Proposal of a flexible detector test setup using low energy electrons from PHIL at LAL and performance tests of Micromegas/InGrid *et al.*

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Outline

Goals and applications

Setup idea & feasibility studies

Work packages

Possible further upgrades

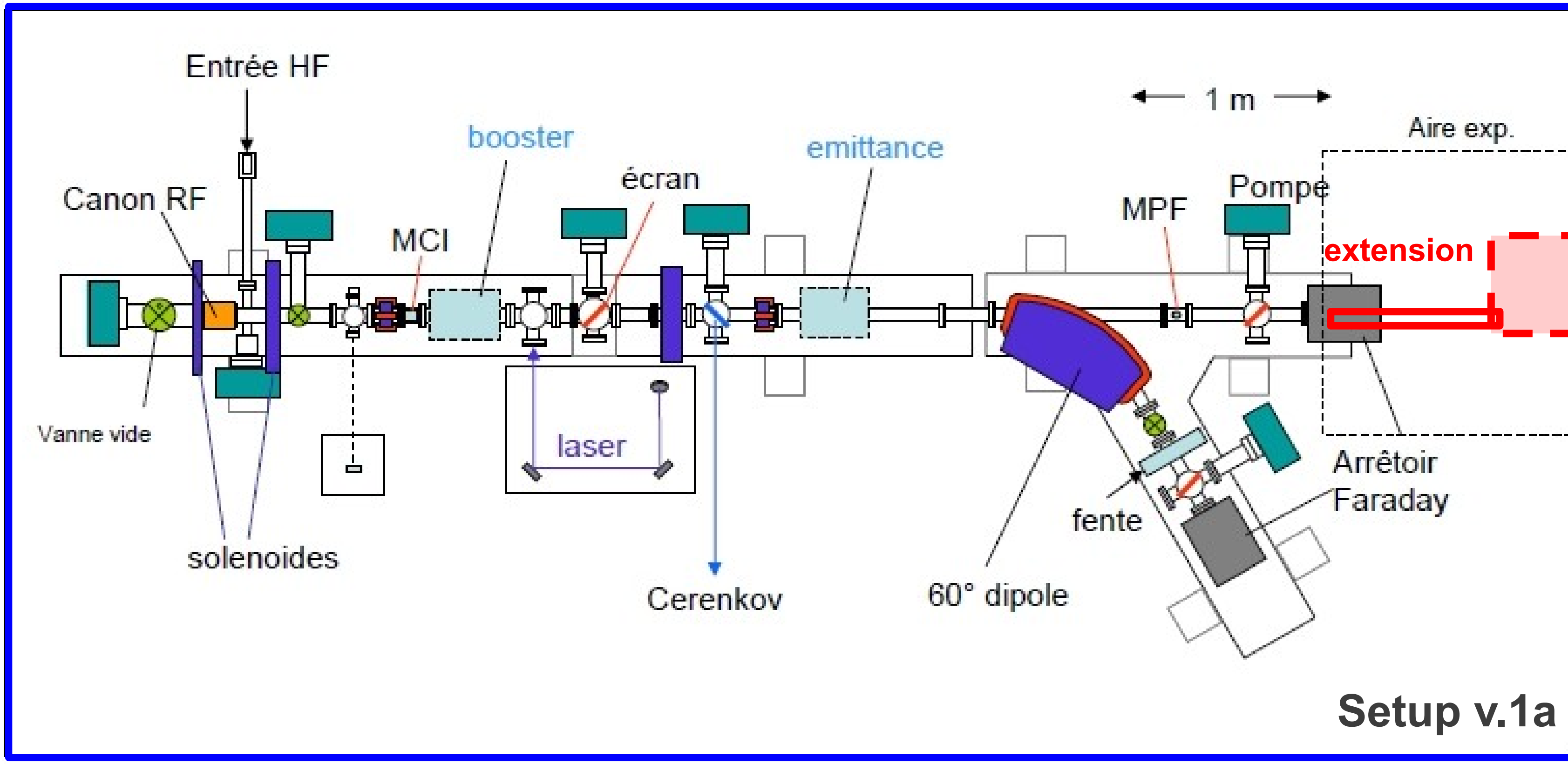
Summary

Goals and applications

Goals and applications

Use electrons provided by PHIL with momentum (3-5 now MeV/c) 5-8 MeV/c and (10^8 now) 10^{10} particles per bunch.
Timing: laser pulse with 7 ps FWHM

PHIL



Goal: obtain samples of “monochromatic” electrons

- → with adjustable energy between 1 MeV and (and less) 5 MeV
- → energy spread of better than 10 %
- → with adjustable intensity down to 10^4 and less electrons per sample

Goals and applications

Test bench:

→ Gaseous detectors tests, e.g. routine **Micromegas/InGrid** performance tests to optimize the protection layer.

Generic R & D

Applications: ILC TPC with Micromegas/InGrid option, CLIC TPC, CAST

→ Studies of the crystal properties and prototype for **UA9/LUA9** project

→ **FTOF**: time-of-flight particle identification detector based on DIRC technique

→ Measurements of **scintillators for SuperNEMO**

→ Tests of **diamond sensors** (profile monitor, tracking, …)

Physics measurements:

→ E.g. non-relativistic electron energy losses with Micromegas/TIMEPIX

Students hands-on:

→ All above + cluster studies, track reconstruction, gaseous detector edge effects

Driving application: Micromegas/InGrid tests

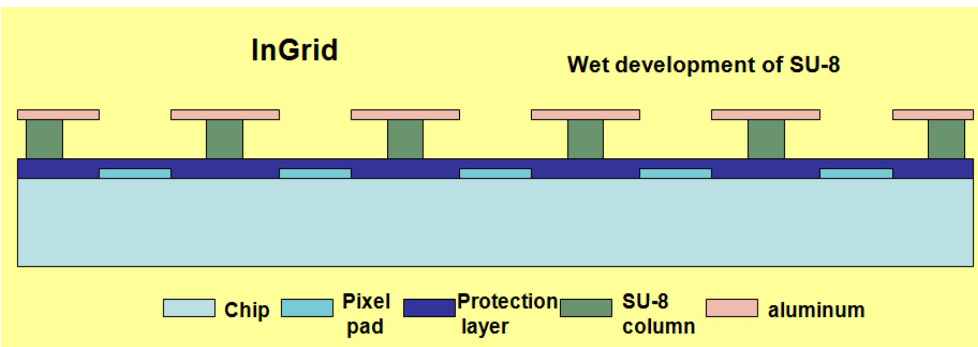
<u>Micromegas/InGrid:</u>

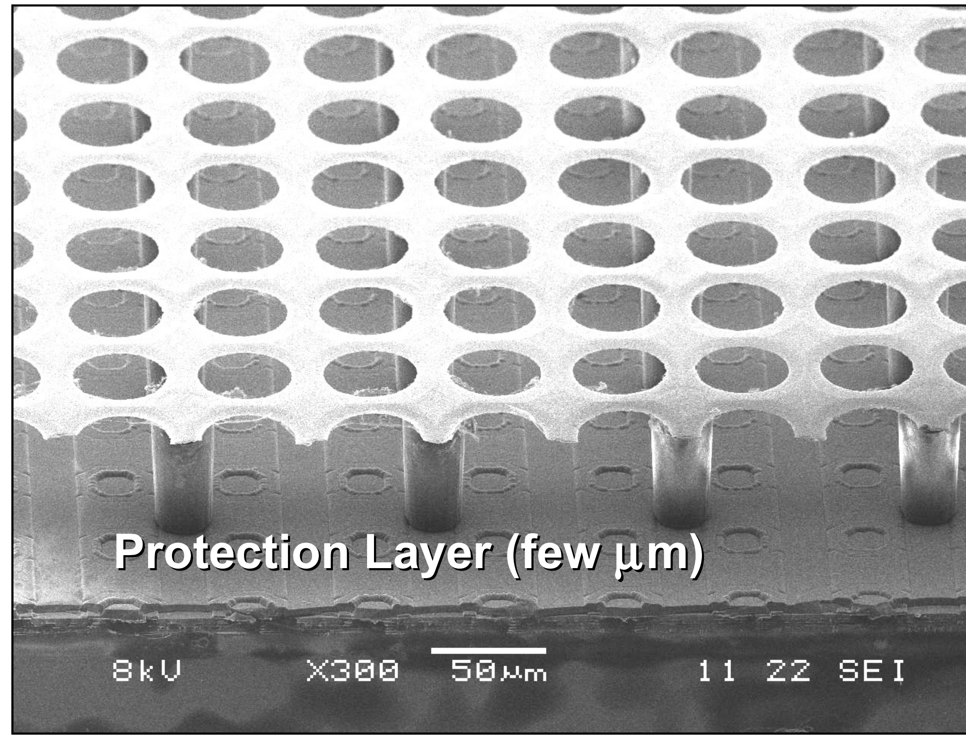
IRFU / NIKHEF / Bonn U development

3D Gaseous Pixel Detector → 2D (CMOS pixel chip readout) x 1D (drift time)

<u>InGrid Concept:</u>

Through POST-PROCESSING INTEGRATE MICROMEGAS directly on top of CMOS chip (covered with protection layer)





M. Chefdeville et al., NIMA556 (2006) 490.

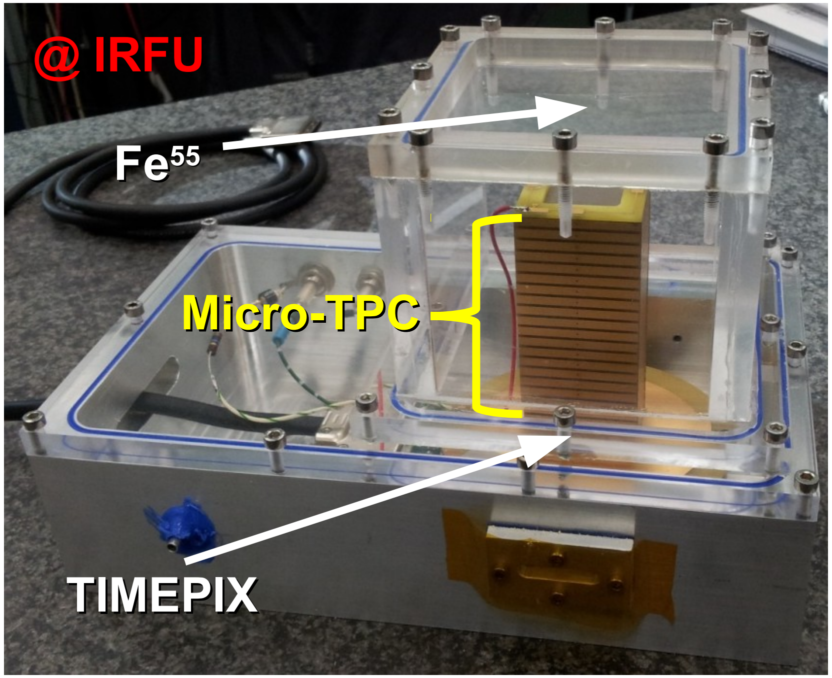
Bump bond pads for Si-pixel Detectors - Timepix or Medipix2 (256 x 256 pixels of size 55 x 55 µm^2) serve as charge collection pads.

Each pixel can be set to:

TOT → Integrated charge

TIME → Time between hit and shutter end

Micro-TPC by Micromegas/InGrid test at PHIL

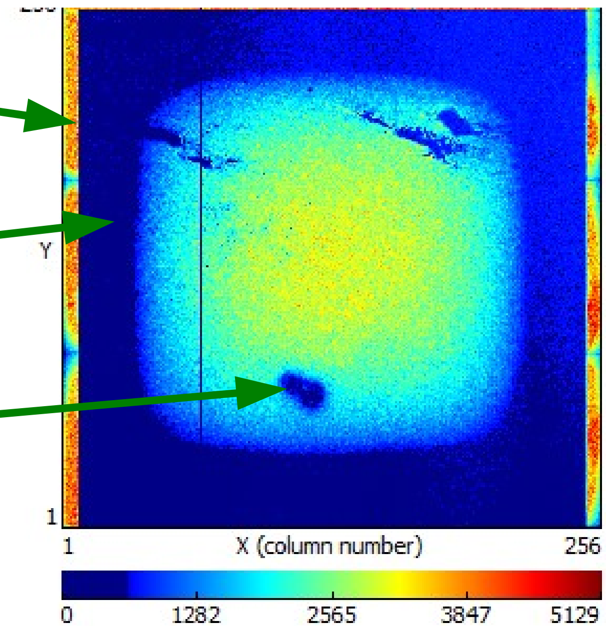


New IZM-3 InGrid: post-processing at the wafer level

Some noise and/or discharges

Guard ring problem in micro-TPC

Some local grid issues



Drift distance in micro-TPC (~10 cm) large enough to allow study of single electron response from Fe^{55} source

Three-leg project:

Tests @ PHIL → LAL
Detector expertise → IRFU
Simulation expertise → LAL + Kiev U
(+ R.Veenhof, CERN)

Tests at PHIL:

- Concept/production adjustment issues: protection layer, lateral uniformity, ...
- Further performance studies: rate dependence, efficiencies, border effects, ...
- Eventual applications: TPCs for ILC, CLIC, CAST
- Physics, R&D, students' hands on: dE/dx for low energy electrons, electron counting, scans, ...

Application for SuperNEMO: a tool to test the calorimeter?

(slide from Laurent Simard)

- Calorimeter (plastic scintillators coupled to PMTs)
- Actually tested at CENBG Bordeaux with a spectrometer : [0.4-1.8] MeV FWHM < 1.8% at 1 MeV
- Constraint : counting rate < ~ 100 Hz (limited by acquisition)

- Possibilities offered by the new tool : extend the energy range [0.1-4] MeV?
- Obtaining a correct beam energy resolution and a reduced counting rate could a priori be possible by adjusting the width of the selection window
- Important to study: background induced by the Bremsstrahlung photons (from the beam interaction)

- Use of a small plastic scintillator inside the spectrometer to tag the electron?
- Optimized geometry/shielding?
- Reduced background if half-turn(s) added, see “upgrade” discussion below

- ~4 MeV seems to be more easy
- ~0.1 MeV more difficult (thickness of the window before the detector, more background ...)

ATF2 Beam halo and Compton electron Diamond sensor project
(slide from Philip Bambade)

Diamond sensors → compact, fast, radiation hard, profile measurements
Providers (presently) : **Element Six Ltd** **CEA-LIST**
Post-processing and packaging : **GSI-Darmstadt** **CEA-LIST** **Systrel-Serma**
Support: **IN2P3 & P2IO**, LAL **electronics**, **mechanics** & **ATLAS-SLHC** groups
Personnel: 1 DR, 1 PhD student, 1 master student, 4 engineers, pending application for a post-doc
Planning: design , initial tests (2012), version 1 full detector production &test (mid-2013), install@KEK (Fall 2013)
Collaborators: DESY-Zeuthen, KEK, KNU (Korea), IHEP (China), Uni. Kiev (Ukraine), INFN (Roma-2 & Napoli)

Location for beam halo measurements in ATF2

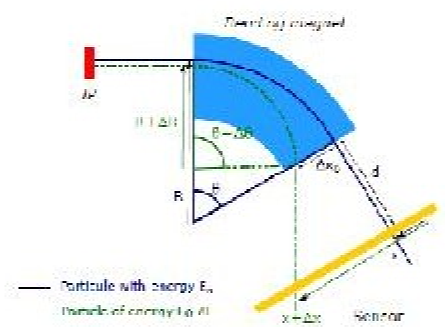
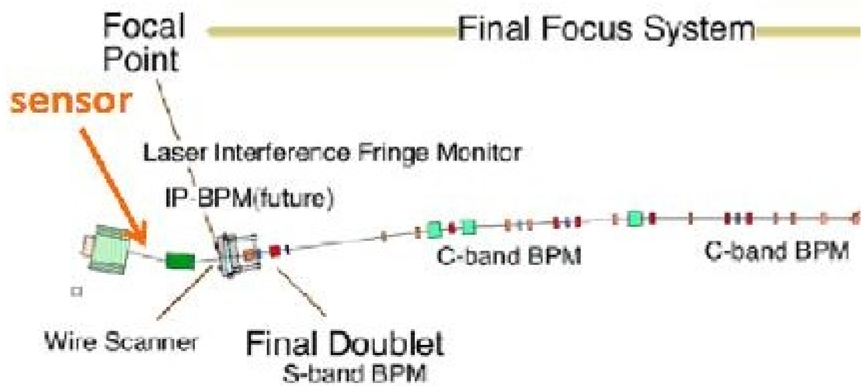
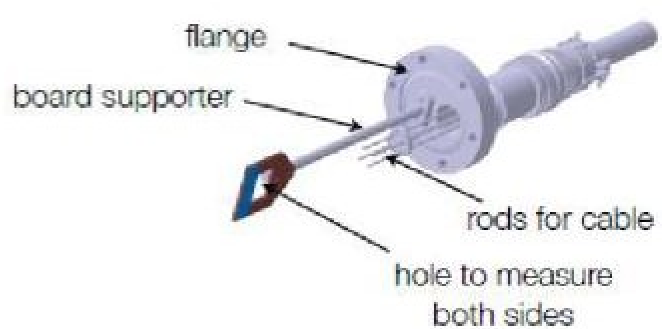
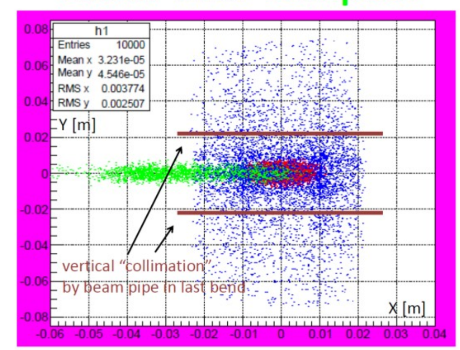


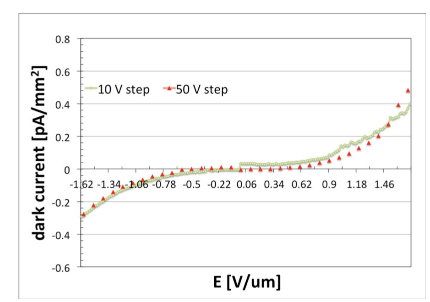
Figure: Positioning of the sensor





Beam halo Compton



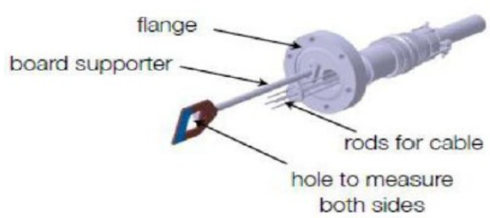


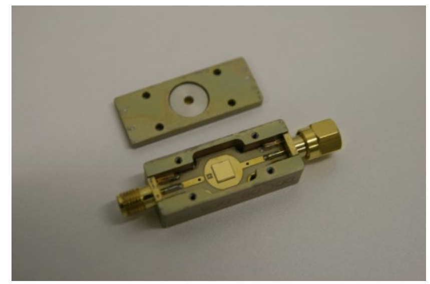
Diamond sensors at PHIL (testing, diagnostics, …)

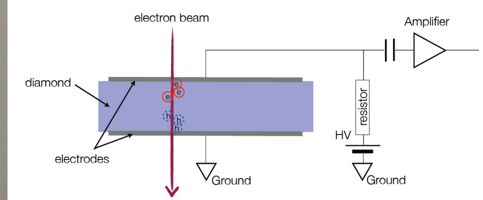
(slide from Philip Bambade)

Test of fast remote readout (fast heliax coax cable + ASIC) with particles at end of beam line, using existing single crystal 4.5x4.5mm CVD diamond pad sensor.

Fixed (moveable) beam profile and halo monitor as diagnostic for PHIL: large area poly crystalline CVD sensor

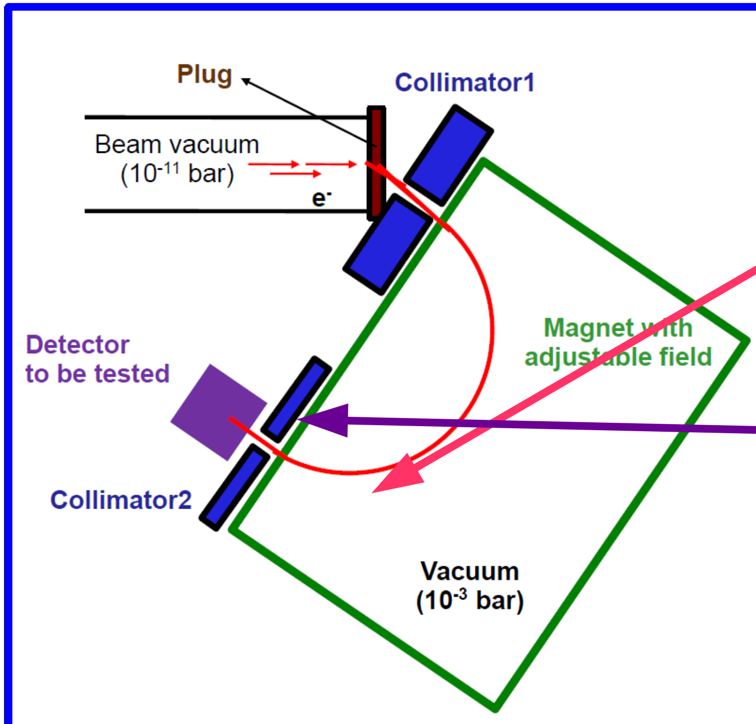






Can be done at once with the present setup !

Test of ATF2 in-vacuum 2x2mm single crystal CVD diamond sensor profile scanner



Low multiplicity rate monitor upstream of second collimator

Resolution test of diamond strip sensor using reconstructed tracks

GEOMETRIES

Diamond detectors:

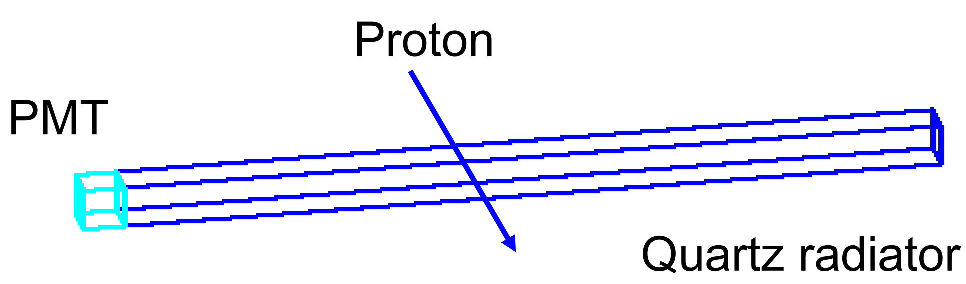
- Pads : mm^2 x 500 mm
- Strips & pixels
- Membranes (→ 5 mm)

Diamond target:

- Pattern of carbon nanotube 0.1 mm strip grown on thin layer

Test bench for UA9: LHC proton halo probe, using Cherenkov light produced in quartz bar

Basic principle



A 10 x 0.5 x 0.5 cm^3 quartz finger/rod connected to the PMT or light guide fibers

Cherenkov light travels inside quartz finger via total internal reflection

Number of detected photons proportional to number of protons crossing the quartz

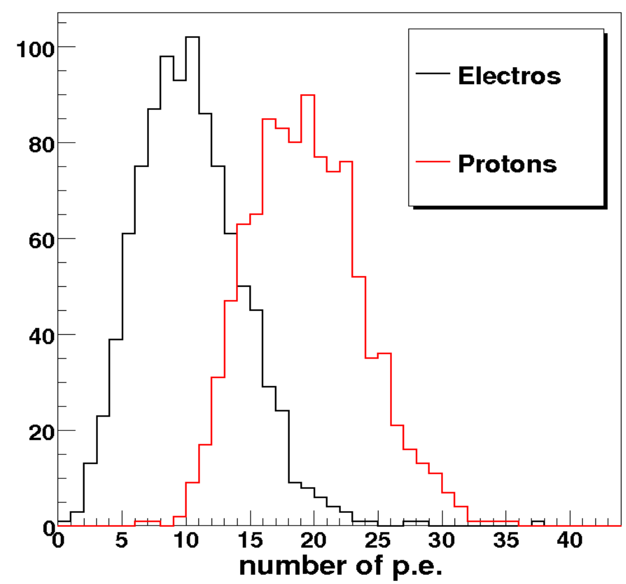
Vacuum compatible system

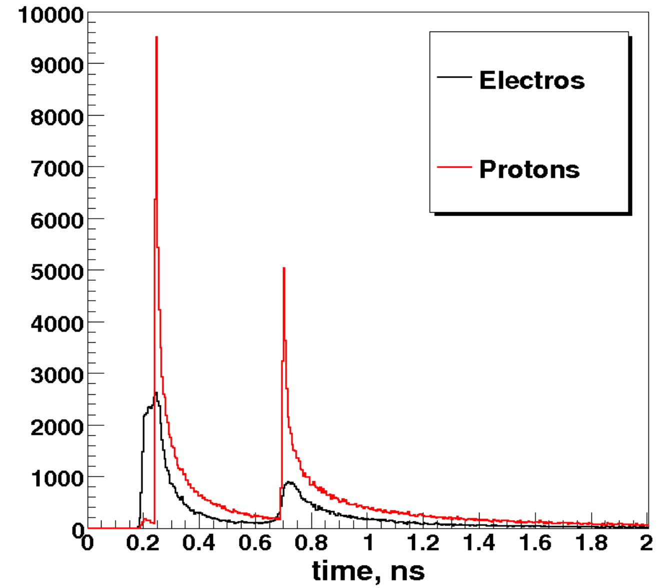
Fast detector, distinguishes LHC bunches

Measure 100 protons with 10% precision

100 GeV/c protons vs. 5 MeV/c electrons (Geant4 simulation)

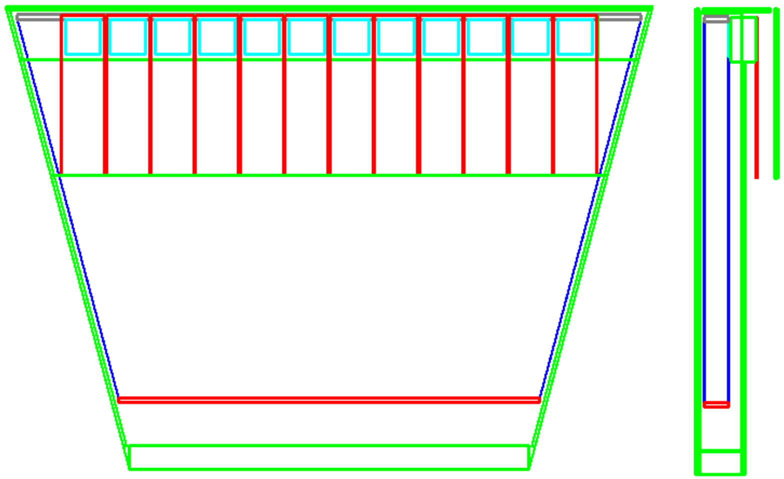
- ~Twice less light for 5 MeV/c electrons
- Slightly degraded timing, but still recuperate 99.9% of light within 5 ns
- Measurements with known number (200 to 1000) and energy of electrons
- Eventual tests with the PHIL halo
- Quartz fibers are potentially useful to measure the length of the PHIL bunches





Test bench for FTOF: DIRC-like time-of-flight detector for particle ID

DIRC: Detection of internally reflected Cherenkov light

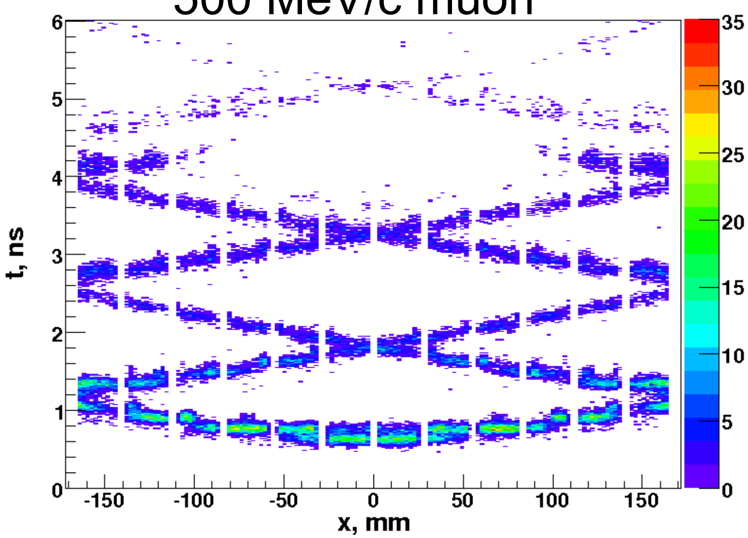


Geant4 simulation of the FTOF detector

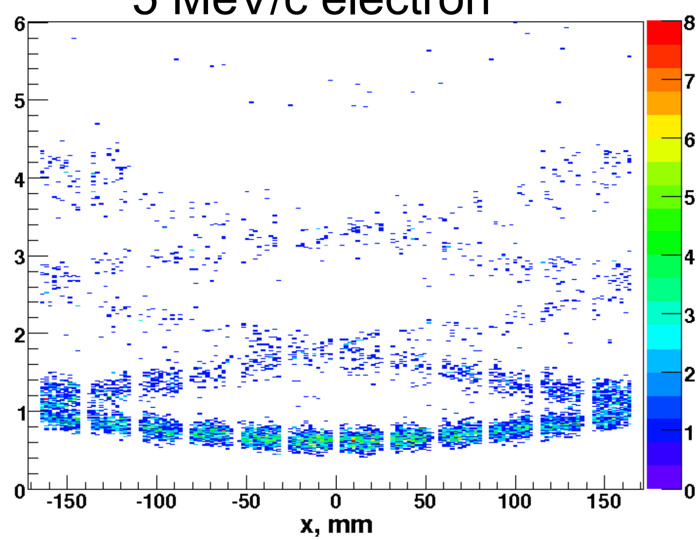
- Detector made of quartz sectors
- The quartz used as radiator of Cherenkov photons and as a light guide (DIRC technique)
- Each sector is readout by MCP or SiPMs.
- Use USB – Wavecatcher electronics
- **Applications**: particle identification
  online luminosity monitor
  background monitor

Time versus channel histograms

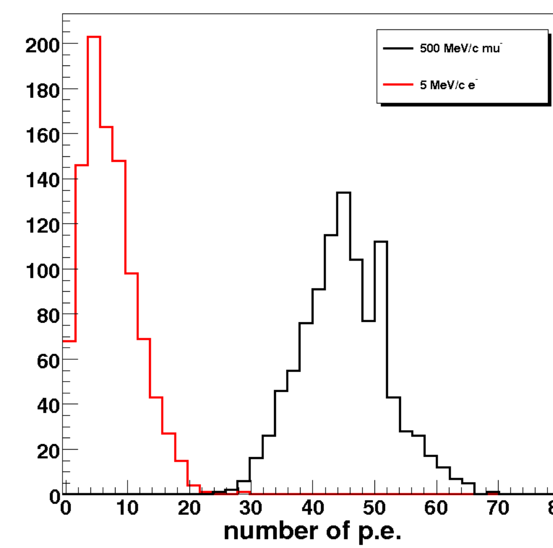
500 MeV/c muon



5 MeV/c electron



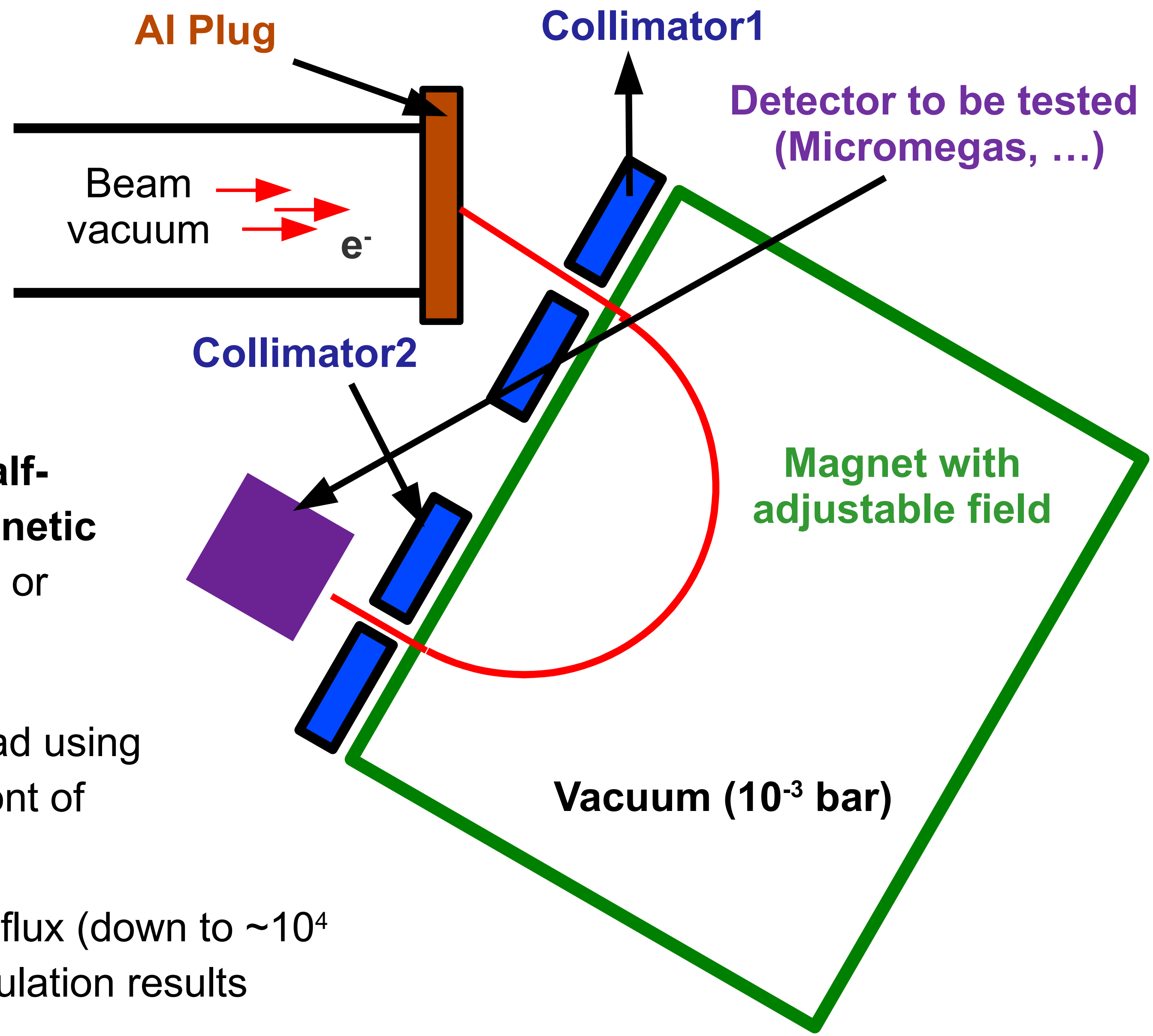
Number of photoelectrons



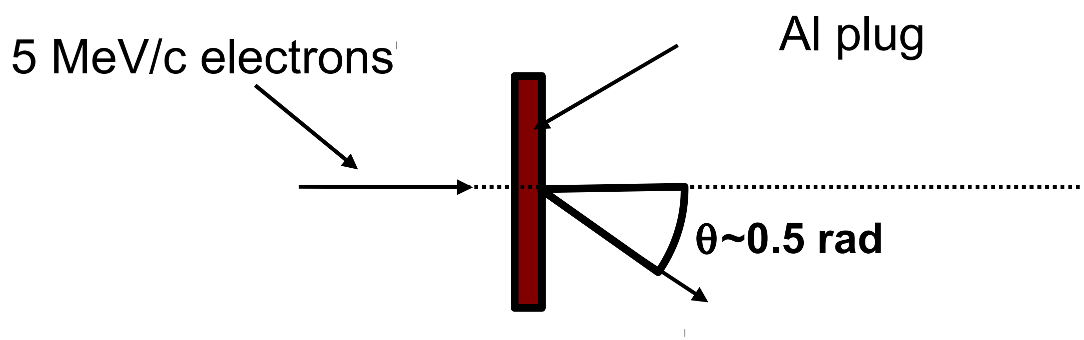
Setup idea & feasibility studies

Spectrometer to sample "monochromatic" low energy electrons

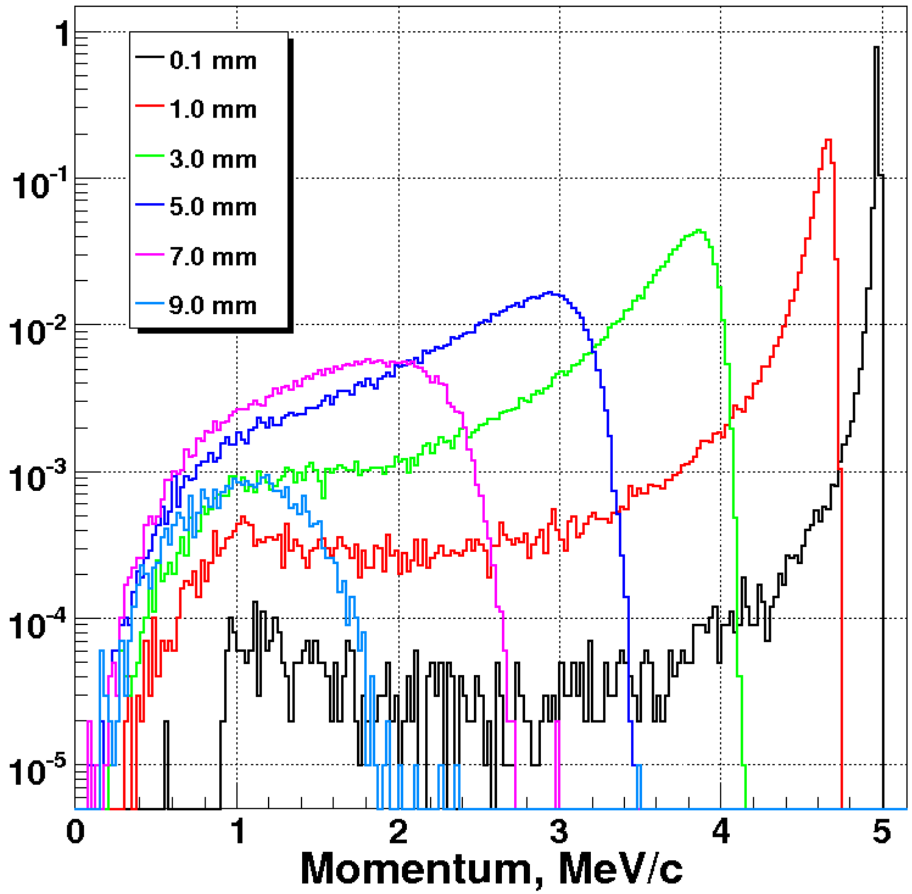
- Use electrons from PHIL
- Reduce energy/intensity using Al plug
- Select unique direction for electrons passing the plug with collimator 1
- Select required energy by **half-turn of electron in the magnetic field** (position of collimator 2 or field value)
- Adjust intensity/energy spread using collimator 2, positioned in front of tested detector
- **Multiplicity** at high electron flux (down to ~10^4 electrons ~1 fC): project simulation results
- **Electron counting** at low fluxes: Micromegas to calibrate detector settings (magnetic field and collimator positions) or count electrons on individual bunch basis

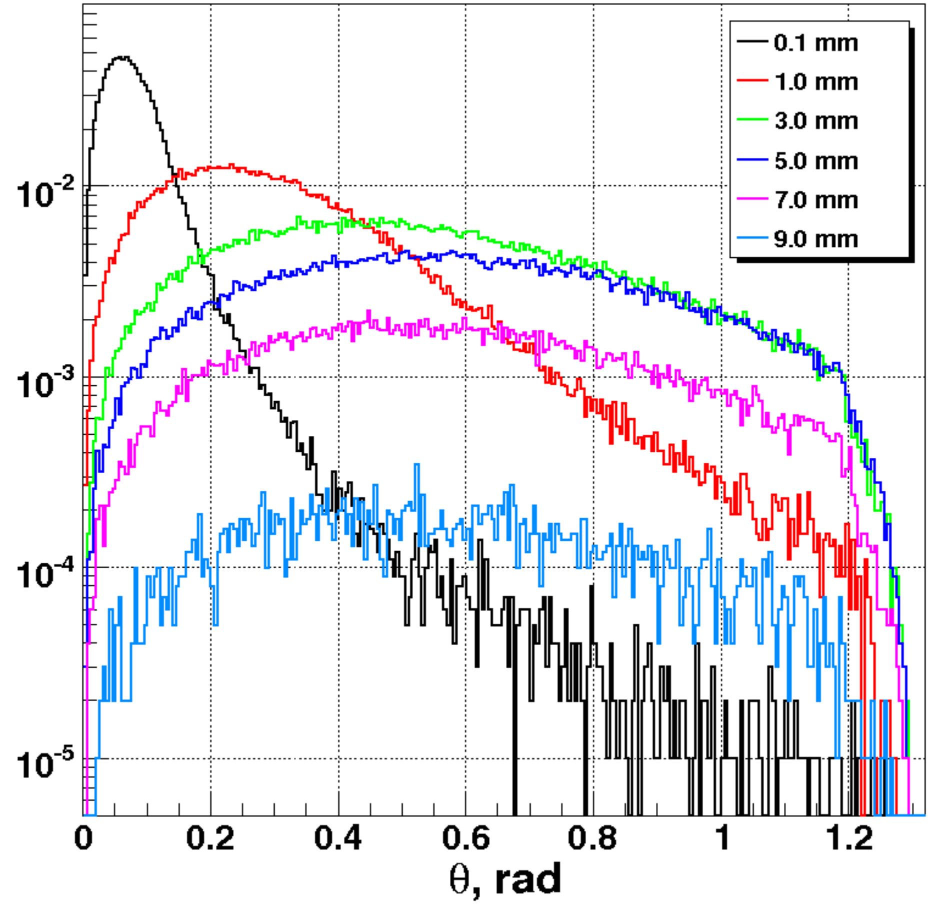


Momentum and angular spectra of electrons passing through the Al plug



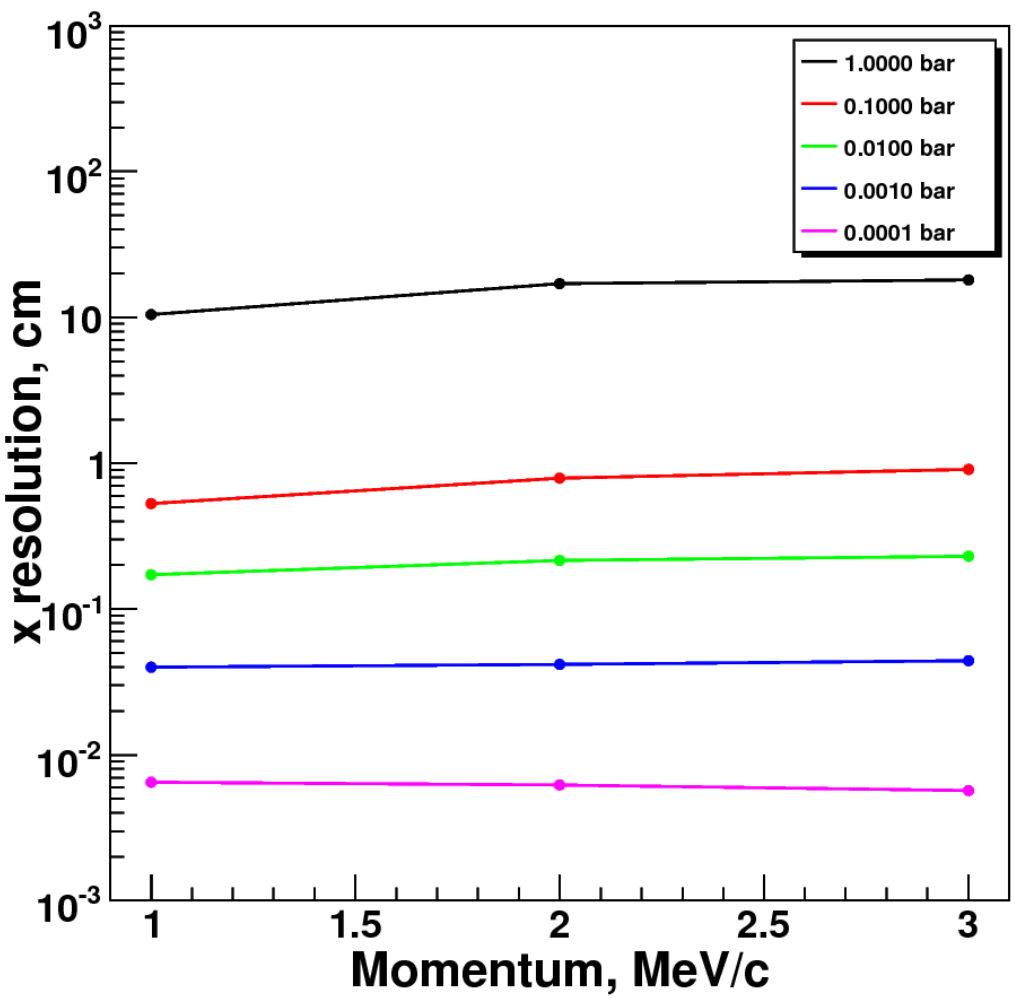
Dependence on the plug thickness (per event probability): Geant4 simulation

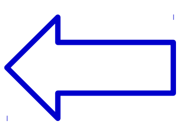




Vacuum quality in the magnet

- Requirements to the vacuum quality in the volume, between the exit window and the detector
- Criteria: effect from multiple scattering to be smaller than that from the initial spread in the direction of electrons

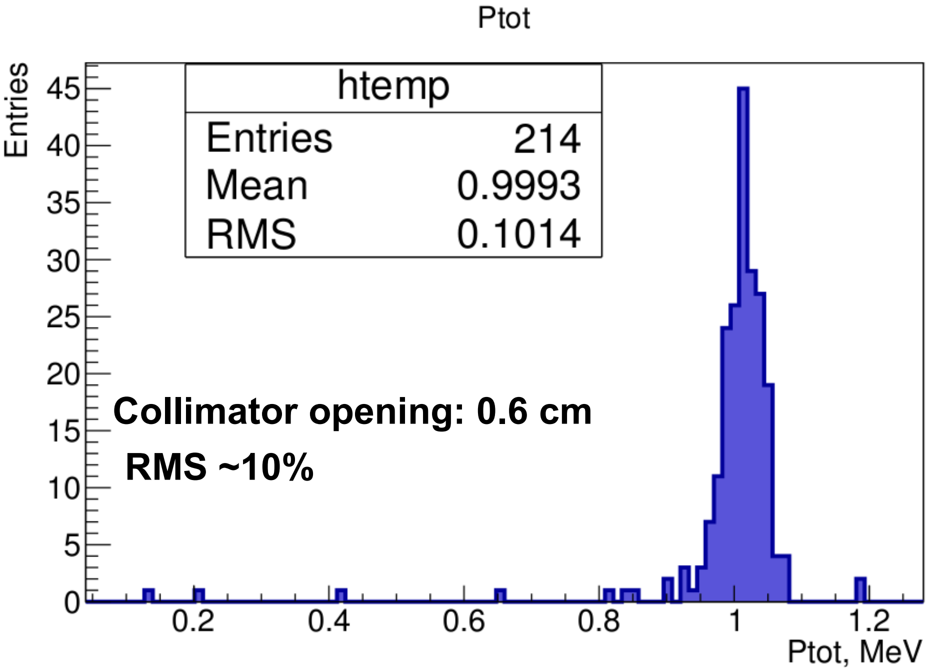


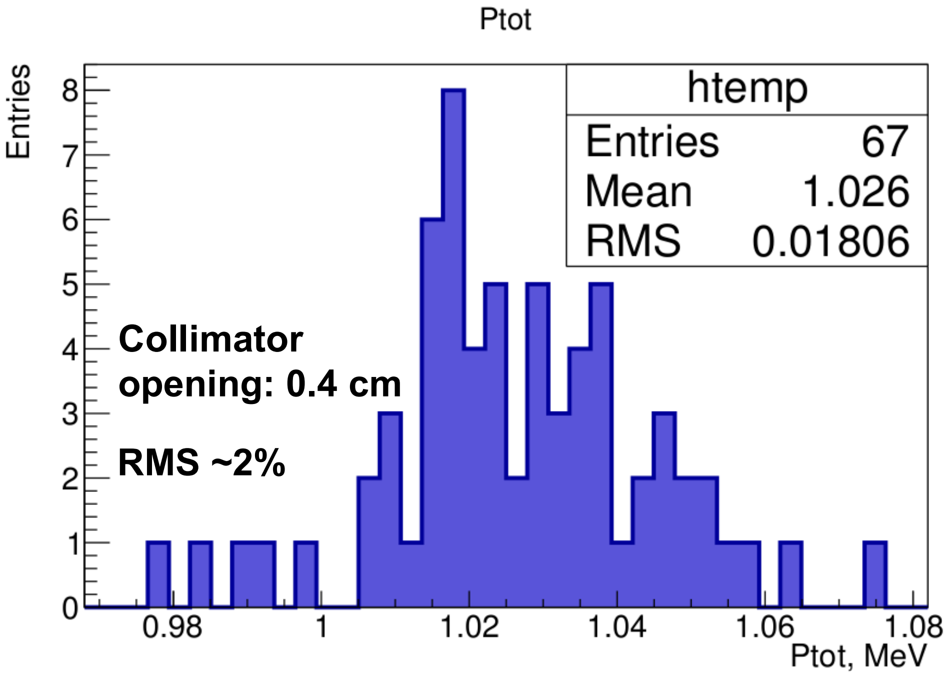


10^{-3} bar

Feasibility studies: multiplicity versus energy spread

- Example of sampling 1 MeV electrons from 5 MeV beam: from simulated 10^8 electrons a sample of $\sim 10^3$ electrons and momentum spread of ~10 % are obtained with collimator 2 opening of 6 and 4 mm.





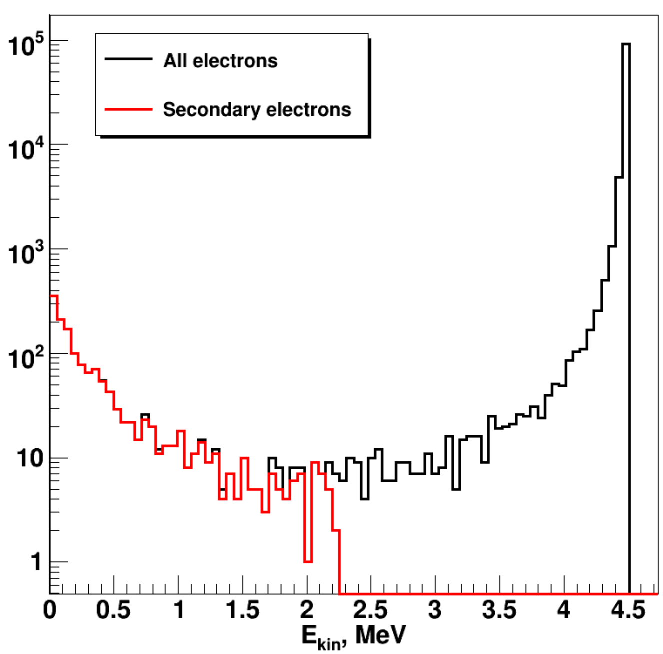
Very low energy: spectrum after the Al plug

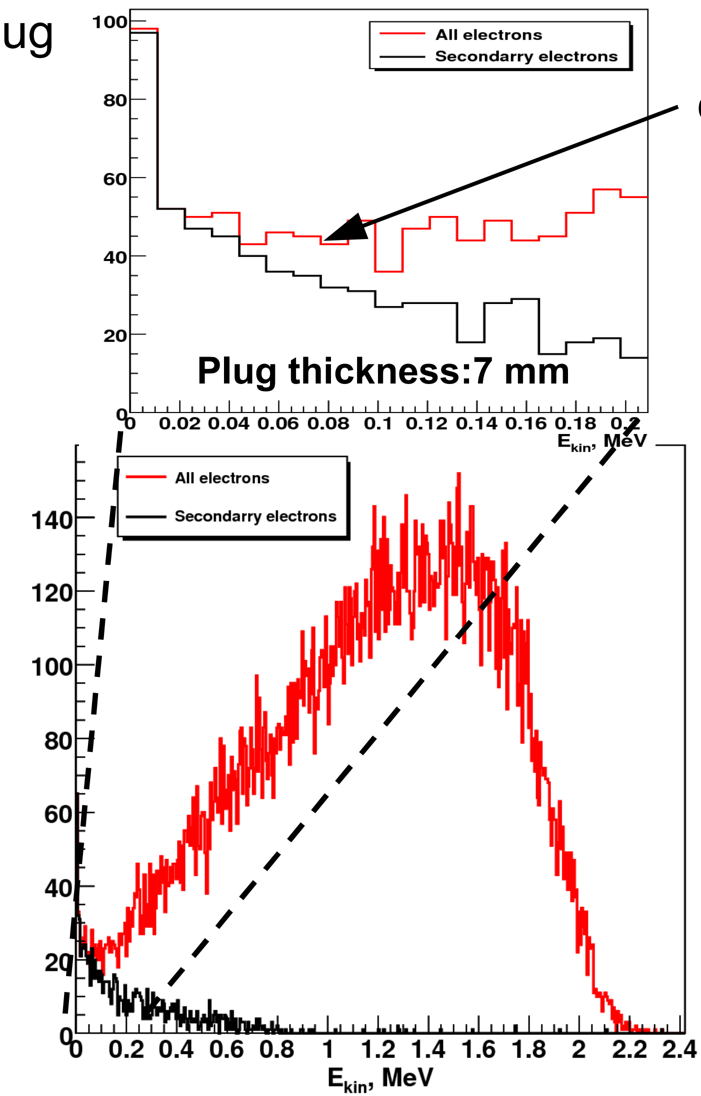
At sub-MeV energies:

- Very sensitive to Geant thresholds, in terms of range for $e^{+/-}$ and gamma in the material: standard Geant 1 mm → reduced step length of 0.001 mm
- Dominant contribution from secondary electrons
- Despite similar amount of secondary electrons, smaller contribution from primary electrons of nearby energies for thin plug

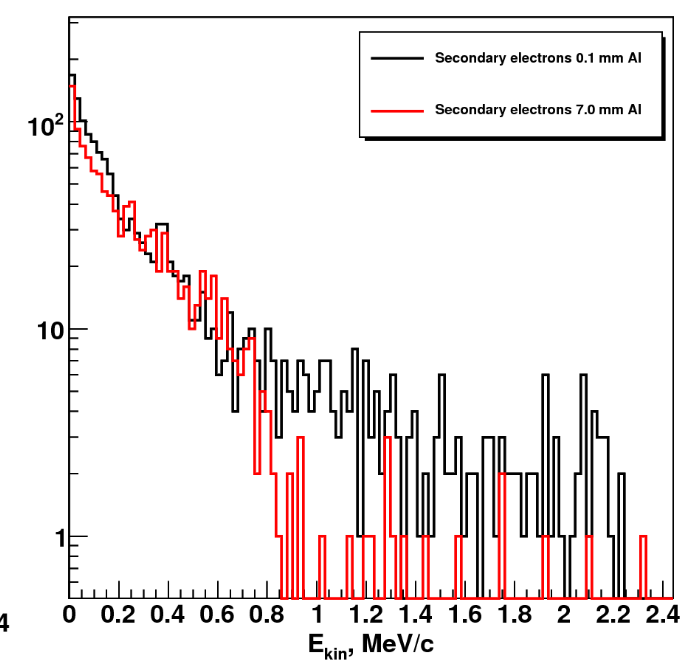
Contribution of secondary electrons

Plug thickness: 0.1 mm





Spectrum of secondary electrons for 0.1 mm and 7 mm thick plug

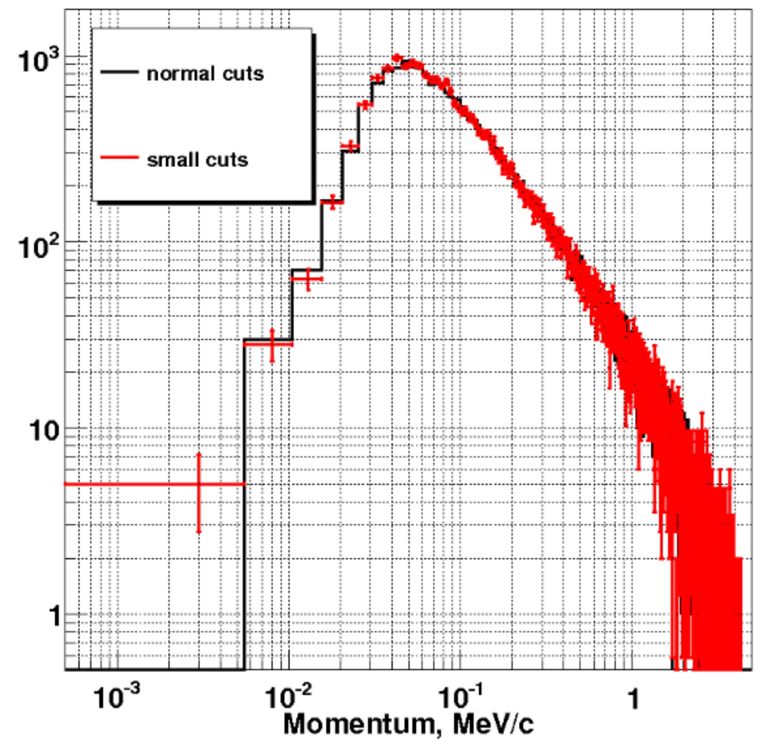


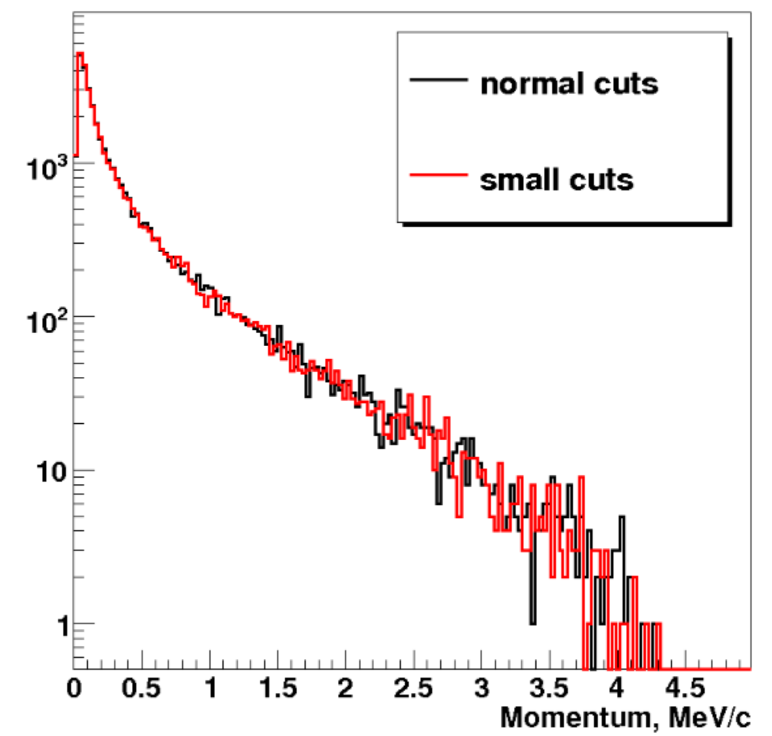
Very low energy: contribution from Bremsstrahlung photons

Bremsstrahlung photons issue:

- Rough (statistically limited, standard Geant thresholds) estimate: < 2 expected Bremsstrahlung photons per 100 expected electrons @95% CL for the settings optimized for 1 MeV electron sample

- Reasonable agreement (standard vs. reduced thresholds) of the photon spectrum after the plug





- Important also to simulate realistic exit window from the vacuum volume !

Work packages

Work packages

General approach, given low availability of the LAL mechanical service:

→ Order work-consuming parts outside, inheriting existing experience of LAL contacts with the firms wherever possible

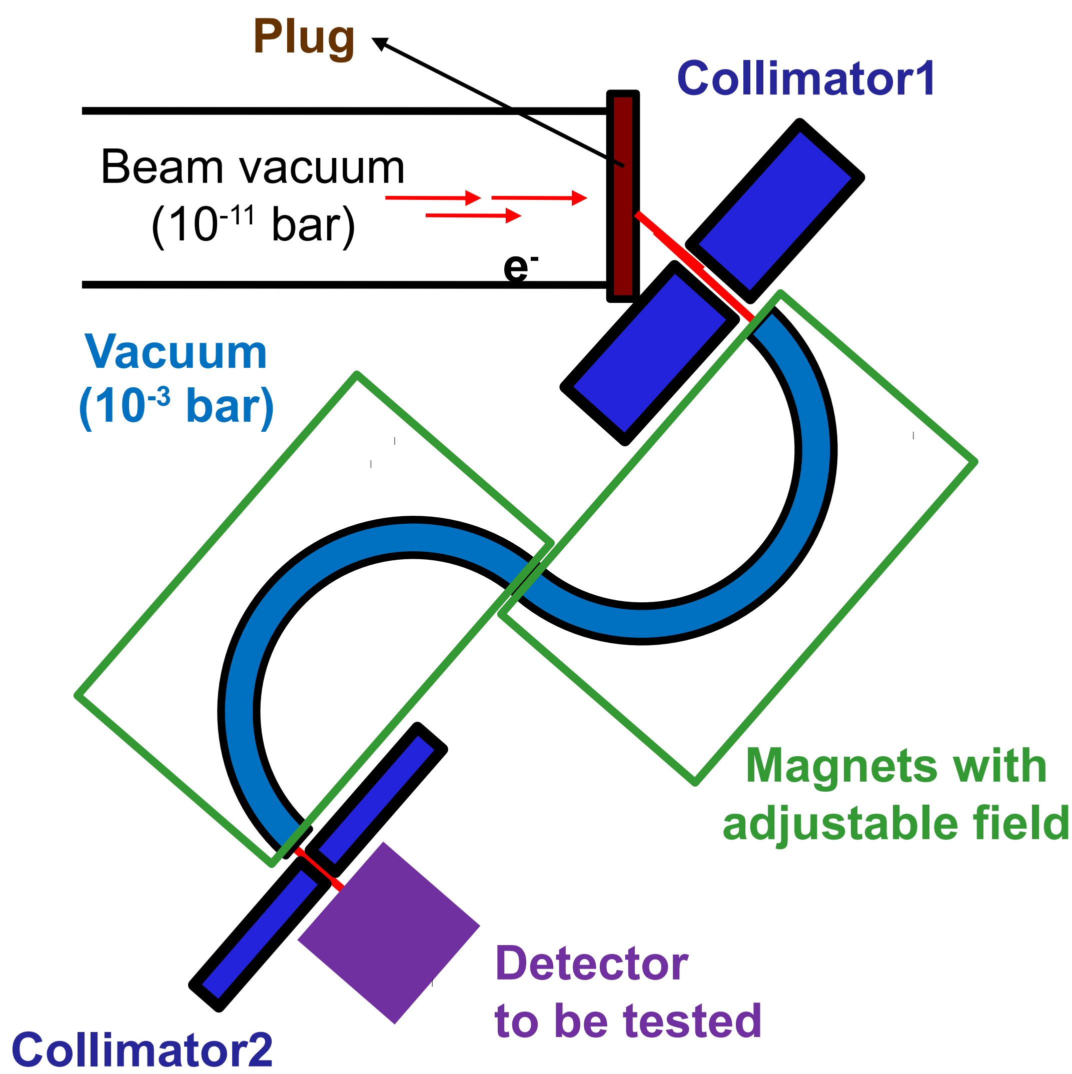
→ Keep at LAL general design and integration, and small work packages

1. **Simulation (Geant4)**
2. **Beam plug(s)**
3. **Collimators.** Due to LAL engineers manpower consolidation around THOMIX, possibility of collimator construction in Kiev is considered.
4. **Magnet.** Production of a dedicated magnet at CERN prototype workshop.
5. **Primary (10^{-3}) vacuum volume**
6. **Shielding of test detector area**
7. **Infrastructure**
8. **System integration, commissioning**
9. **Flux calibration**

Possible further upgrades

Upgradability:

- More **adjustable plugs**: thickness and material
- Reducing material at the entrance/**exit window**
- Possibility of insertion of the **test detector into the vacuum area**
- Improving **vacuum quality**
- Adding **more turns in the magnetic field**, will further reduce background



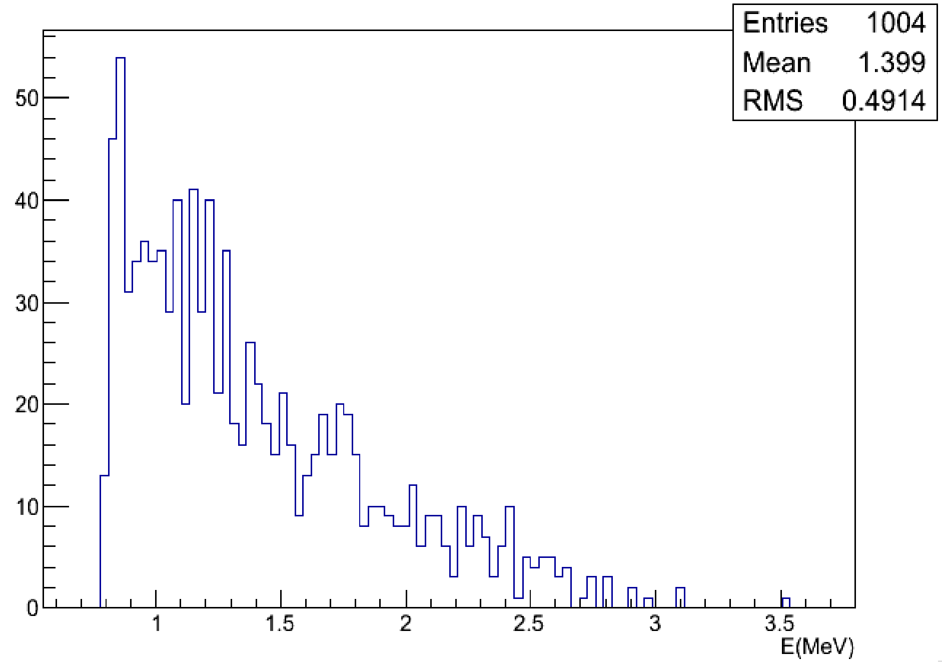
Possible further upgrades
(slide from Olivier Dadoun)

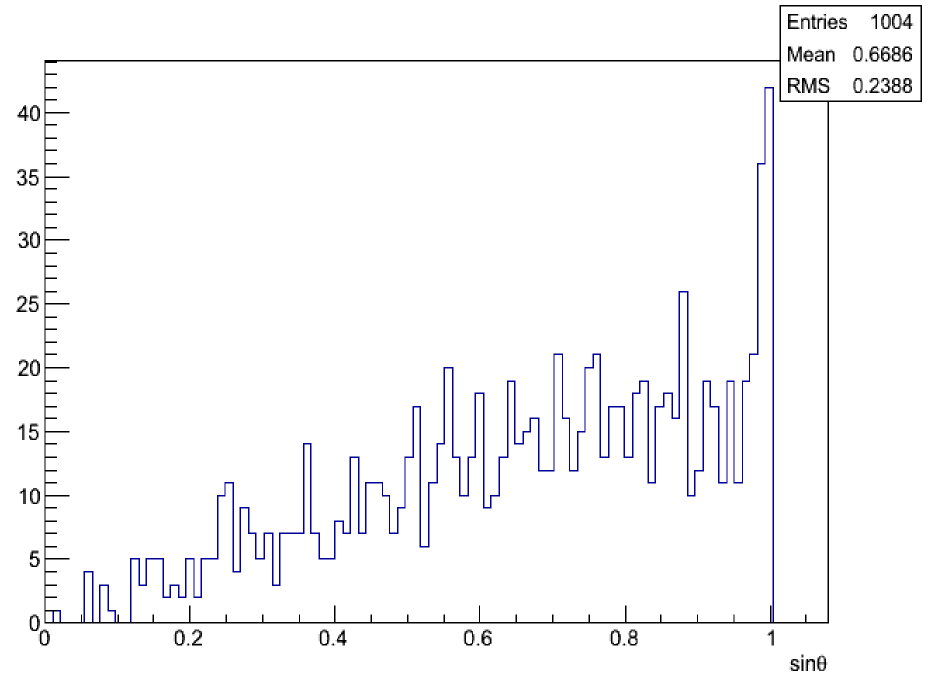
Example: Positron @ PHIL (5MeV)

Simulated 10^7 e^-, beam energy 5 MeV, spot size 2.5 mm (rms), no divergence

Optimal **tungsten** target (plug) ~ 0.95 mm

Yield ~10^{-4}



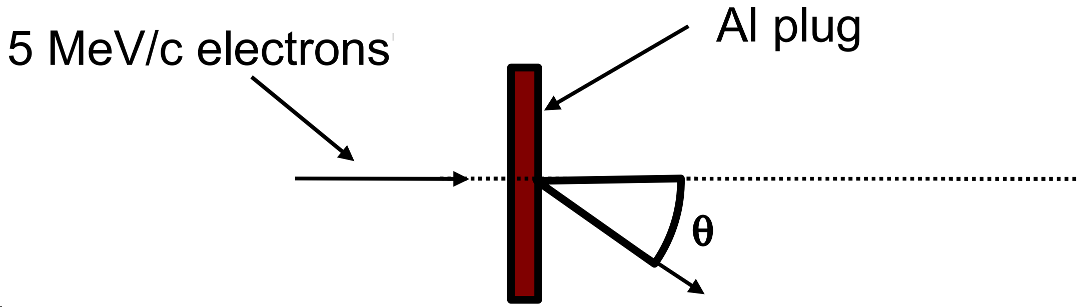


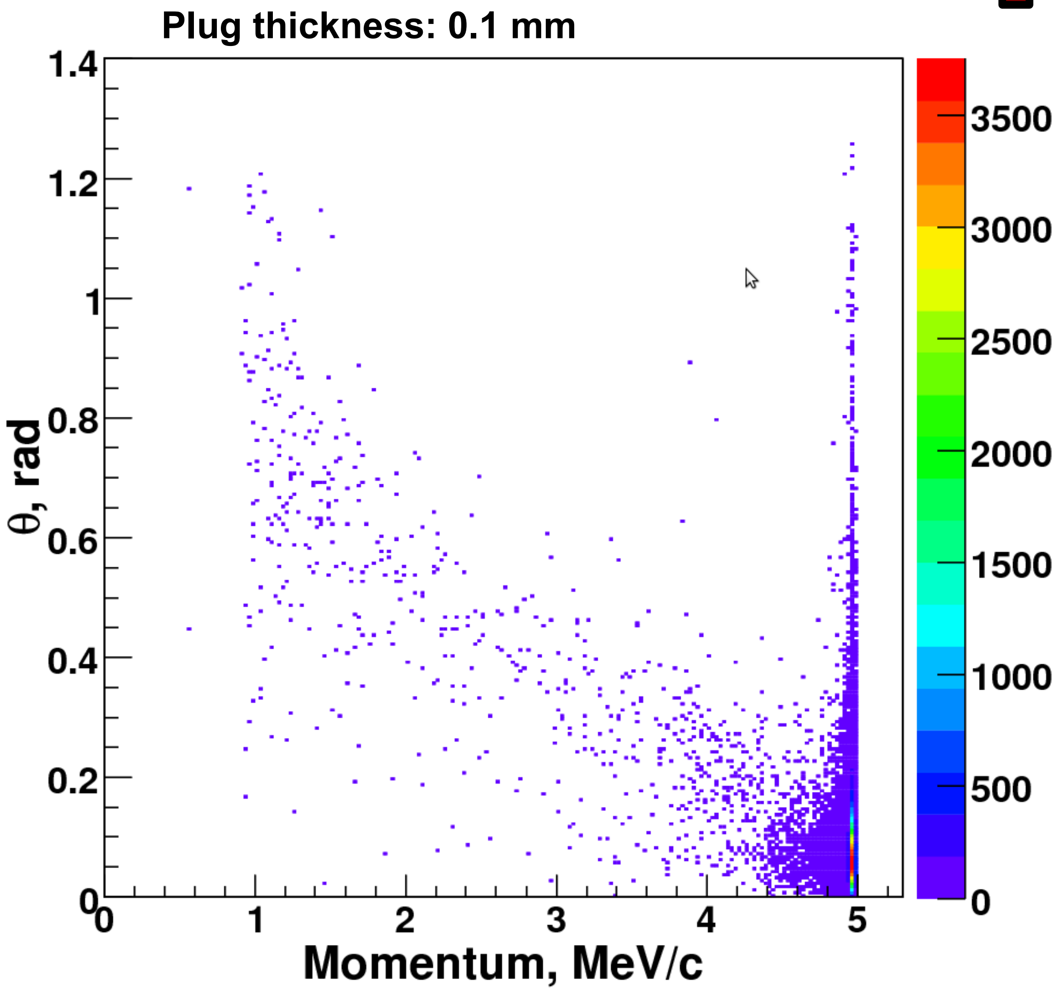
Summary

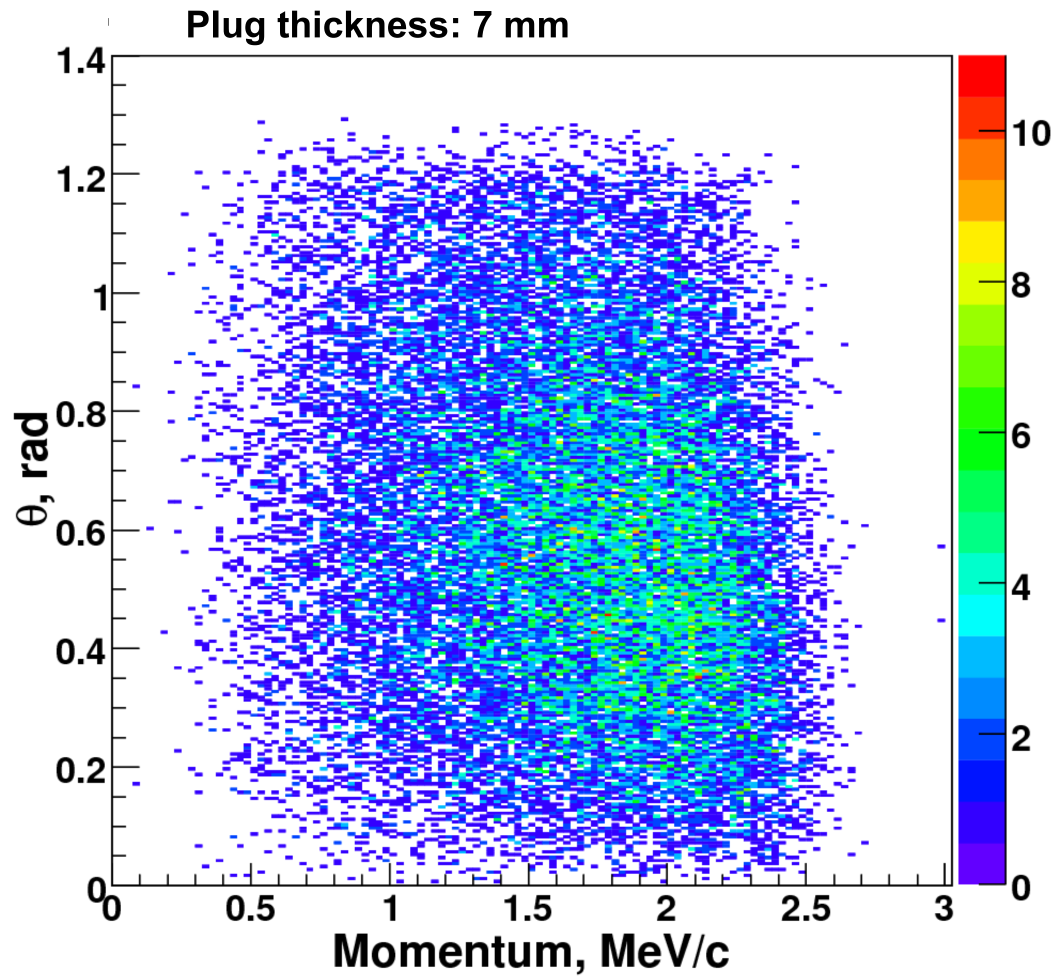
- Setup using electrons from PHIL and yielding **“monochromatic” low energy electron samples with adjustable energy and intensity** is proposed
- Both detector and accelerator expertise important
- Proposal initially motivated by the **Micromegas/InGrid** studies, three-leg (LAL-IRFU-Kiev U) project, naturally re-establishes gaseous detectors at LAL
- Other potential **applications**: from detector (and beam) studies to low energy electron dE/dx studies and students’ hands-on
- Principal design identified, feasibility studies (full Geant 4 simulation) prove the idea
- Project cost estimate amount → 25.8 kE (+ Magnet & PS: 25 kE)
- After the basic version is realized, **stageable upgrades** are proposed to improve signal-to-background conditions and energy resolution
- ANR and P2IO application have been submitted
- Estimated time of the project is around 12 months

Backup

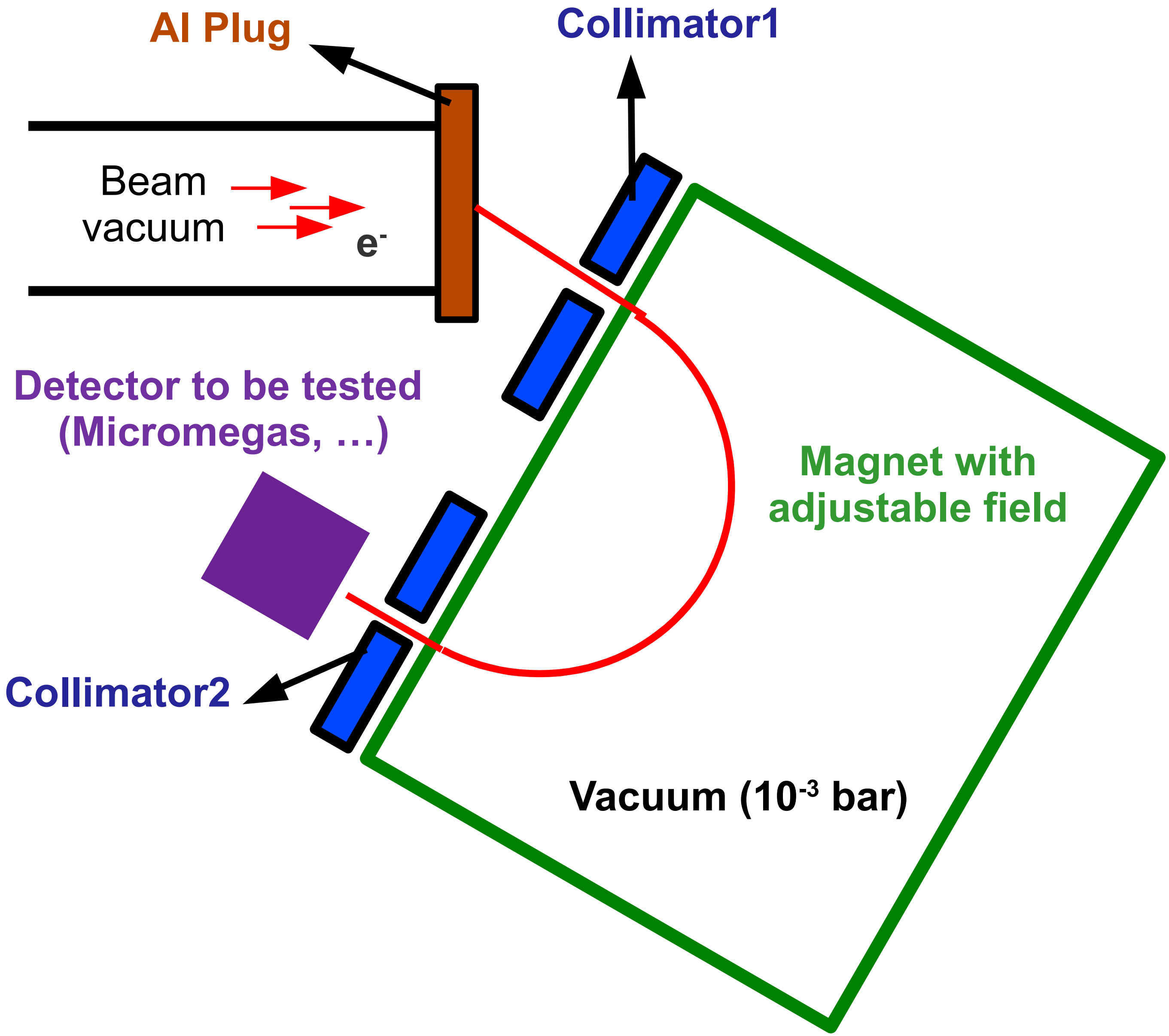
Angular-momentum correlations







No strong correlation at thicker plugs.


Al Plug
Collimator1
Beam
vacuum
e-
Detector to be tested
(Micromegas, …)
Magnet with
adjustable field
Collimator2
Vacuum (10-3 bar)