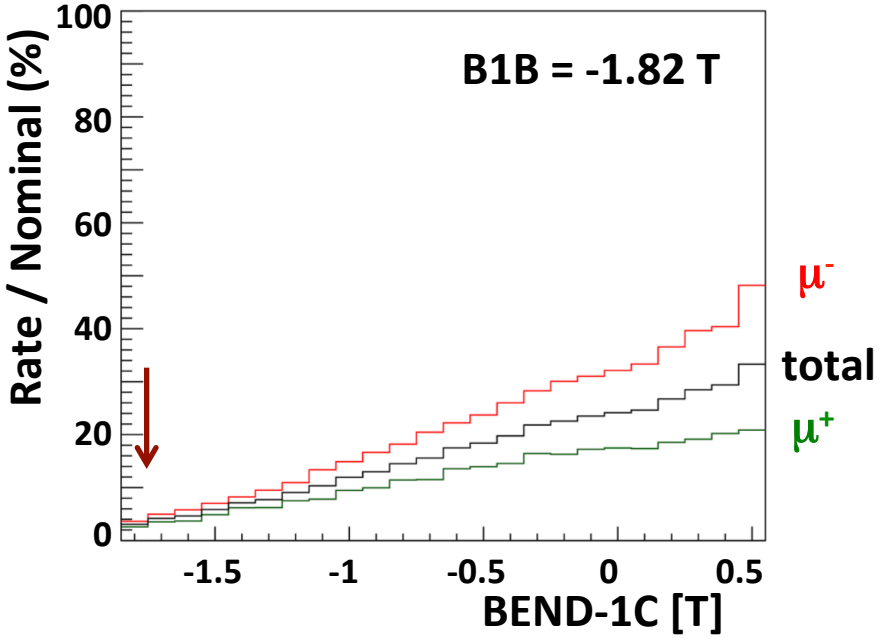


Setup optimization: reduction of halo muons

Two scenarios have been considered:

2. Lowest expected rate of μ's > 15 GeV in the MUV3 acceptance, for BEND-1B = -1.82 T and BEND-1C = -1.82 T, rate ~ 1/20 of the nominal





Rationale of the optimization and future work

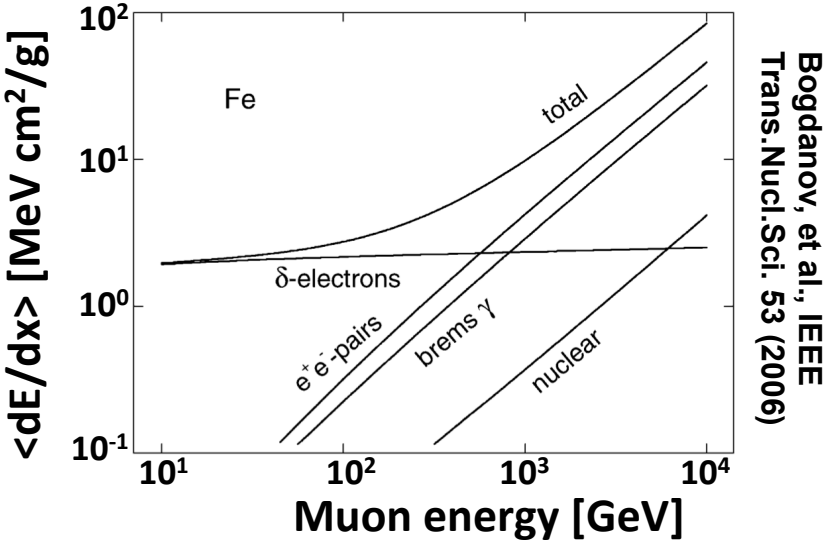
The trigger rates are modest: the optics might be further tuned to minimize the expected background to the search for two opposite charged particles in time:

1. Secondary interactions (bremsstrahlung, e^+e^- production, nuclear interaction) upstream of the decay volume (final collimator, BEND6, TRIM5) can produce hard photons and/or two or more charged particles mutually in-time

2. Combinatorial pairing of μ^+ and μ^-

A dedicated tuning of the optics might be explored, to:

- **Soften the μ spectrum, to reduce 1.**
- **Alter the μ^+/μ^- balance, to reduce 2.**



Conclusions

10^{18} POT to be collected in Run3 in beam-dump mode provide sensitivity to NP models:

- Dark photons, Heavy Neutral Leptons, Axion-like particles, etc.

Expected sensitivity is competitive with other projects in the world (see the BSM Summary document for plots and details)

Demonstrated background rejection, using Run2 data, for the searches proposed (charged modes) up to 3×10^{16} POT's: further studies on going for the extrapolation to 10^{18} POT

An anti-halo detector is under study for Run3, to ease the background rejection

Taking advantage of the extension of the PBC mandate, the optimization of the optics performed within the Conventional Beam WG could be further tuned to reduce the expected background