P348:
Search for new physics in missing-energy events

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SHIP Collaboration Meeting
CERN, 08.10.2015.

The P348 Collaboration

Prepared for submission to SPSC

Proposal for an Experiment
to Search for Light Dark Matter at the SPS

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CERN-SPSC-2013-034 / SPSC-P-348
06/12/2013

December 6, 2013

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- Proposed in December 2013
- Approved for tests April 2014
- Currently

~ 30 members

UP, Patras(Greece)
DESY (Germany)
IHEP Protvino(Russia)
INR Moscow (Russia)
JINR Dubna (Russia)
LPI Moscow (Russia)
TPU Tomsk (Russia)
ETH Zurich (Suisse)
KAIST Daijeon (S.Korea)
UTFSM Valparaiso (Chile)

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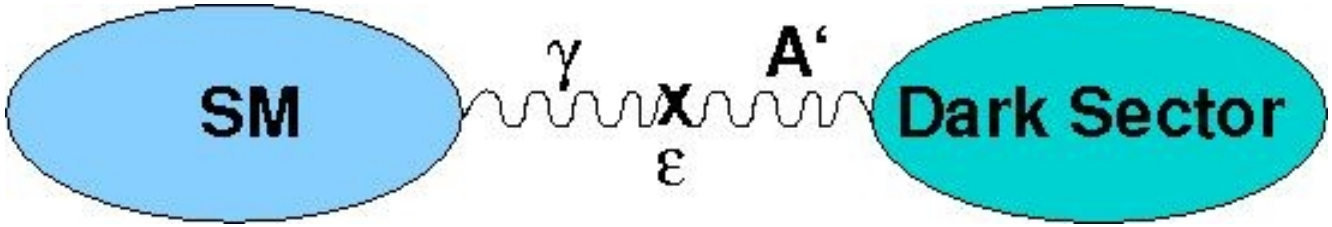
One of main goals: search for A`->inv

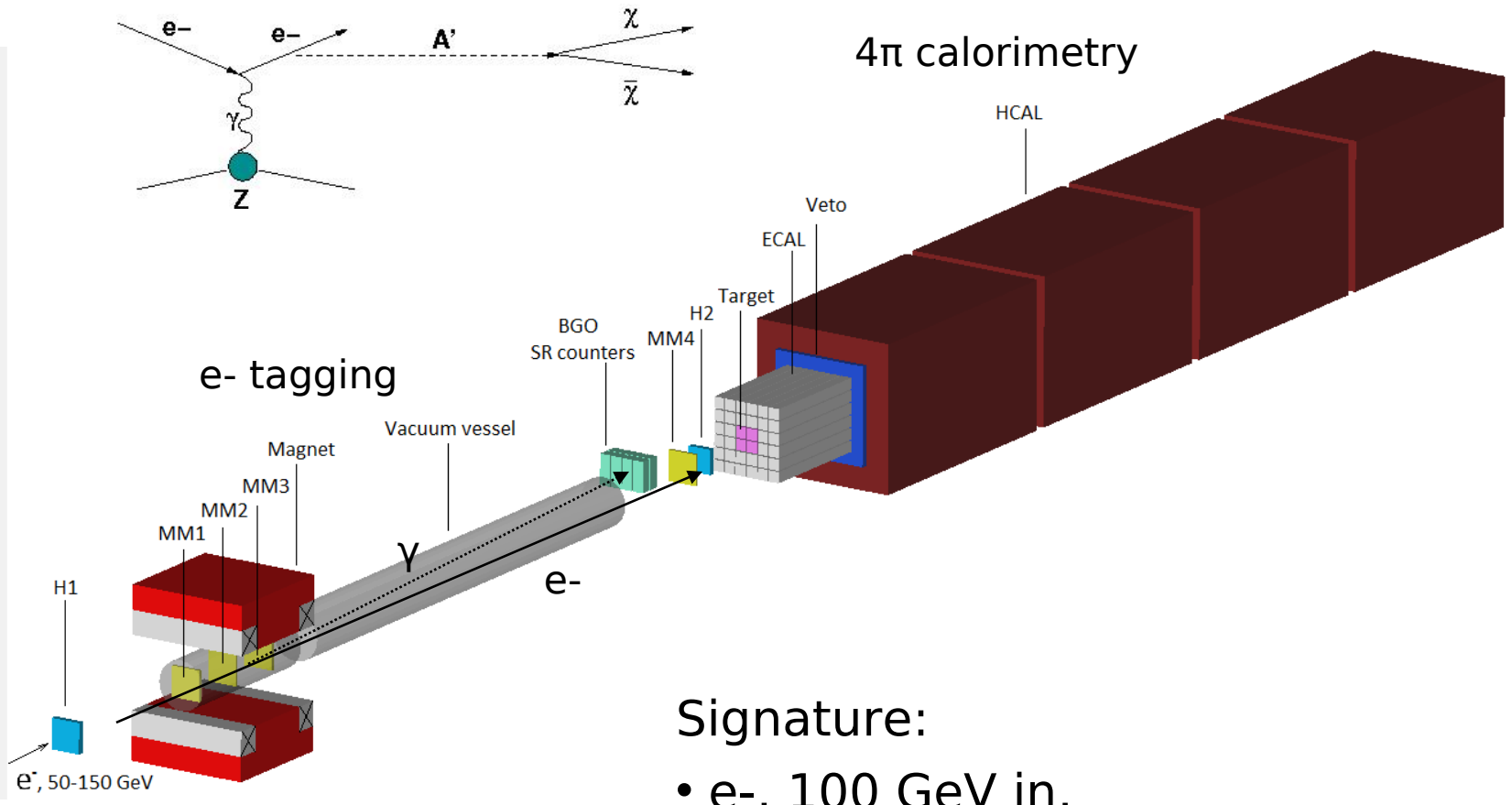
Okun, Holdom'86 ..



- extra (broken) U`(1), new massive boson A`(dark photon)
- $\Delta L = \varepsilon F^{\mu\nu} A`_{\mu\nu}$ - kinetic $\gamma$-A` mixing , ε - strength of coupling
- A` could be light: e.g. $M_{A`} \sim \varepsilon^{1/2} M_Z$
- new phenomena: γ-A` oscillations, LSW effect, A` decays, possible contributions to g-2
- A` decay modes: e+e-, μ+μ-, hadrons,.. or A`-> invisible if $M_{A`} > M_{DM}$ and $\alpha_{DM} >> \varepsilon$

Large literature, many new theoretical and experimental results

Direct Search for A`->invisible decay



S.G., PRD(2014)

Signature:

- e-, 100 GeV in,
- e-m shower in ECAL < ~ 50 GeV
- no activity in the Veto+ HCAL

A` production in a thick Pb target

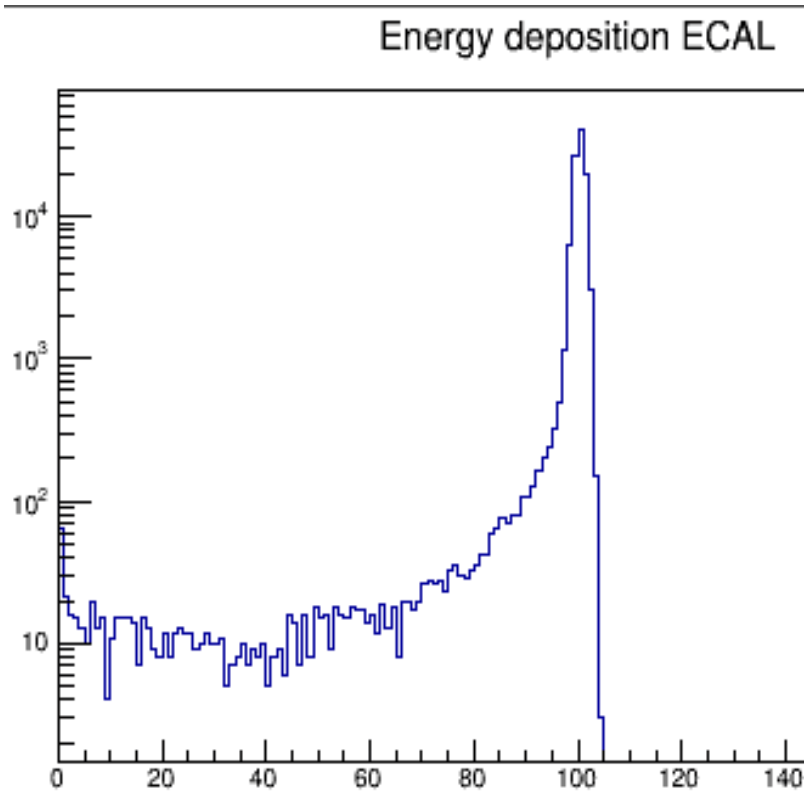
$\varepsilon \sim 10^{-1}$, $M_{A`} = 100$ MeV

Full simulations

- GEANT4 + A`emission in e-m shower (M.Kirsanov, D. Kirpichnikov)
- eZ->e Z A`cross section, Bjorken'09

$$10^{-4} < \varepsilon < 10^{-5}$$

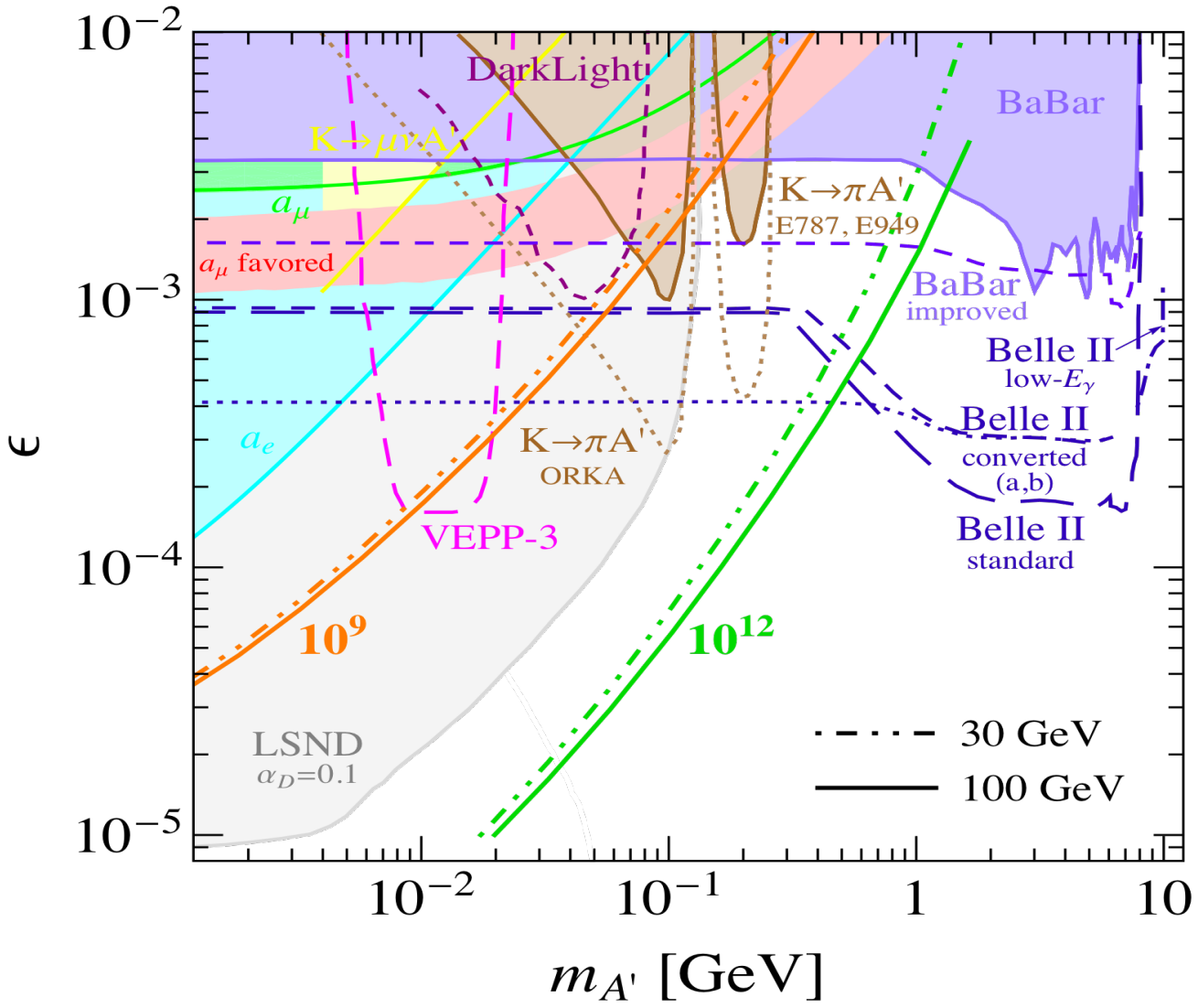
- very rare events: $\sigma_{A`}/\sigma_{\gamma} < 10^{-12}$-$10^{-9}$



Summary of background sources for A`-> invisible

Source	Expected level	Comment
Beam contamination		
-π, *p*, μ reactions and punchthroughs,…	$< 10^{-13}$-10^{-12}	Impurity < 1%
- e- low energy tail due to bremss., π,μdecays in flight,..	$< 10^{-12}$	SR photon tag
Detector		
ECAL+HCAL energy resolution, hermeticity: holes, dead materials, cracks…	$< 10^{-13}$	Full upstream coverage
Physical		
-hadron electroproduction, e.g. eA->neA*, n punchthrough;	$< 10^{-13}$	~10 mb x nonherm.
- WI process: e Z->e Zνν	$< 10^{-13}$	WI σ estimated. textbook process, first observation?

Expected limits vs N_{e^-}

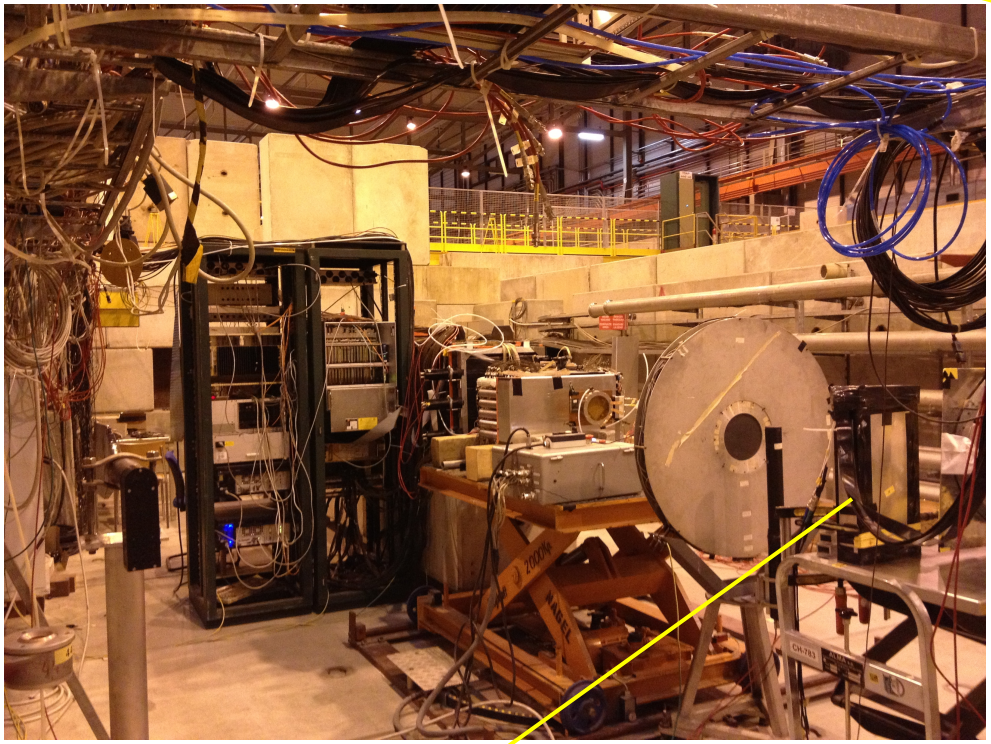


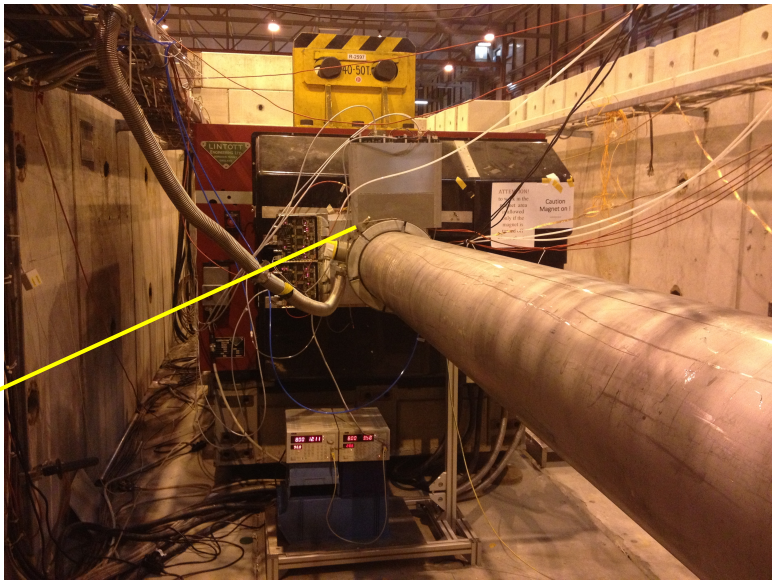
The P348 detector

The P348 detector

BGO, Micromegas, straw, hodoscopes

Micromegas

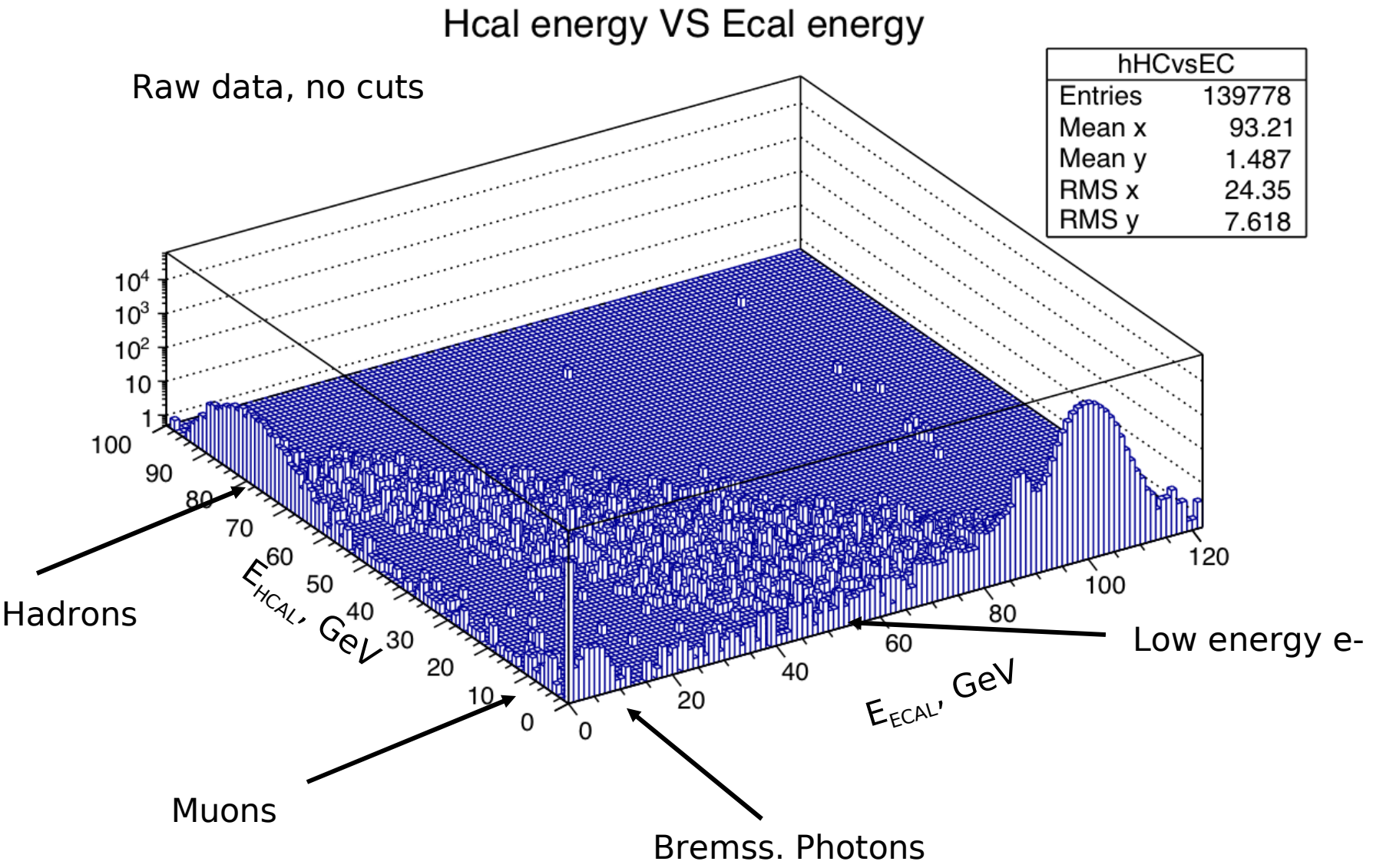




BGO SR array

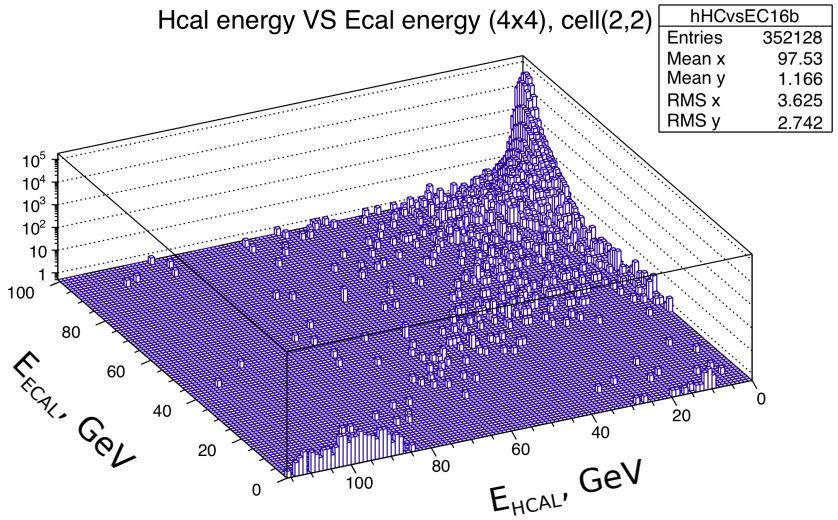
Strow tubes

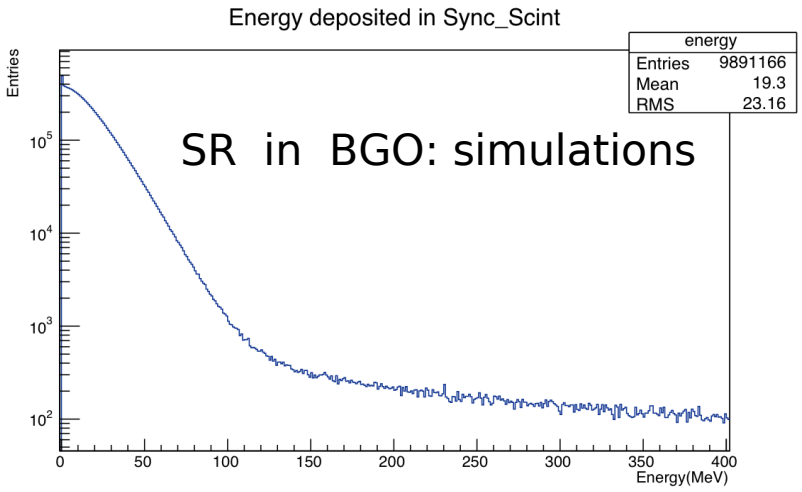
First look and first problems.



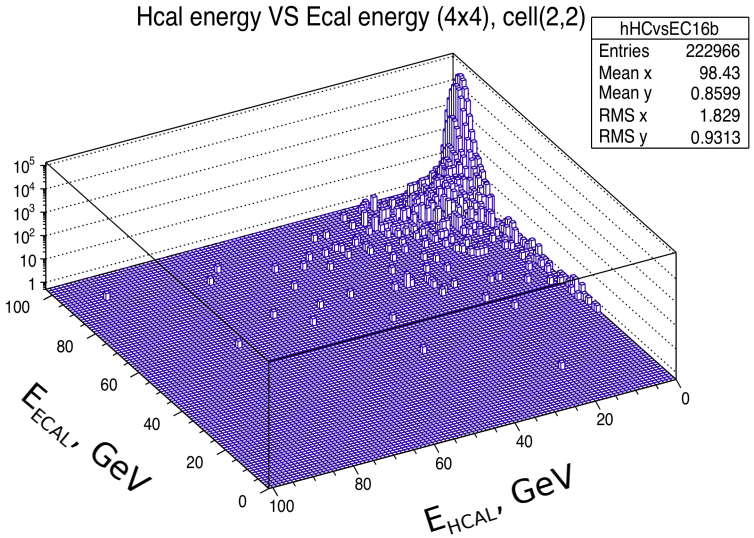
SR tagging of 100 GeV e-

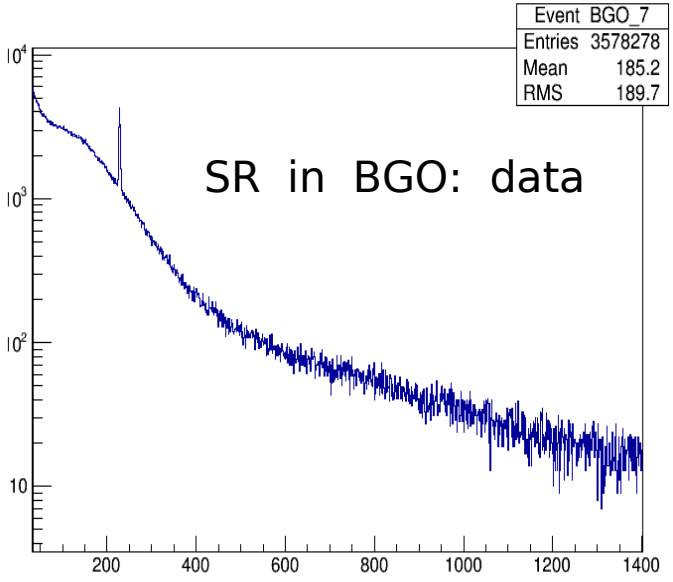
No synchrotron tagging





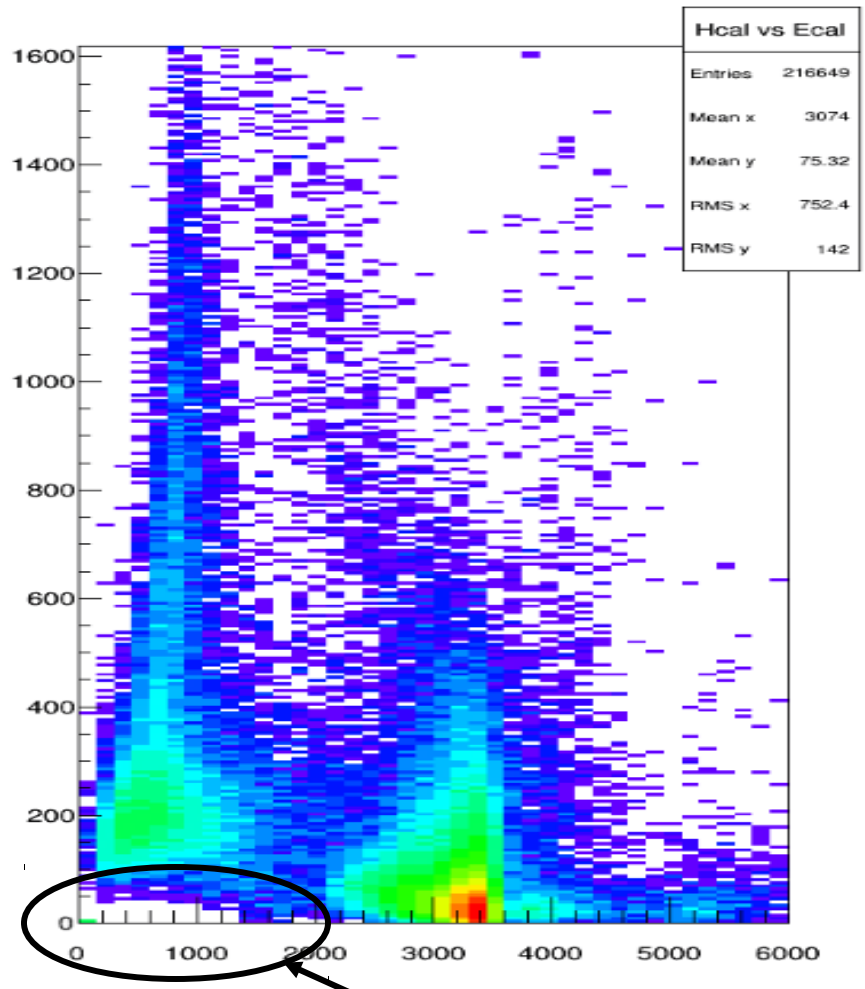
With synchrotron tagging



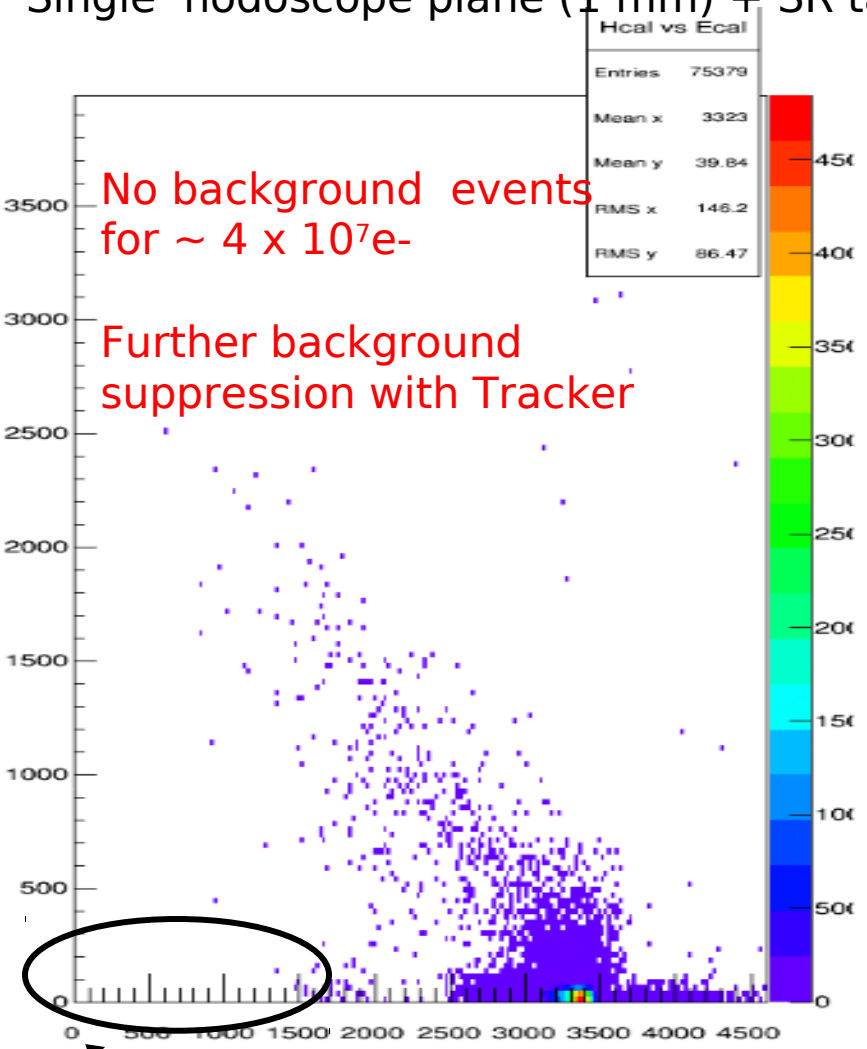


A`Signal in the HCAL vs ECAL plane

No selections



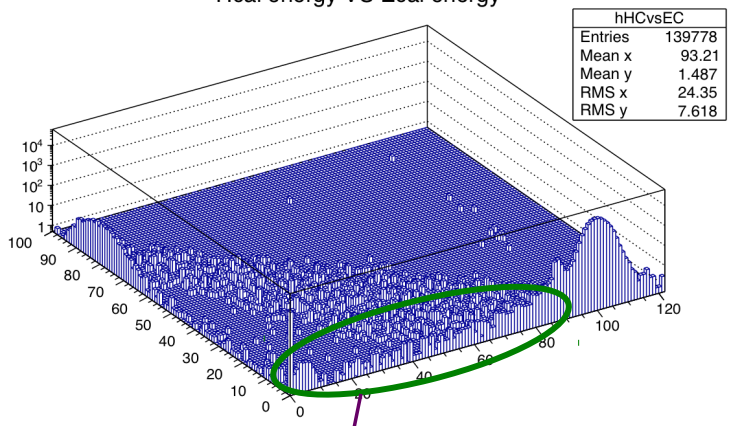
Single hodoscope plane (1 mm) + SR tag



SIGNAL REGION

MM performance and background rejection

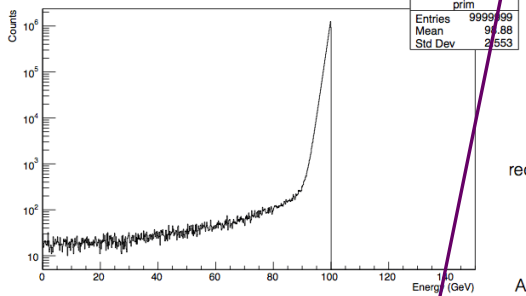
Hcal energy VS Ecal energy



No background events are expected with MM tracker for > 10^{11} e-

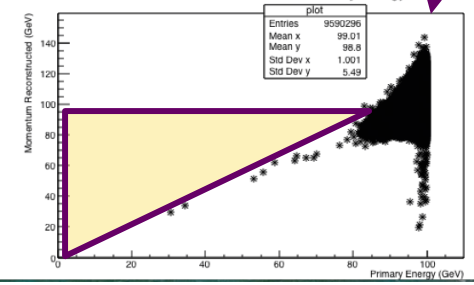
MM Tracker Simulation Summary

Primary Energy



A spread of energy as shown in the plot was given to the primaries and the reconstructed momentum (when there is a hit in the ECAL) compared with the actual primary energy.

Reconstructed Momentum vs Primary Energy

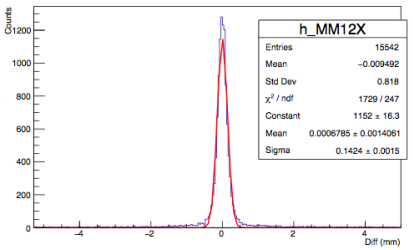


As seen in the second plot the reconstructed momentum compares well with the actual primary energy of the particles hitting the ECAL. Most low energy primaries miss the ECAL due to the field.

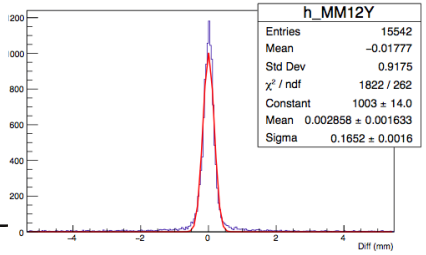
Level of rejection of events when energy deposited in ECAL< 50 GeV and momentum reconstructed with tracker > 50 GeV .... **< 10^{-10}** for 100 GeV primaries.

MM Tracker Summary from beam run

Difference between X pos on MM1 and MM2

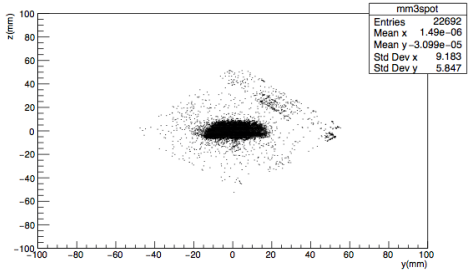


Difference between Y pos on MM1 and MM2



Resolution of Micromegas confirmed comparing hit points on two modules.

$\sigma_{MM} \sim \sigma_{plot}/\sqrt{2} \sim 100\ \mu$

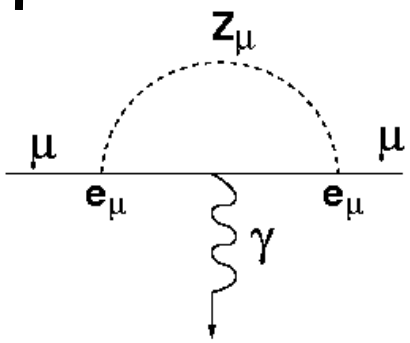


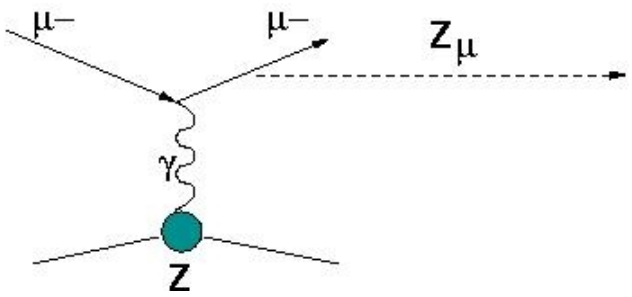
Beam Spot on MM for 100 GeV electrons without field.

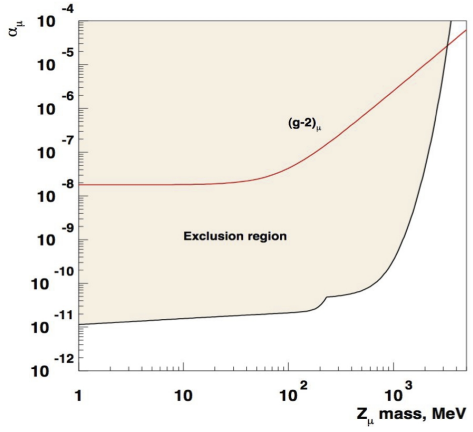
Physics prospects for P348

Reaction	Physics	Sensitivity
1. *eZ ->eZ +..*		
◇ *A`-> e+e-* ◇ *A`-> invisible* ◇ *alps* ◇ *mQ*	Dark photons, Hidden sectors, $(g-2)_\mu$ new particles, milliQ, charge quantization	$10^{-4}<\varepsilon<10^{-5}$ $M_{A`}$ ~ sub-GeV  $e`/e < 10^{-5}$-10^{-7}
2. μZ->μZ+…		
◇ $\mathbf{Z}_\mu$-> νν, μ+μ- ◇ μ->τ	$(g-2)_\mu$, gauged L_μ-L_τ, L-phobic boson Z_μ, LFV	$\alpha_\mu < 10^{-11}$-10^{-9} $< 10^{-9}$-10^{-8}/μ
3. *π(K)p-> M⁰n*		
◇ K_L-> *invisible* ◇ K_S-> *invisible* ◇ $\pi^0, \eta, \eta`$-> *invisible*	Bell-Steinberger Unitarity, CP, CPT , NHL, 2HDM,	~ 10^{-5} Br < 10^{-8} $< 10^{-8}$-10^{-7}
4. ***p****A*		
◇ *leptophobic X +h*	~ GeV DM	$<10^{-7}$-10^{-8} /p

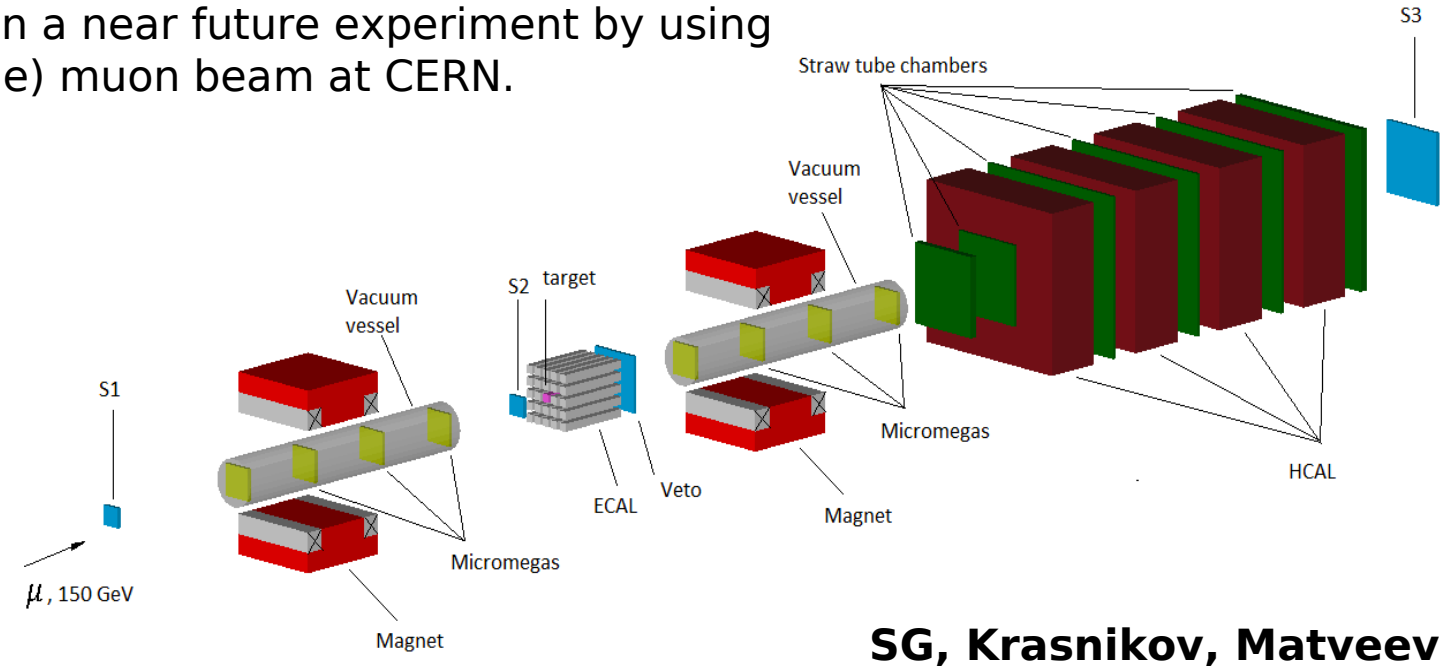
$(g-2)_\mu$ and new leptophobic Z` from L_μ-L_τ







strong motivation for a sensitive search for Z`in a near future experiment by using (unique) muon beam at CERN.



SG, Krasnikov, Matveev PRD(2015)

K_L -> invisible: nothing in, nothing out

Rare kaon decays with "missing energy"

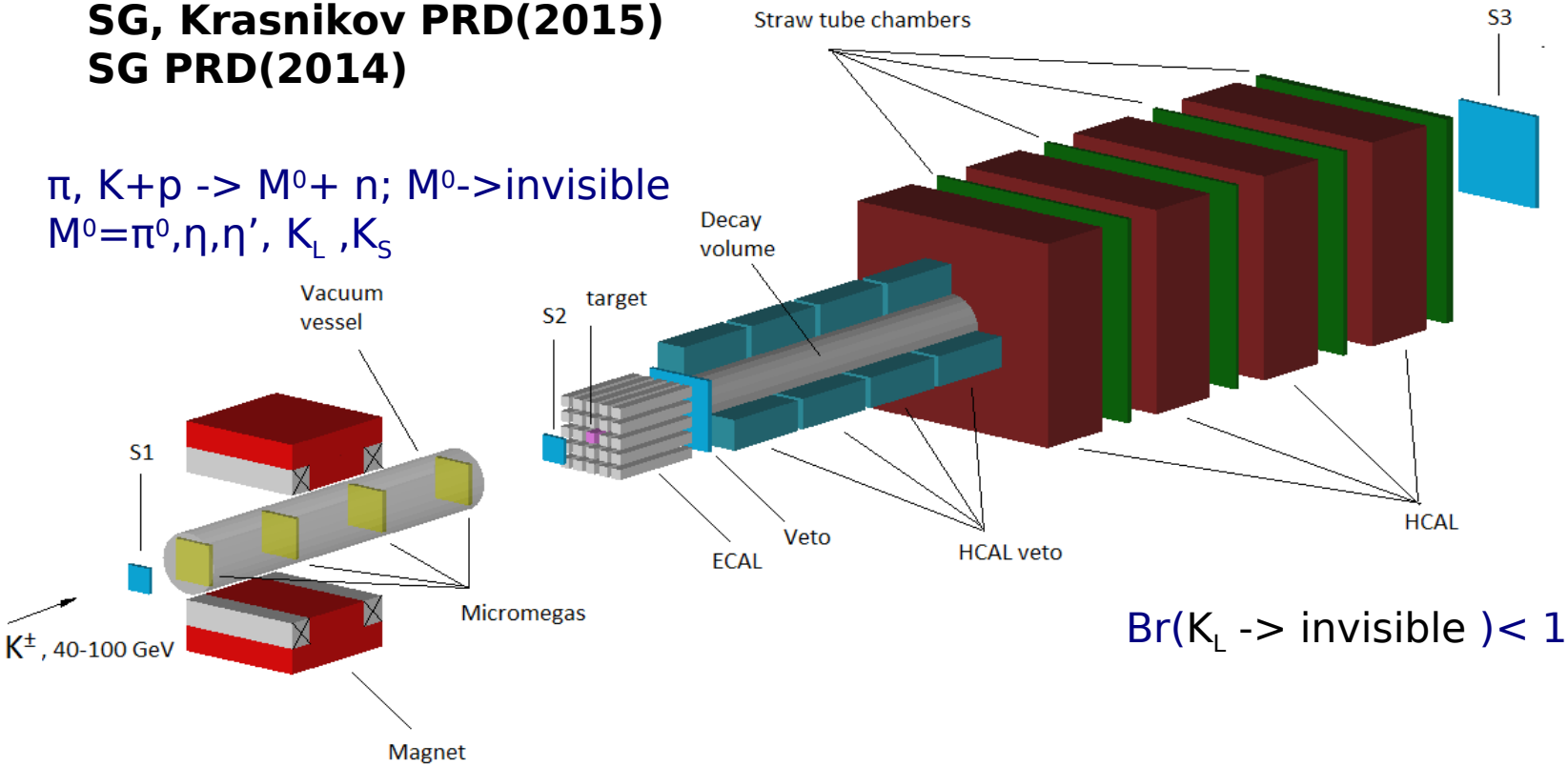
PRD(R)'96.

William J. Marciano and Zohreh Parsa (K_L->νν, ννγ)

and $K_L \to \nu\bar{\nu}$ (if neutrinos have mass). Those decays would be interesting to explore, but their detection looks essentially impossible. New ingenious experimental ideas are required.

SG, Krasnikov PRD(2015)
SG PRD(2014)

π, K+p -> M^0+ n; M^0->invisible
M^0=π^0,η,η', K_L ,K_S



Br(K_L -> invisible)< 10^{-8}

Summary

Searching for missing-energy events in an active beam dump is a sensitive probe of new physics developed by P348.

The simulations and recent test beam results show that after a small modification the detector is ready for data taking.

The experiment is complementary to NA62, KLOE, and planned SHIP.

These 2 weeks of beam tests would be impossible without support from CERN Vice-DG S. Bertolucci,

and people including H. Wilkens, A. Fabich, H. Fischer, I. Konorov, V. Frolov, D.-L. Lazic, M. Jeckel, J. Novy who helped us in many ways, the CERN LCD group and the SPS crew.

THANK YOU !