



NA64

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On behalf of the NA64 collaboration



NA64 Collaboration

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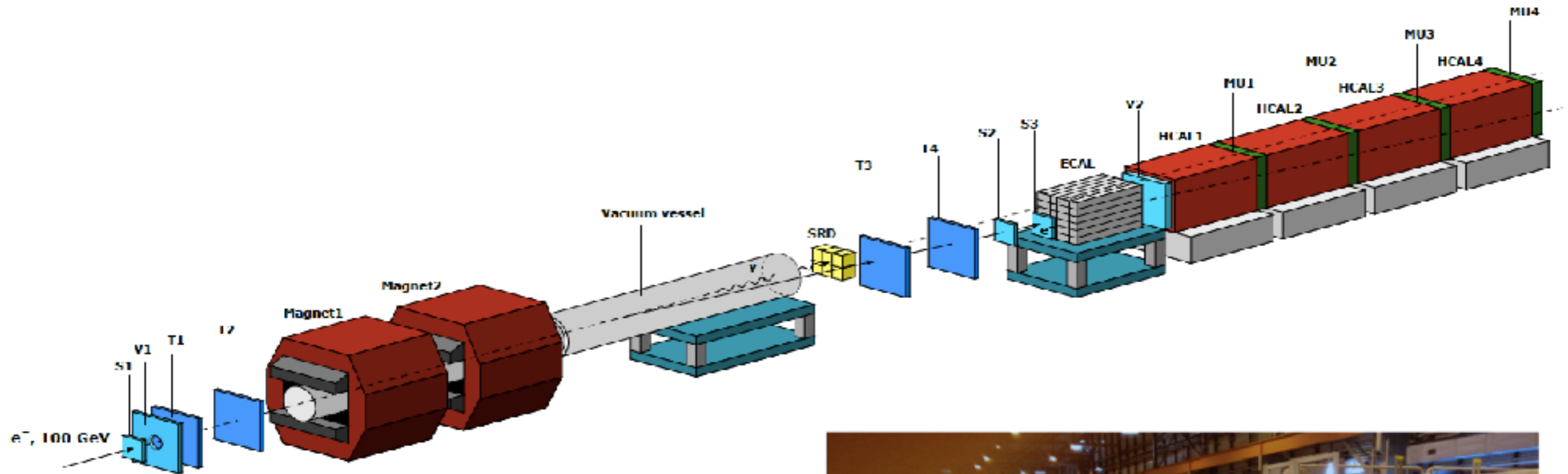
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NA64: Search for dark sector physics in missing energy events

- **Approved in March 2016 for the A' \rightarrow invisible decay search with electron beam.**
- **Two runs in 2016 \rightarrow focus on the A' parameter space suggested for the $(g-2)_\mu$ anomaly.**
- **First results from the two weeks beam time in July'2016 published, most of the $(g-2)_\mu$ favoured parameter space excluded.**
- **10 times more statistic acquired in October'2016. Analysis in progress.**

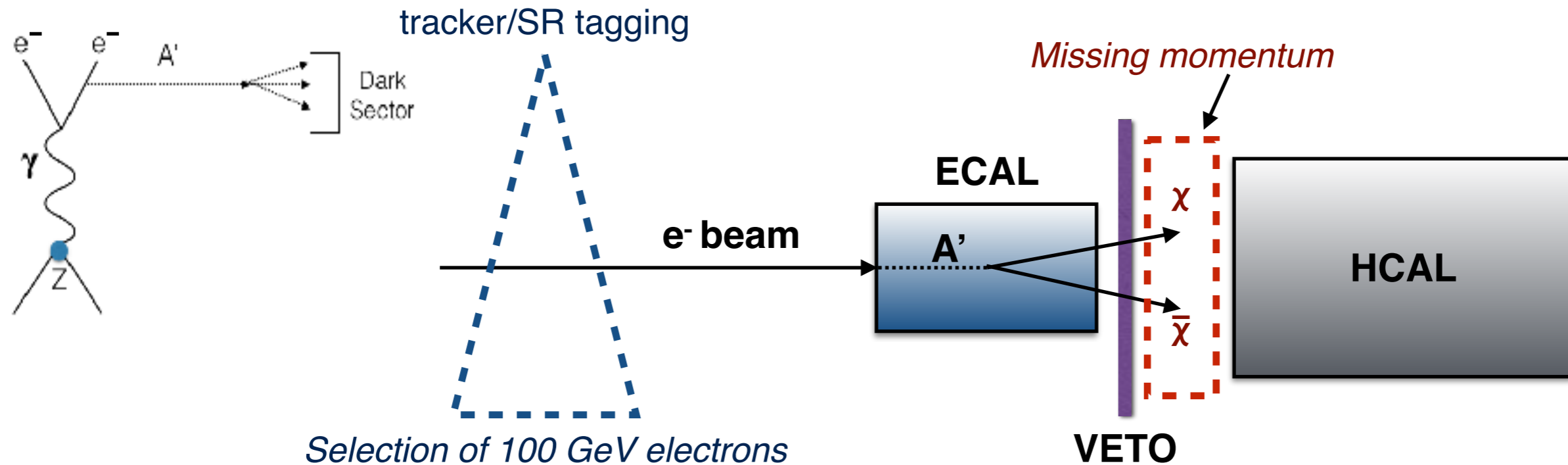
NA64: Setup



Key Features of the setup:



NA64: Search for dark sector physics in missing energy events



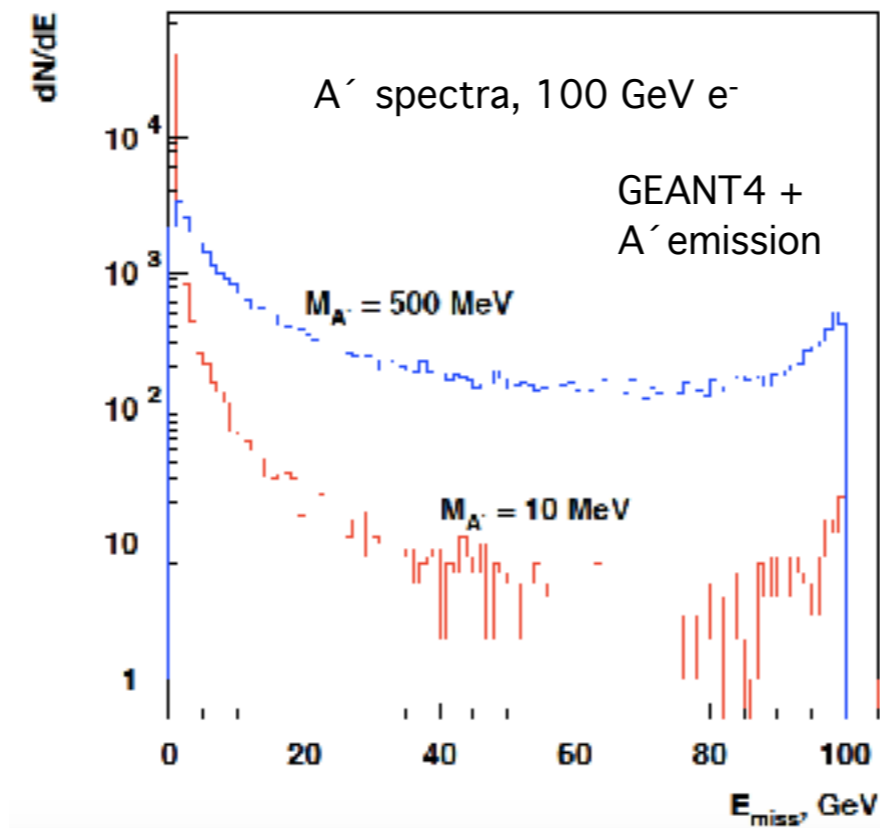
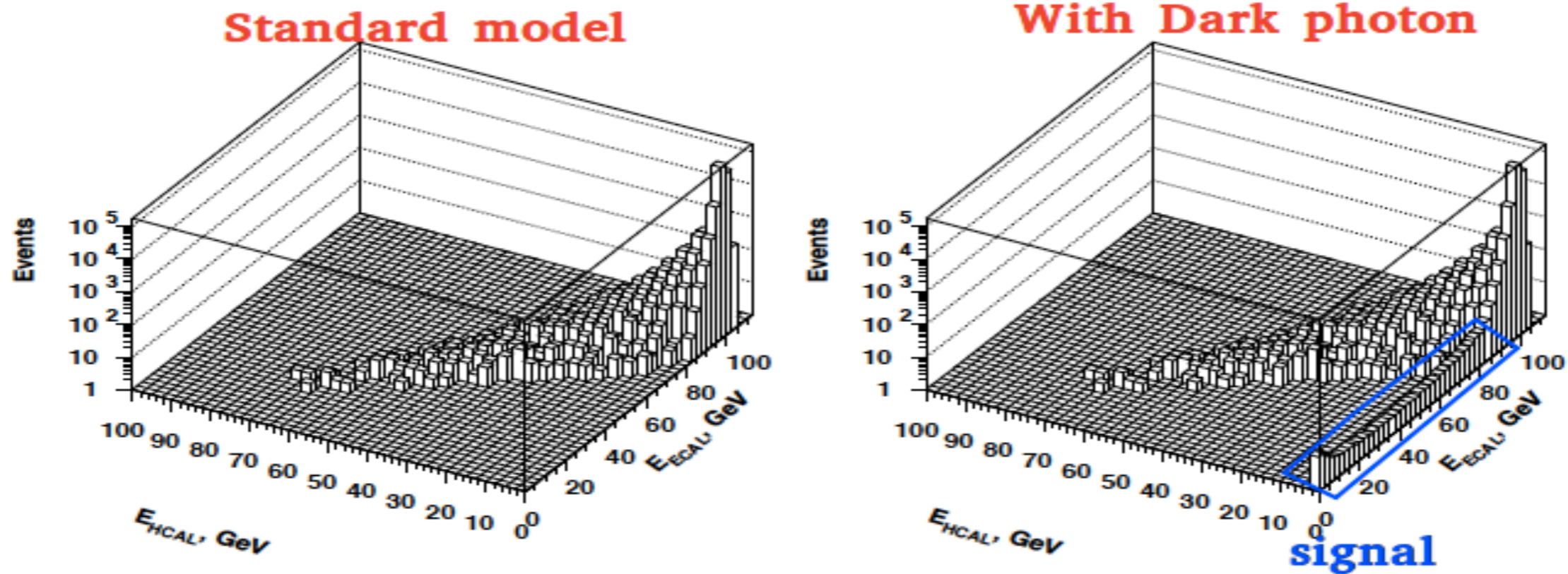
NA64 \rightarrow fixed target experiment combining the active beam dump technique with missing energy measurement searching for invisible decays of massive A' produced in the reaction $eZ \rightarrow eZA'$ of electrons scattering off a nuclei (A, Z), with a mixing strength $10^{-6} < \epsilon < 10^{-3}$ and masses $M_{A'} \sim$ sub-GeV range.

100 GeV electrons dumped against an ECAL, a sandwich of lead and scintillators ($34 X_0$), to produce massive A' through scattering with the heavy nuclei.

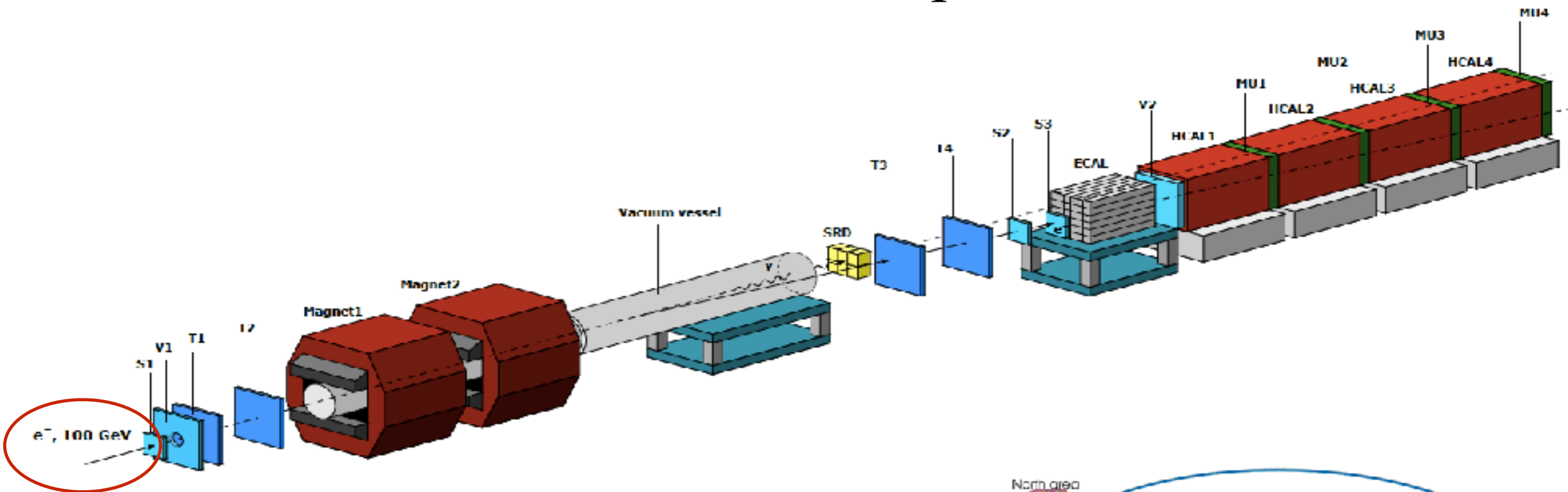
The typical signature for a signal will be **missing energy in the ECAL** and no activity in the the VETO and HCAL.

Background from hadrons, muons and low energy electrons must be rejected upstream.

NA64: Search for dark sector physics in missing energy events

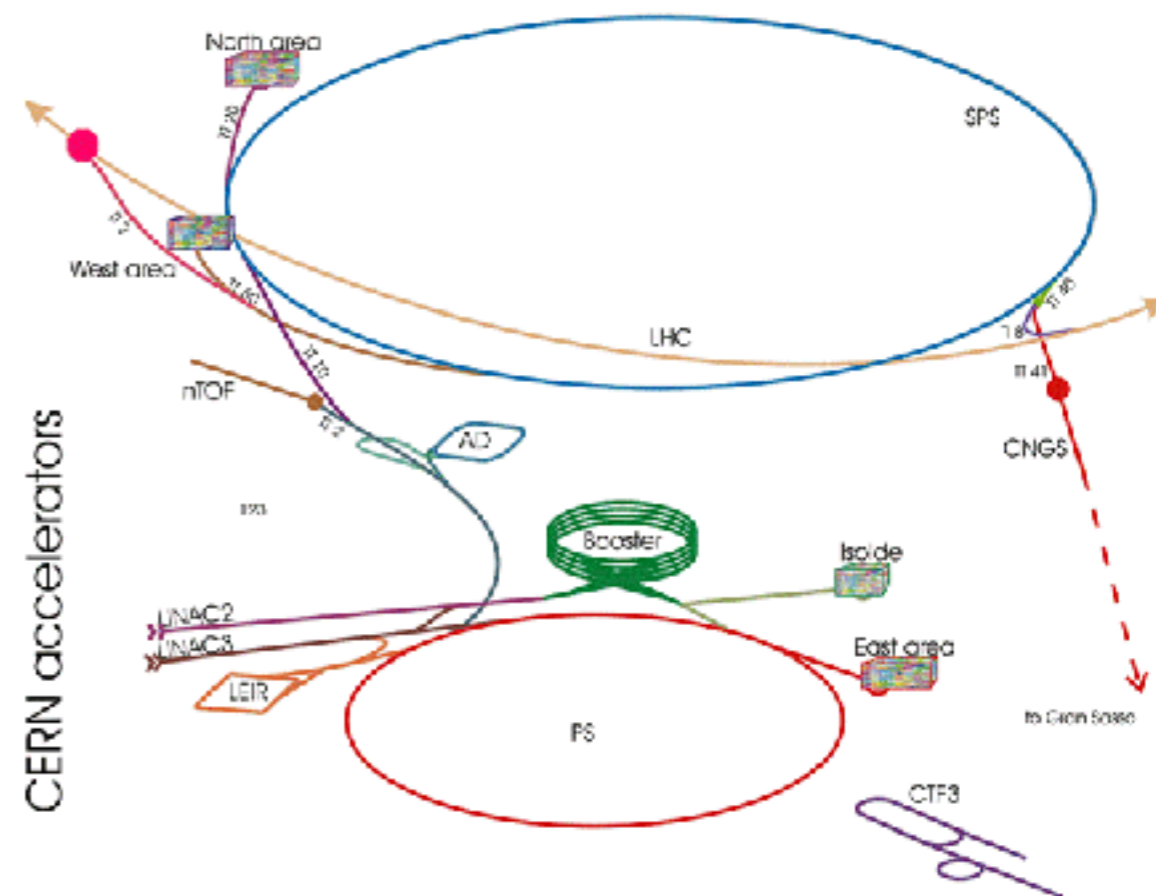


NA64: Setup

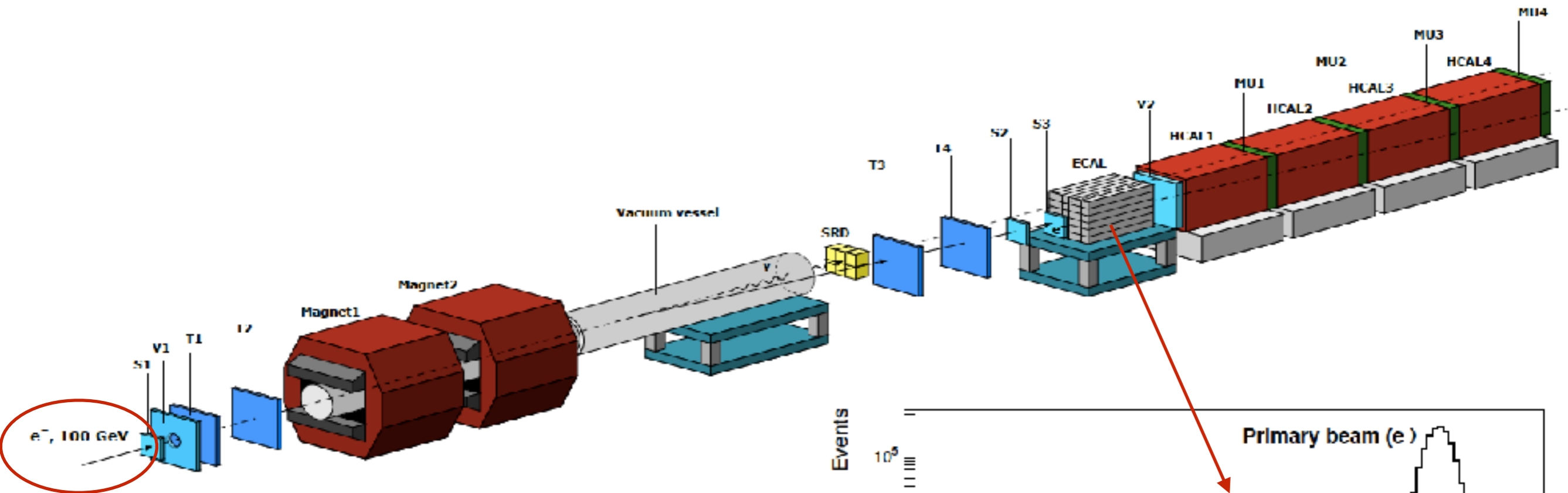


Key Features of the setup:

- High energy beam to trigger the reaction: 100 GeV e- beam from the CERN SPS.
- Max intensity $\sim 5 \times 10^6$ e- / spill.
- Typically 2 spills/min
- Main impurities of H4 beam: π^- , low energy e- ($\sim 1\%$) μ^- and K^- ($\approx 0.1\%$)

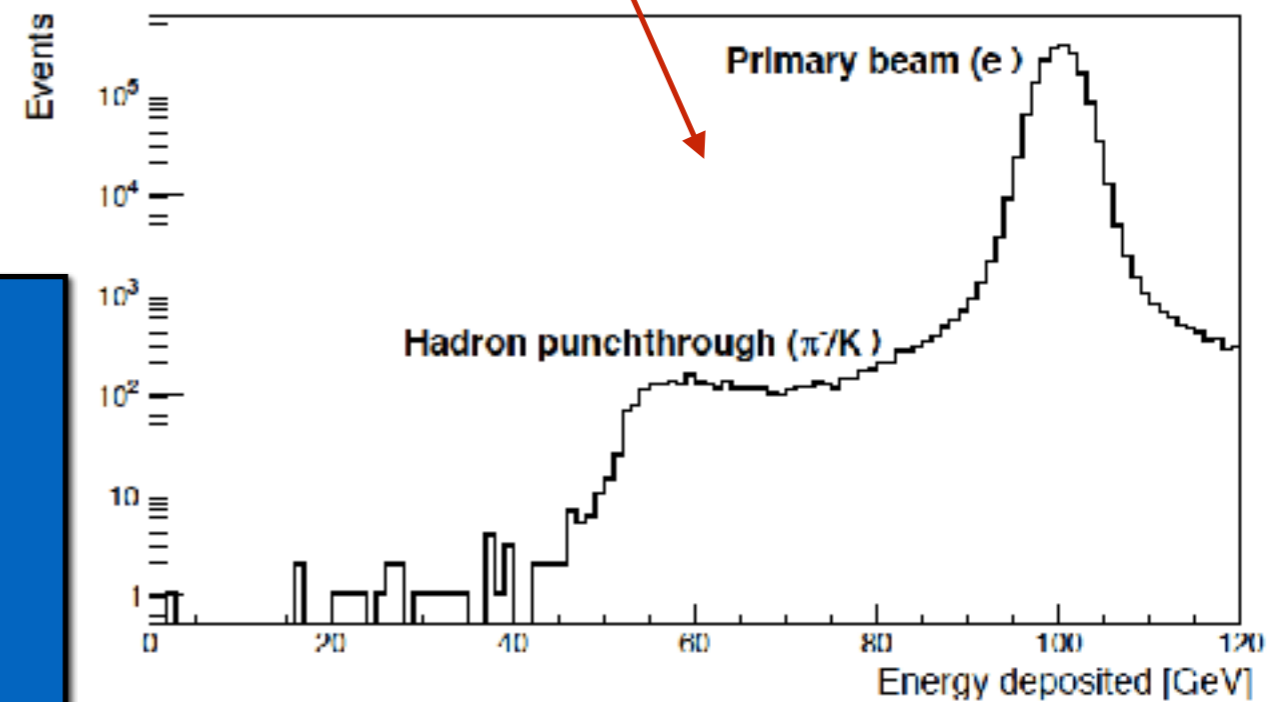


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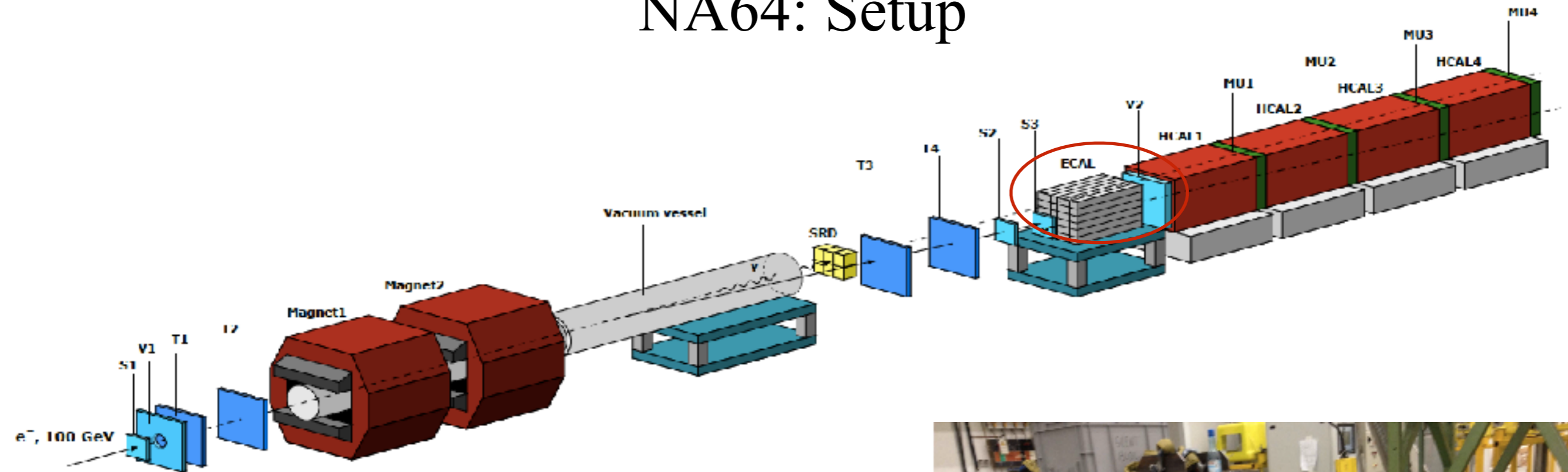


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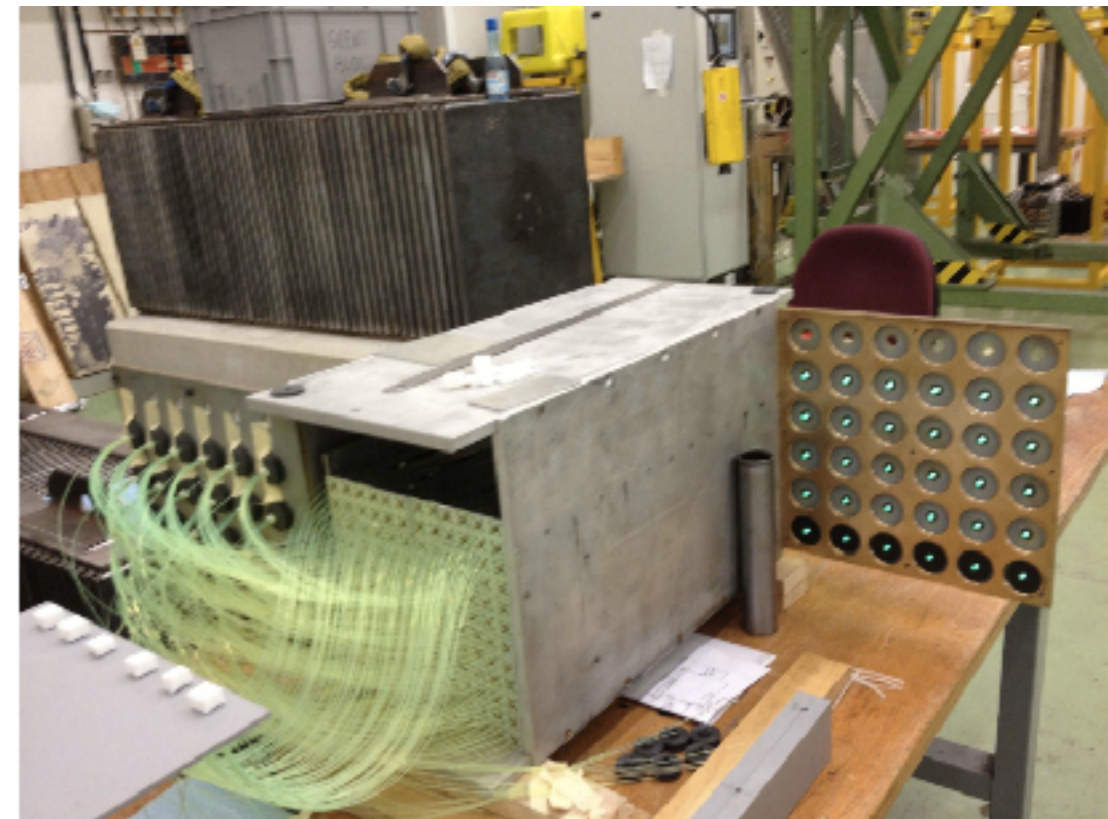


NA64: Setup

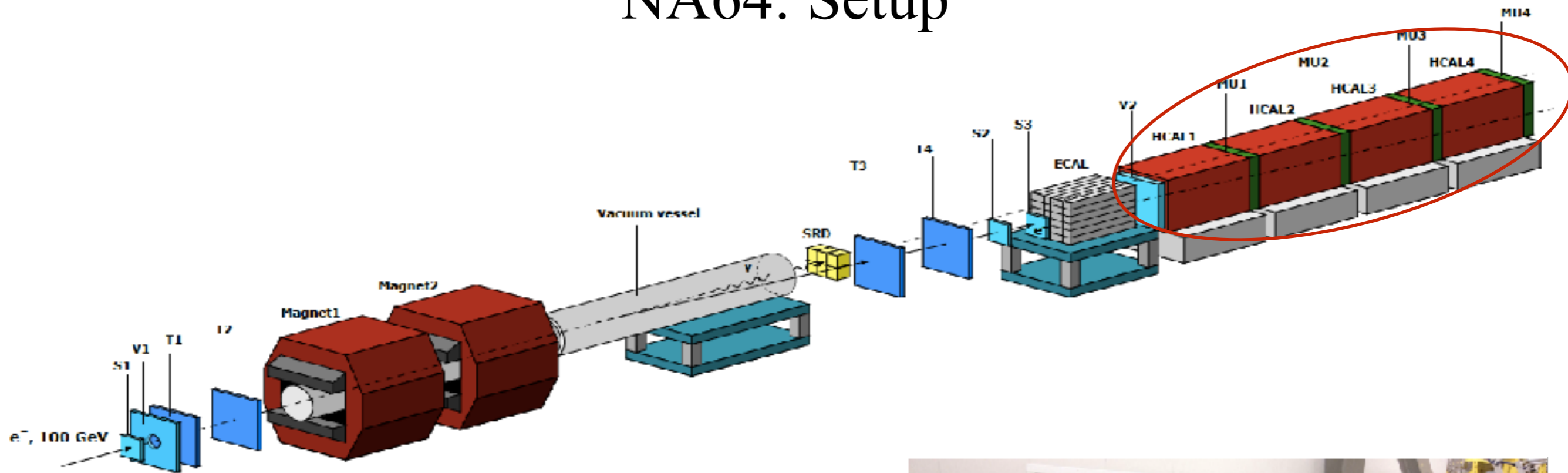


Key Features of the setup:

- High hermeticity: ECAL - PbSc sandwich, $38 \times 38 \times 445 \text{ mm}^3$ ($\sim 40 X_0$) with WLS fiber inserted in spiral $\sim 9\%/\sqrt{E[\text{GeV}]}$ energy resolution



NA64: Setup

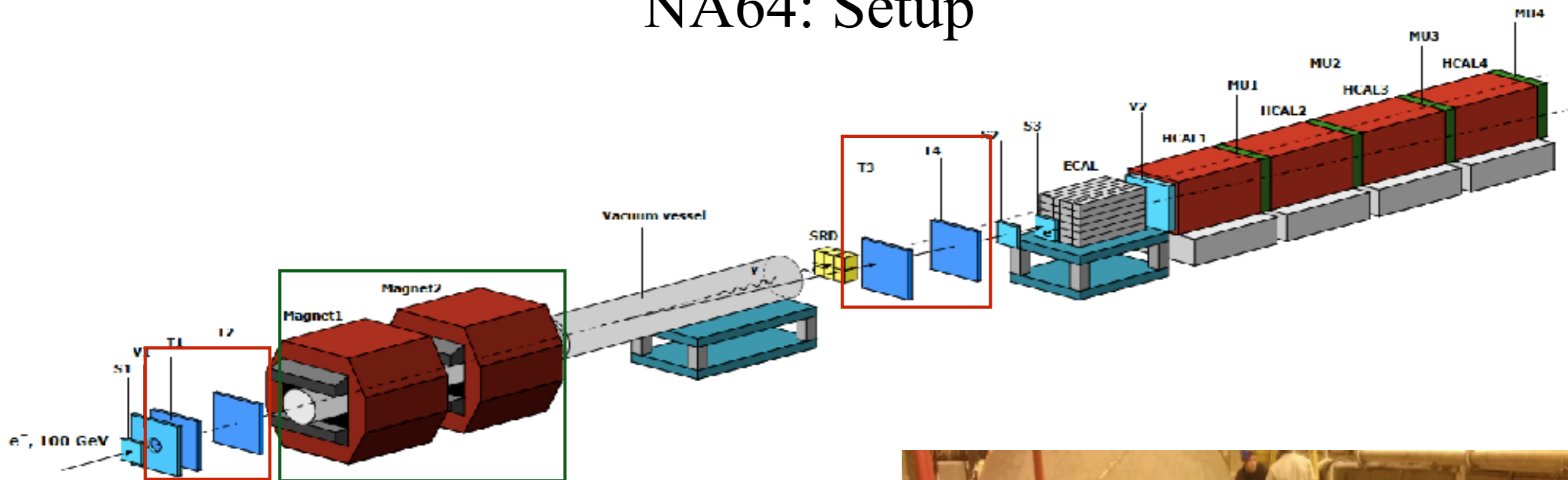


Key Features of the setup:

- High hermeticity: 4 HCAL FeSc sandwich modules, $60 \times 60 \times 150$ cm³ ($\sim 7 \lambda$ for each module) with WLS fiber and $60\%/\sqrt{E[\text{GeV}]}$ energy resolution.

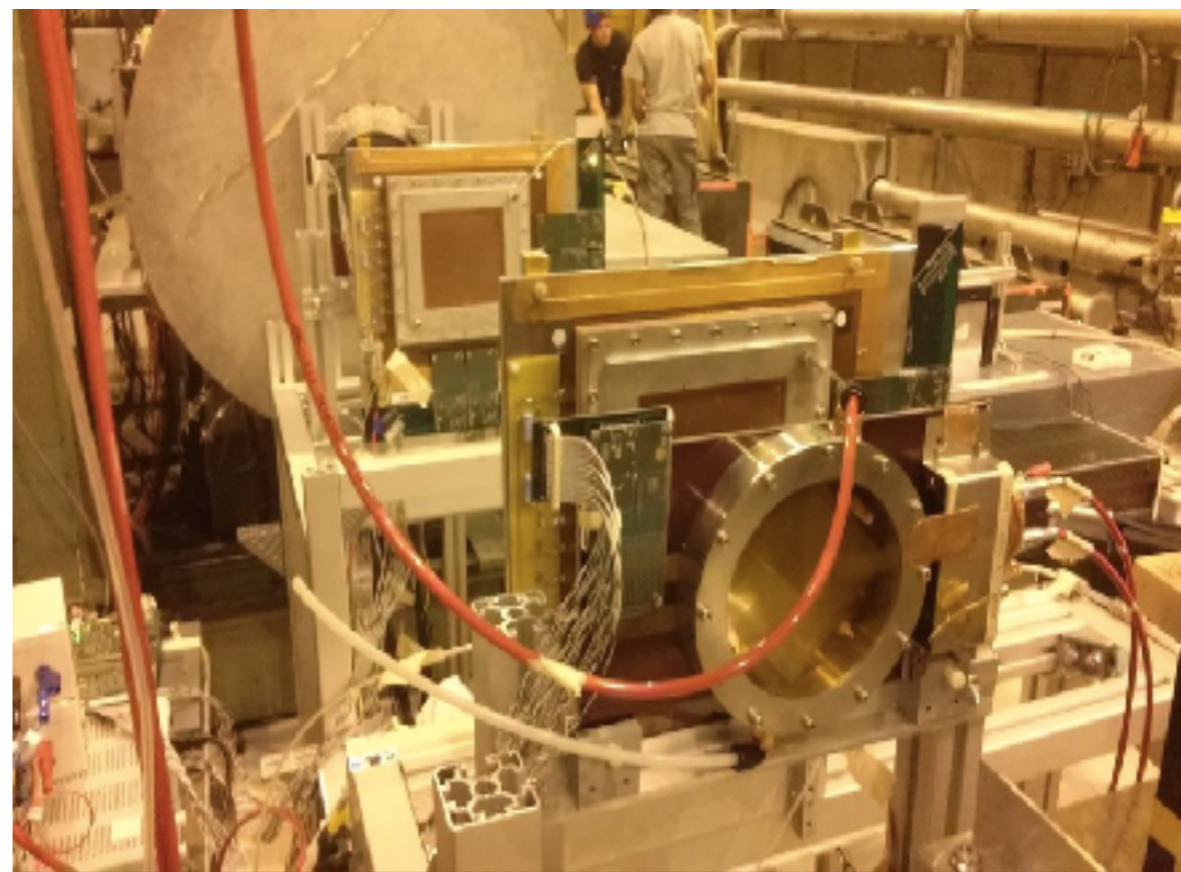


NA64: Setup

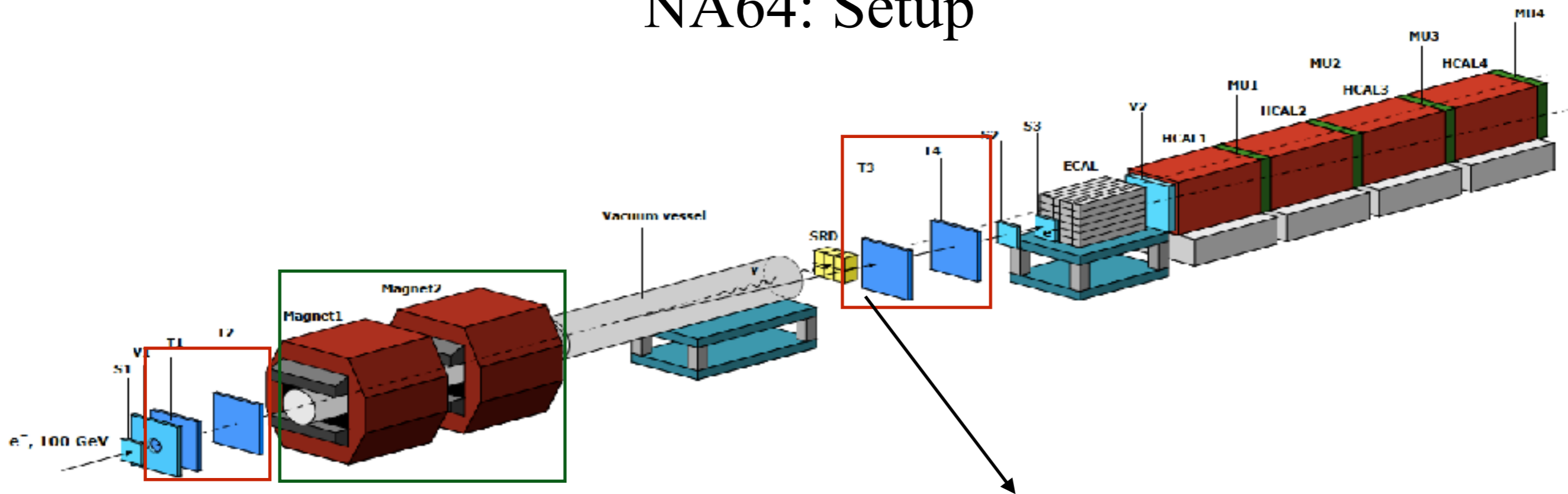


Key Features of the setup:

- Measure momentum: Tracking system made of 4 MicroMegas modules and 2 GEM detectors together with 2 MPBL magnet $\sim 7 \text{ T} \cdot \text{m}$ to measure momentum of incoming particles.

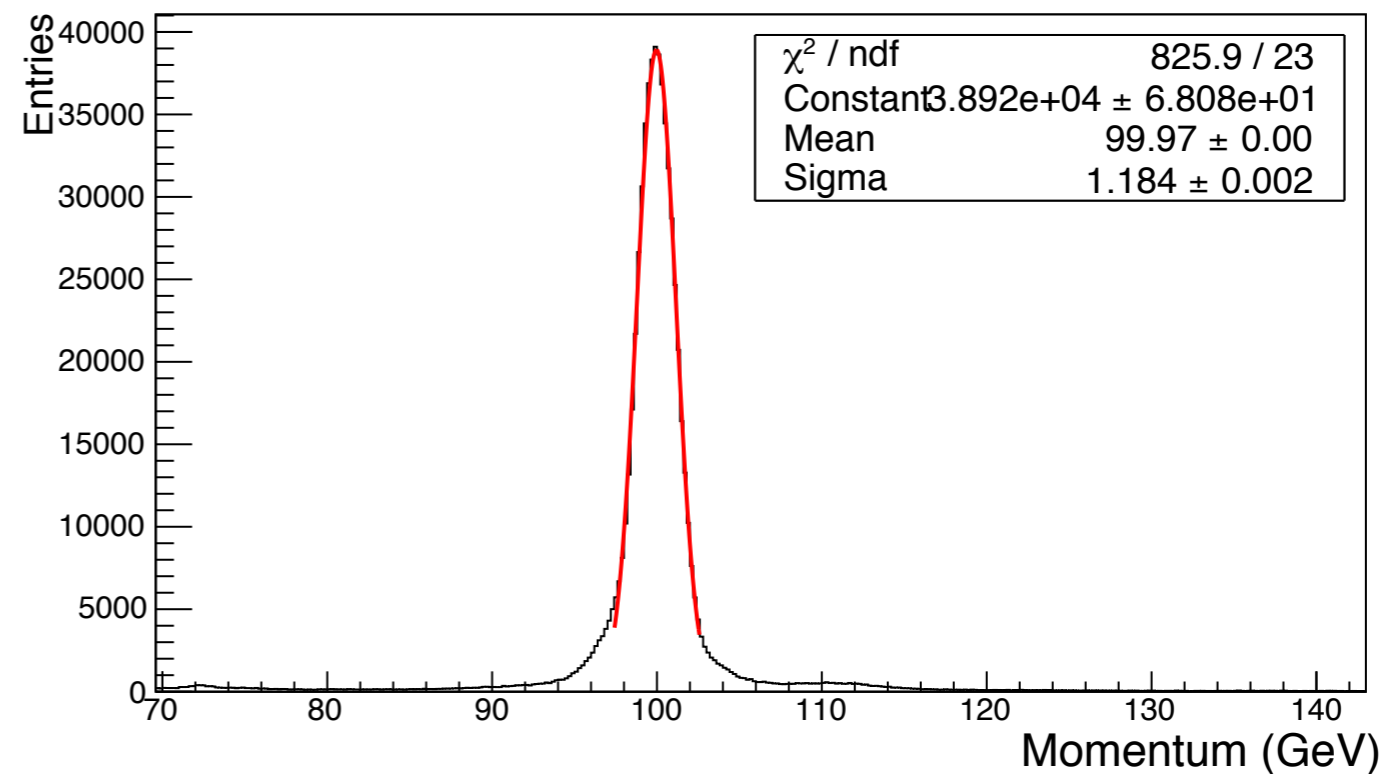


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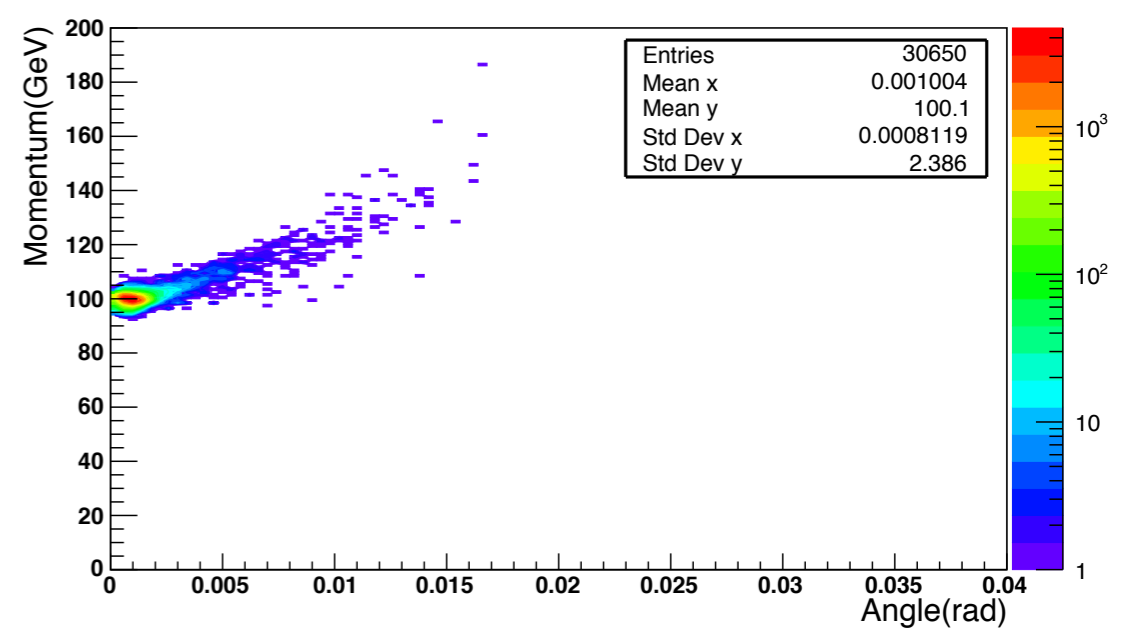
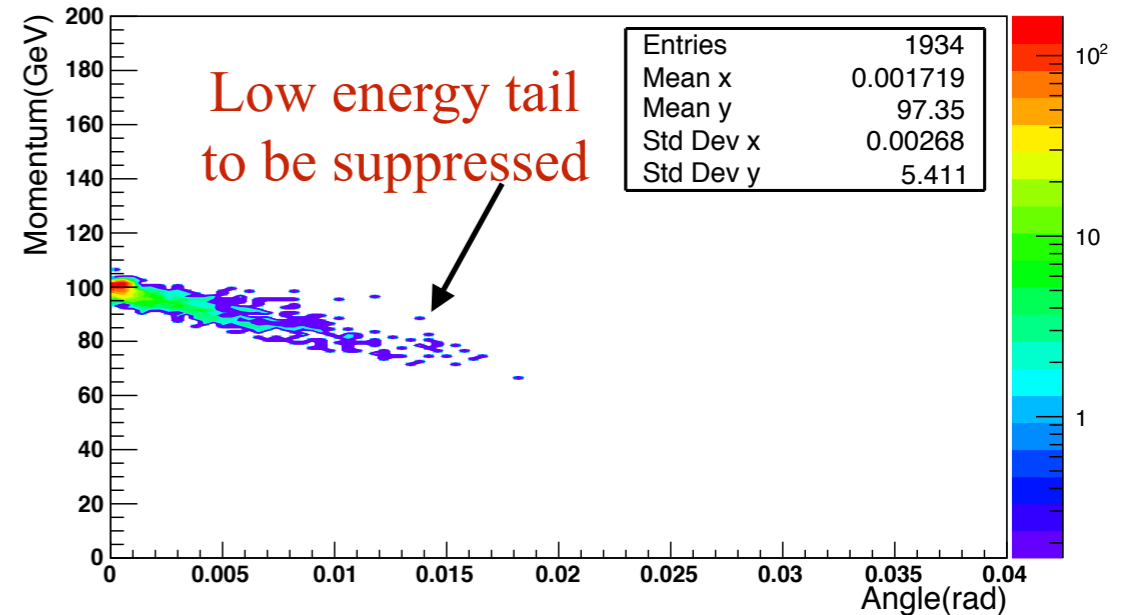
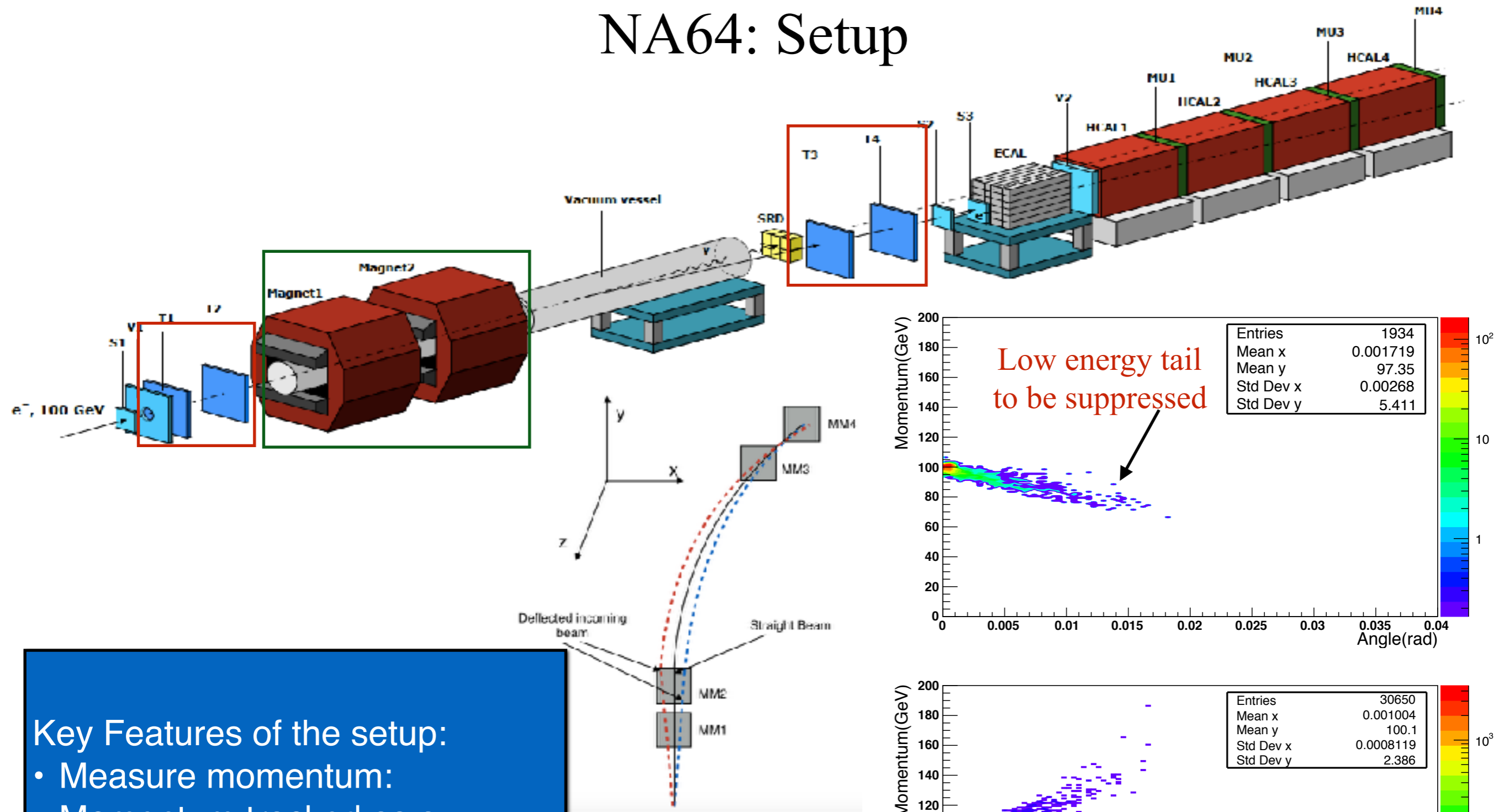


Key Features of the setup:

- Measure momentum:
Reconstructed momentum



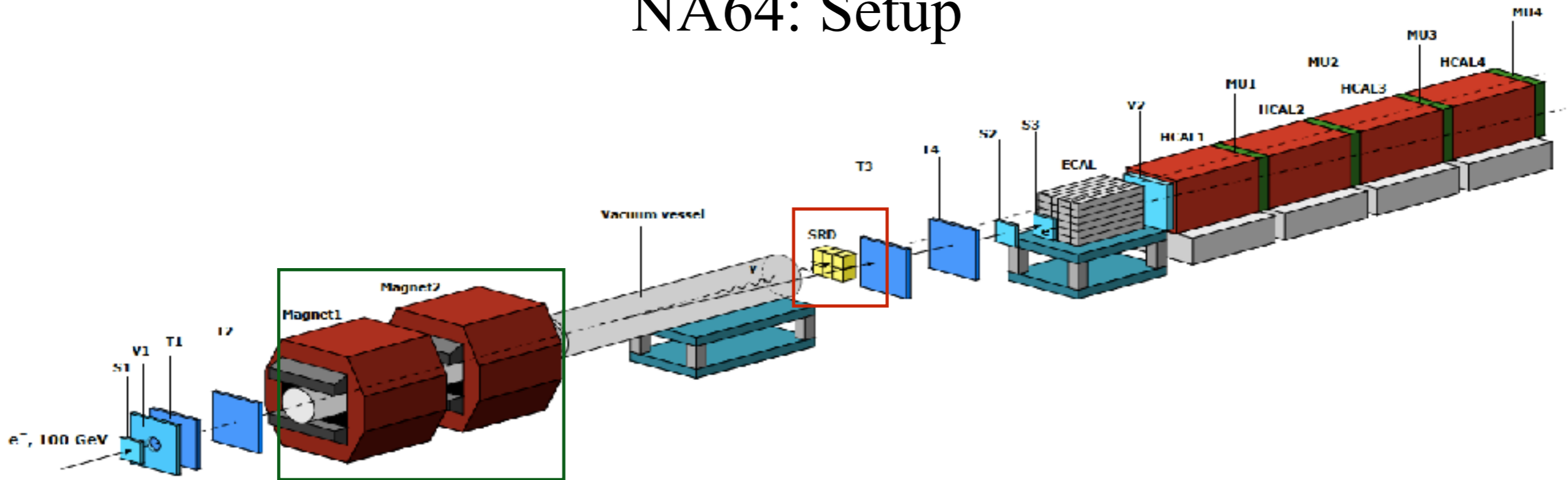
NA64: Setup



Key Features of the setup:

- Measure momentum: Momentum tracked as a function of incoming angle

NA64: Setup

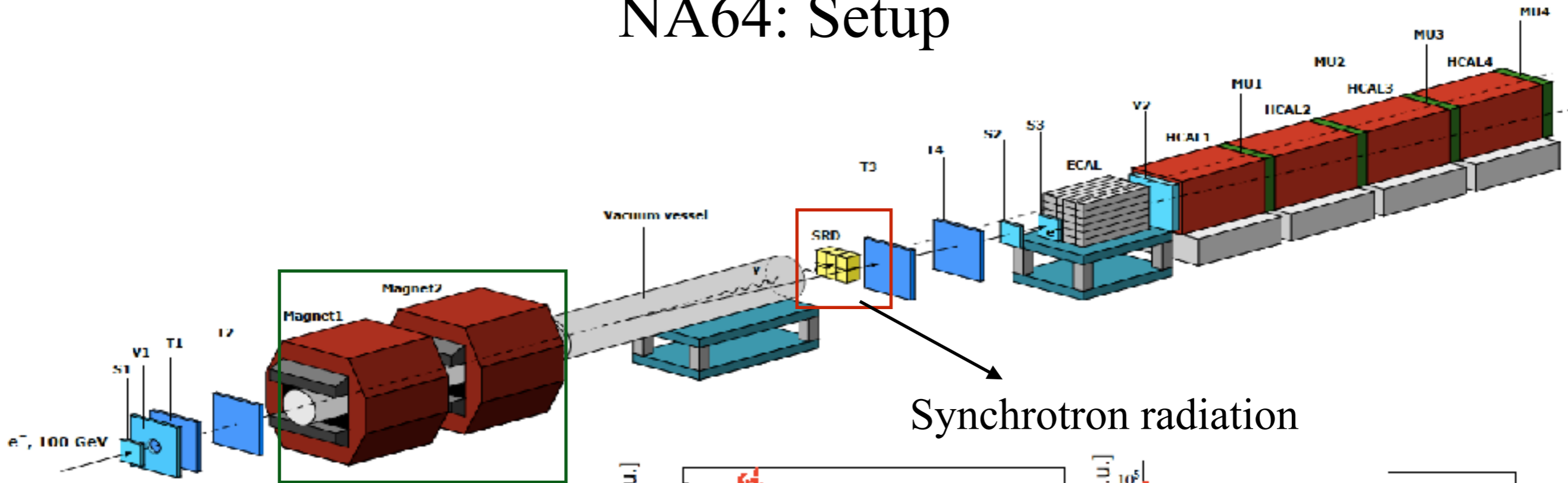


Key Features of the setup:

- Suppress hadronic background: Synchrotron radiation tagging system (BGO/PbSc sandwich calorimeter) to reject μ^- , π^- and K^- decay in flight after interaction with ECAL.

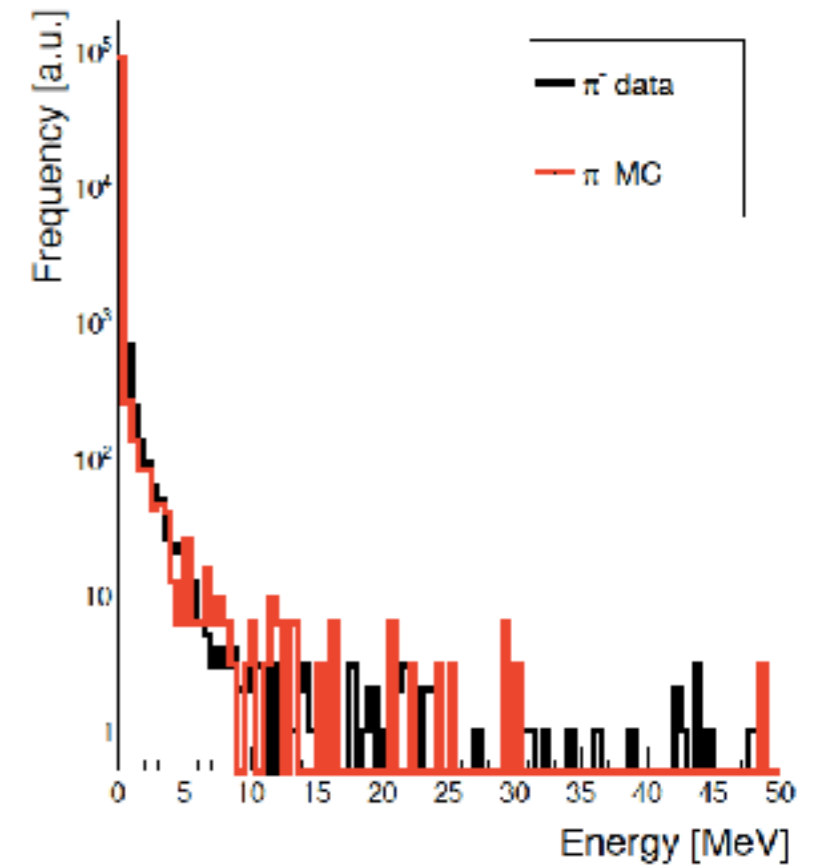
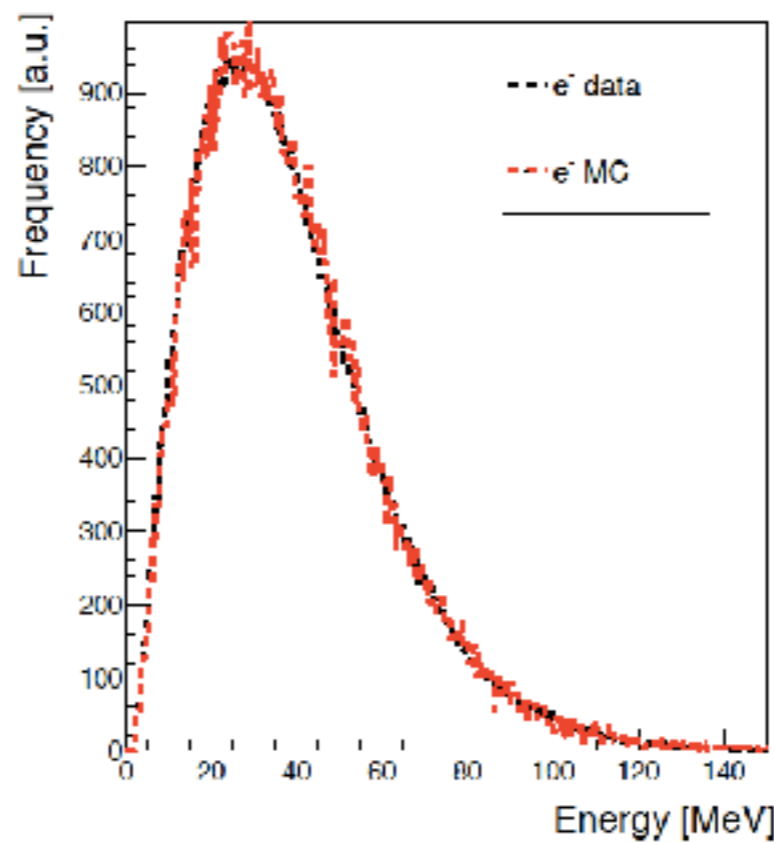


NA64: Setup



Key Features of the setup:

- Suppress hadronic background: Synchrotron radiation tagging to reject hadrons at a level of 10^{-5} .

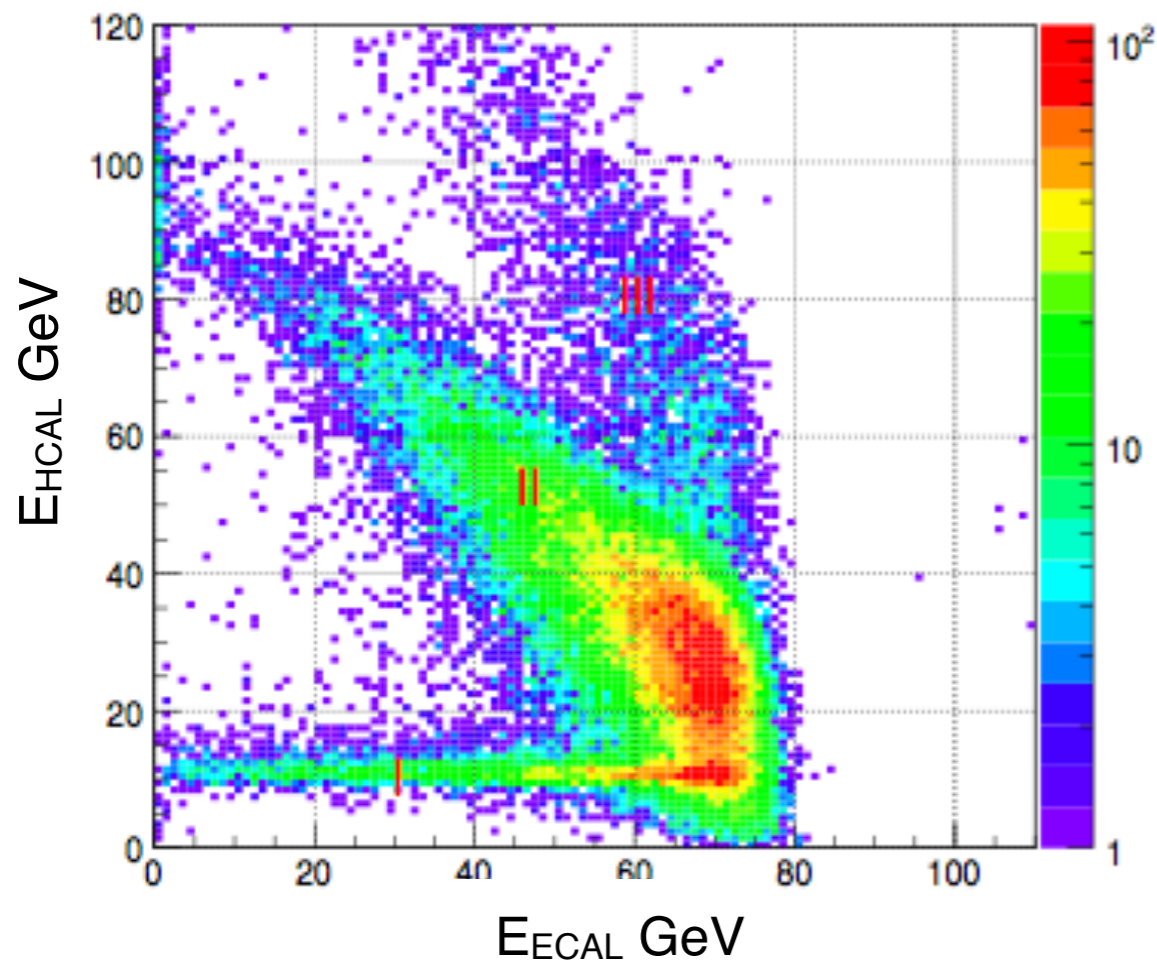


arXiv: 1703.05993

July' 2016 Run

July 2016 results

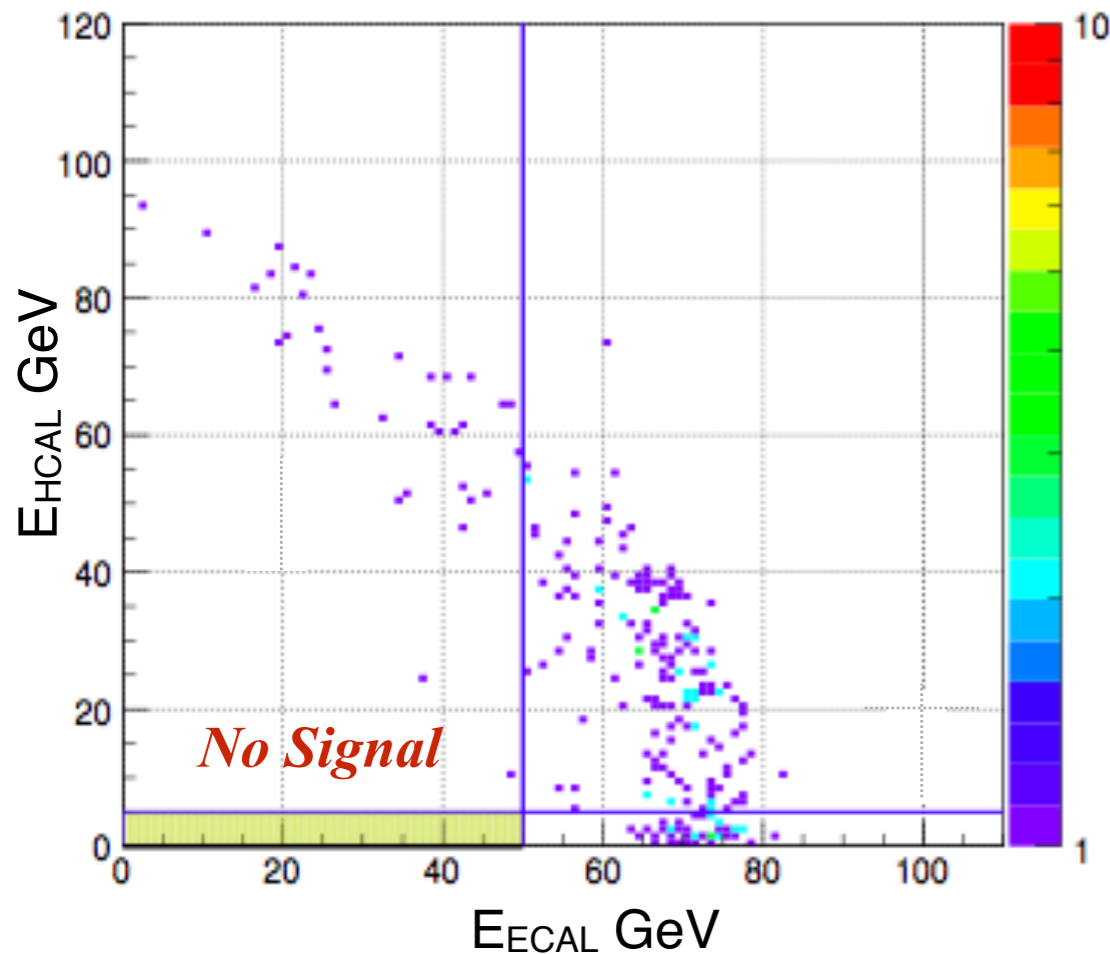
No selection cut applied



2.75 x 10⁹ electrons on target with beam intensity of 1.4 x 10⁶ e⁻/ 4.8 s spill for a ~ 2 cm diameter beam:

- Region I → rare QED dimuon production $e^- Z \rightarrow e^- Z\gamma; \gamma \rightarrow \mu^+\mu^-$, characterised by the energy of ≈ 10 GeV deposited by the dimuon pair in the HCAL.
- Region II → SM events from the hadron electroproduction in the target: $E_{ECAL} + E_{HCAL} \approx 100$ GeV.
- Region III → few $\sim 10^{-2}$ mostly pile-up of e⁻ and beam hadrons.

July 2016 results

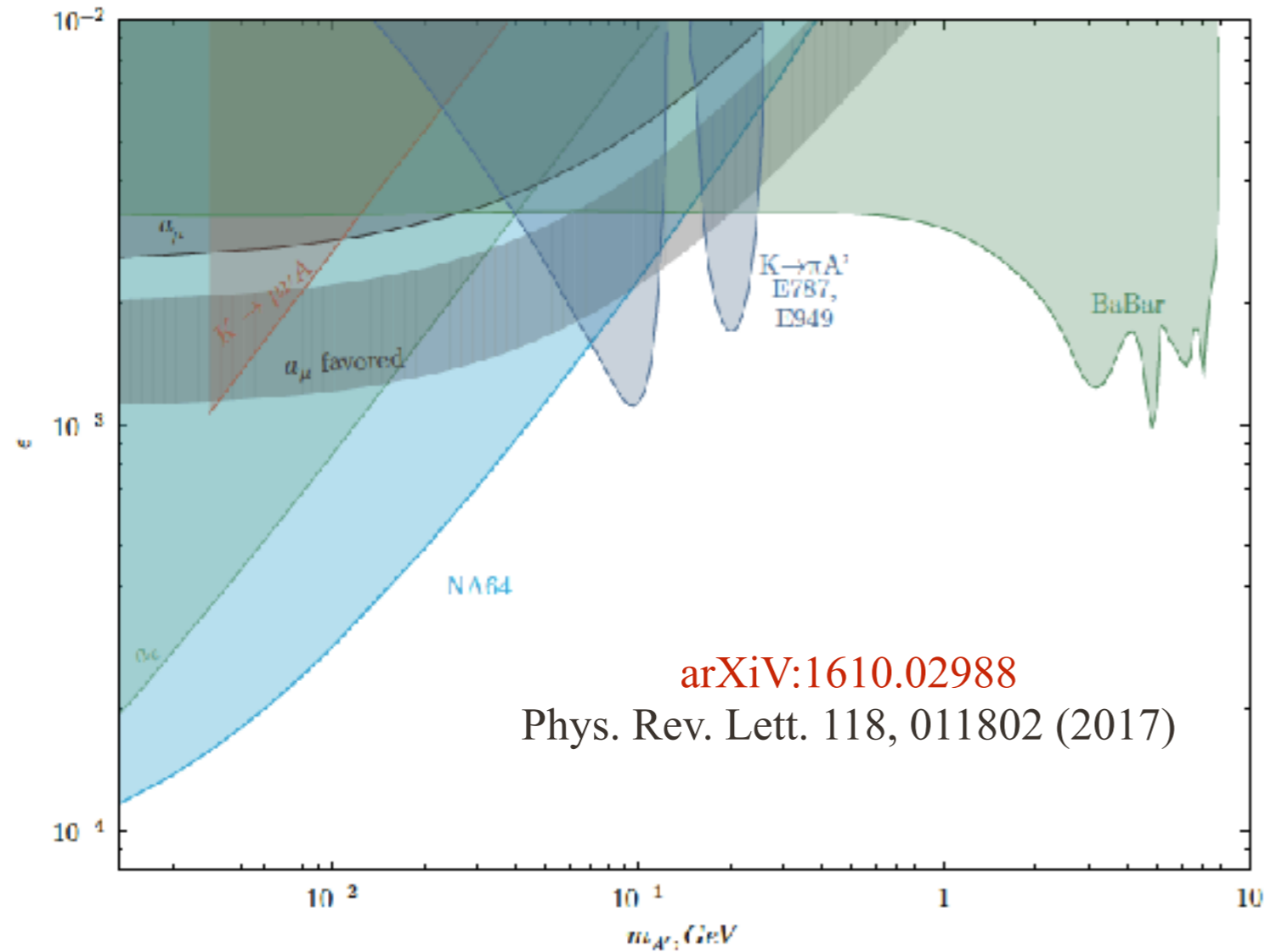


Event Selection Criteria:

- Pile up suppression using timing information.
- Selecting clean incoming track (angle + single hit in all 4 MMs) with correct momentum.
- Hadron suppression with synchrotron radiation.
- Events with shower profile as expected.
- No activity in Veto 2.

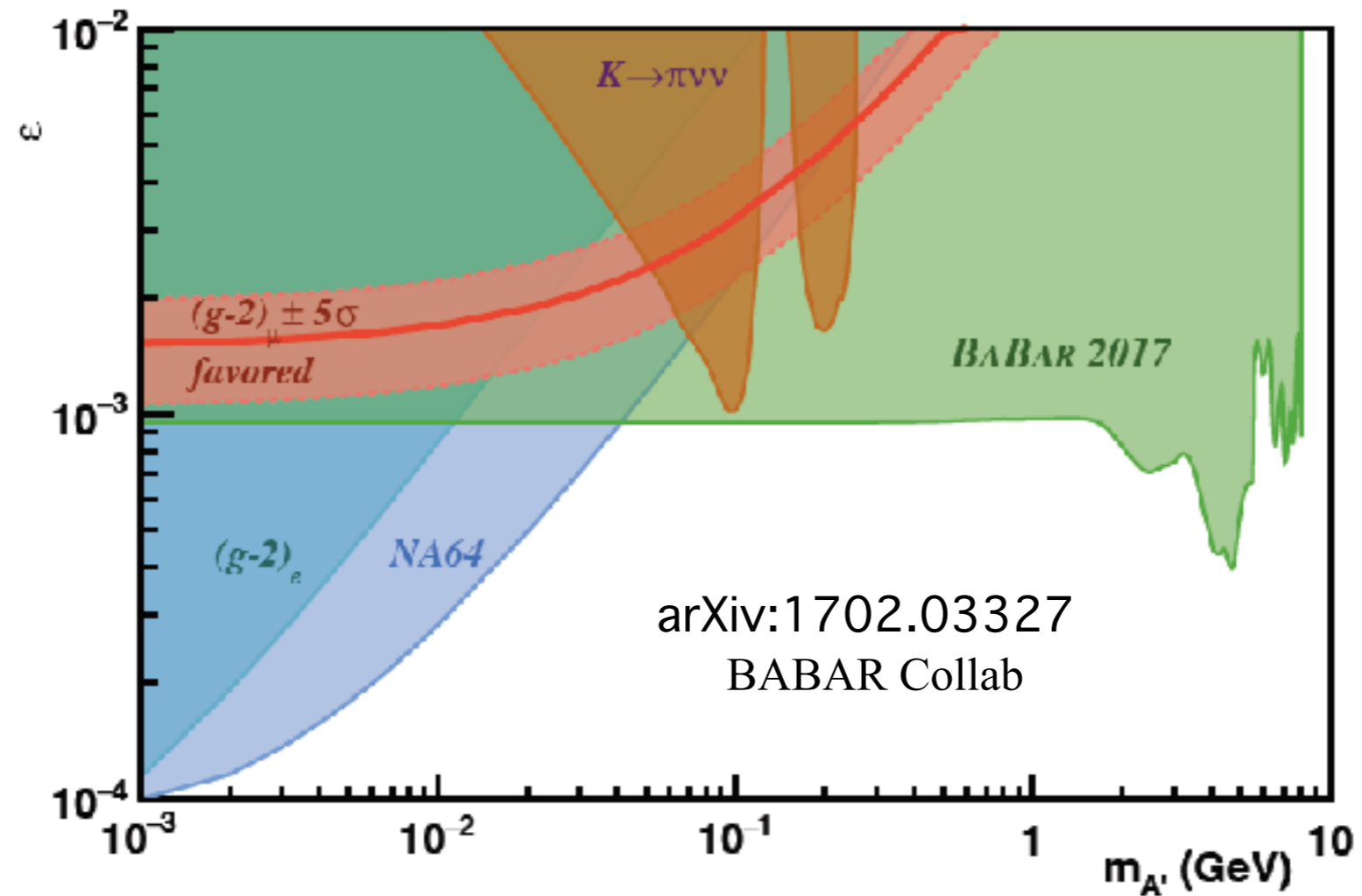
Selection cuts applied

July 2016 results



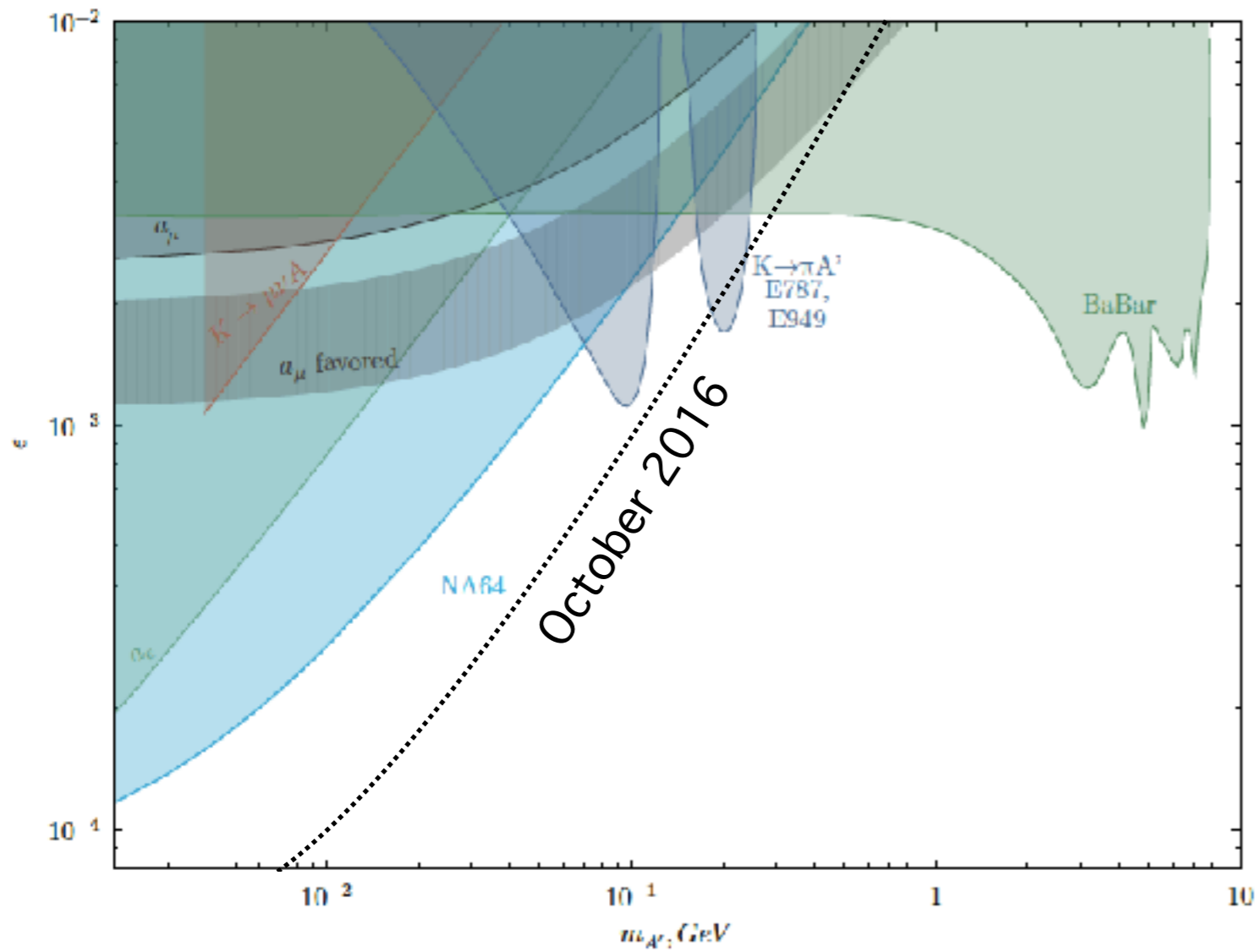
- No event observed in the signal box from the July'2016 data.
- New limits set on the γ - A' mixing strength.

New BaBar Results



Explanation of $(g-2)_\mu$ with invisible A' is excluded.

October 2016 run and prospects



Projected Sensitivity

- October 2016 run :
 - Good performance at 5×10^6 e-/spill
 - 4×10^{10} eot collected.
 - Data analysis in progress.
- 2017 run
 - Improved e- tagging: tracker+SRD
 - Tests at intensity $(7-8) \times 10^6$ e-/spill
 - Goal $(2-3) \times 10^{11}$ eot.

Summary

The conceptual idea of NA64 is to search for dark sector physics in missing-energy events with an active beam dump experiment.

The run 2016:

- *All detectors performed quite efficiently at high intensity and showed positive results for being able to run at even higher flux.*
- *The July 2016 run set new limits on the γ - A' mixing and explanation of the $(g-2)_\mu$ anomaly with invisible A' is excluded.*
- *October 2016 data analysis in progress.*

The run 2017 :

- *Plan to collect up to few 10^{11} electrons on target for the invisible channel and cover significant area of the A' parameter space.*
- *Upgrades to the tracking system as well as to the synchrotron radiation detectors are foreseen.*
- *We also intend to switch to visible mode to collect few 10^{10} eot (> 1 week) to address the $Be8$ decay anomaly which could be explained by a 17 MeV boson.*

Physics Prospects

Process	New Physics	Sensitivity
1. $e^- Z \rightarrow e^- Z + E_{\text{miss}}$		
<ul style="list-style-type: none"> ◇ $A' \rightarrow e^+e^-$ ◇ $A' \rightarrow \text{invisible}$ ◇ alps ◇ milli-Q 	Dark Sector: Dark Photons and DM New light states (V,S) weakly coupled to e- ^8Be excess	$10^{-3} < \epsilon < 10^{-6}$ $M_{A'} \sim \text{sub-GeV}$ $m_Q < 10^{-5} - 10^{-7} \text{ e}$ $M_{mQ} \sim \text{sub-GeV}$
2. $\mu^- Z \rightarrow \mu^- Z + E_{\text{miss}}$		
<ul style="list-style-type: none"> ◇ $Z_\mu \rightarrow \nu\nu, \mu^+\mu^-$ ◇ a_μ ◇ $\mu \rightarrow \tau$ conversion 	$(g-2)_\mu$ anomaly, New Z_μ from $L_\mu - L_\tau$ gauged symm., scalars coupled to μ LFV	$\alpha_\mu < 10^{-11} - 10^{-9}$ $\sigma_{\mu\tau}/\sigma_\mu < 10^{-9} - 10^{-8}$
3. $\pi(K)p \rightarrow M^0 n + E_{\text{miss}}$		
<ul style="list-style-type: none"> ◇ $K_L \rightarrow \text{invisible}$ ◇ $K_S \rightarrow \text{invisible}$ ◇ $\pi^0, \eta, \eta' \rightarrow \text{invisible}$ 	CP, CPT symmetry Bell-Steinberger Unitarity, new WC particles: NHL, $\phi\phi$, VV	$\text{Br} < 10^{-8} - 10^{-6}$, Complementary to $K \rightarrow \pi\nu\nu$ $\text{Br} < 10^{-8} - 10^{-7}$
4. $pA \rightarrow Z' + E_{\text{miss}}$		
<ul style="list-style-type: none"> ◇ leptophobic Z' 	$\sim \text{GeV DM}$	$\sigma_{Z'} < 10^{-7} - 10^{-8} / \text{p}$

Thank You !!