i-MCP Progress Report
[fast timing of showers with MCPs]

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INFN and Università Milano-Bicocca and Roma La Sapienza

Activity up to June 2014

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1. Procurement of MCP wafers (MiB)

- Purchase order of MCP wafers placed to Incom Ltd. in April (lengthy administrative procedure), delivery expected by July 2014
- Boxes to host wafers designed, preparation to start as soon as wafers are in hands
- Meanwhile, several PMT-MCPs procured (borrowed) from different sources and used for preliminary studies

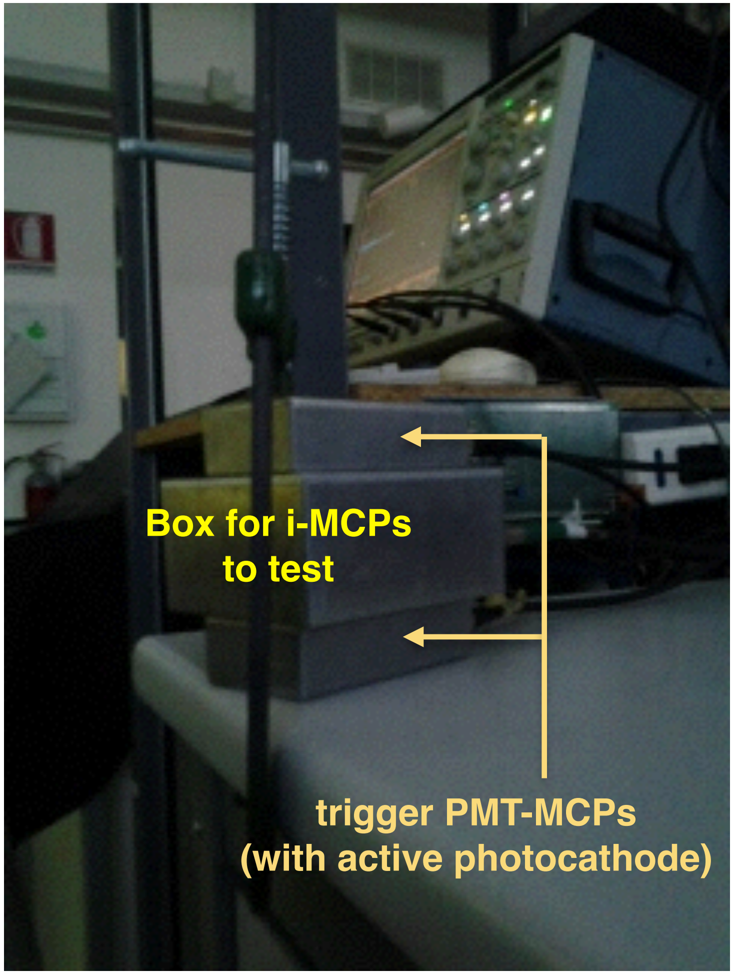
2. Test station for cosmic rays ready (MiB)

- Two PMT-MPCs for trigger and fast time reference
- One (or more) MCPs to test in between
- Readout on a 50 Ohm load with a DSO and/or a 5 Gs/s waveform digitiser

3. Test beam infrastructure ready (Rome1)

- Mechanics (box to host detectors, absorbers, hodoscopes) and DAQ with digitizers at 5Gs/s, ADC and TDCs

4. Preliminary studies with cosmic rays and at the BTF with available MCPs (MiB and Rome1)



Concept and goals: a reminder

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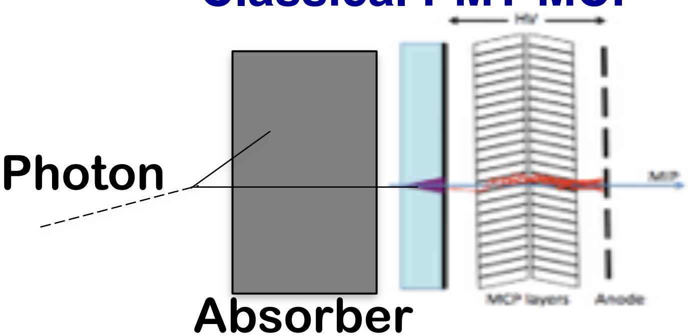
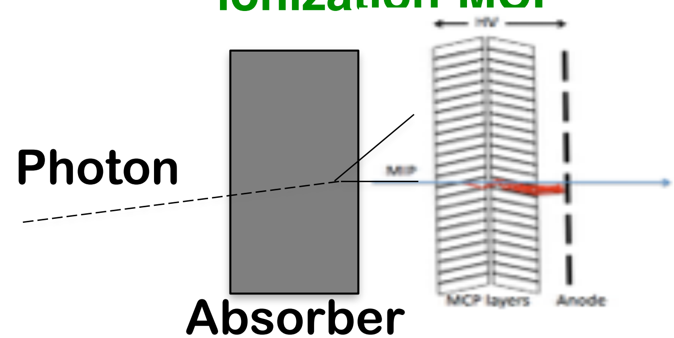
- Timing layer(s) embedded in the calorimeter for fast timing of showers (<50 ps)
  - Possibly a pre-shower: quest for precise timing decoupled from calorimeter choice
- **This R&D: micro-channel plates as m.i.p. detector**
  - By now tested existing devices with ***direct*** or ***retarding*** photocatode bias
  - Devices tested: *Ekran FEP MCPs* developed at BINP [1] and *Planacon Photonis*
    - **Devices tested have two MCP layers in Chevron configurations**

Classical PMT-MCP



Cherenkov emission from PMT window

"ionization-MCP"



Secondary emission from MCP layers [no photocathode - easier assembly]

[1] Courtesy of M. Barnyakov (Budker Inst. of Nuclear Physics, Novosibirsk)

Time resolution with cosmic rays

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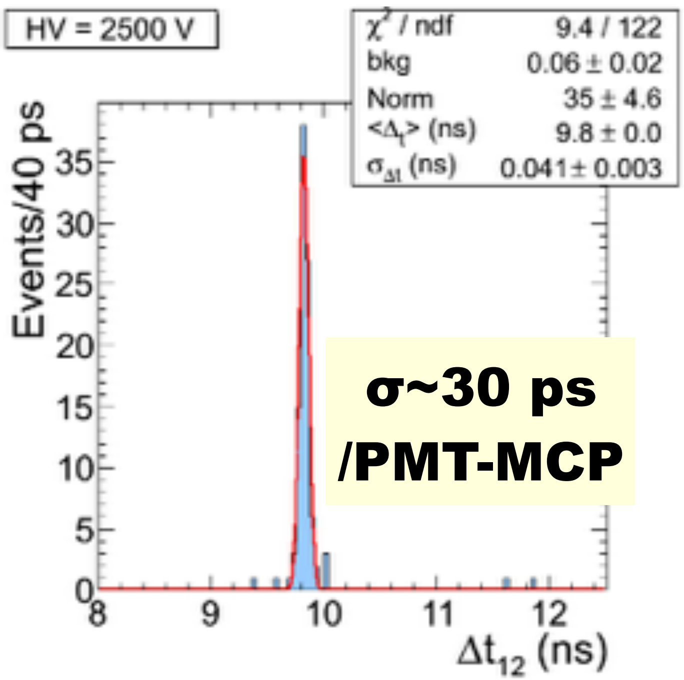
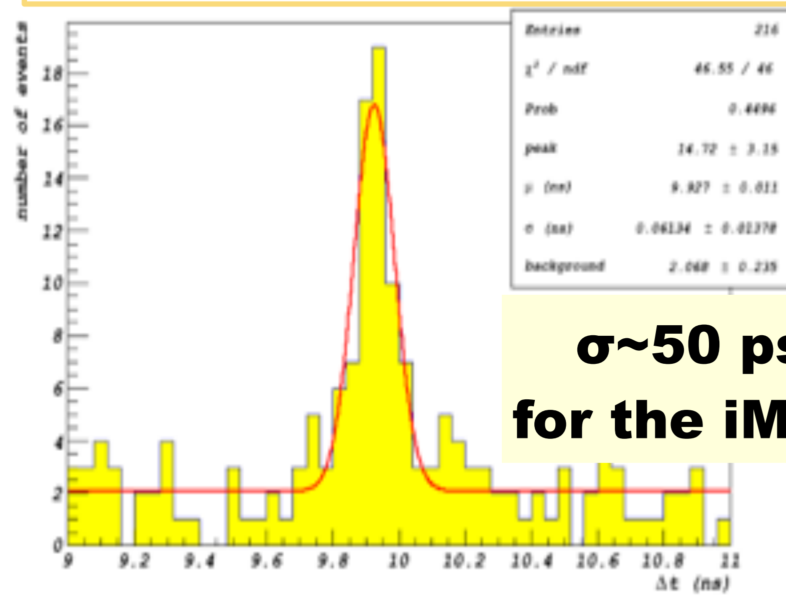
- Time resolution from Δt spread of events in coincidence in two identical tubes (CF-discrimination on Digital Scope)

PMT-MCP:
photocathode with direct bias
efficiency to mips ~ 100%

MCP in "ionization-mode":
photocathode with retarding bias
efficiency to mips ~ 20-50%
(depending on the bias)

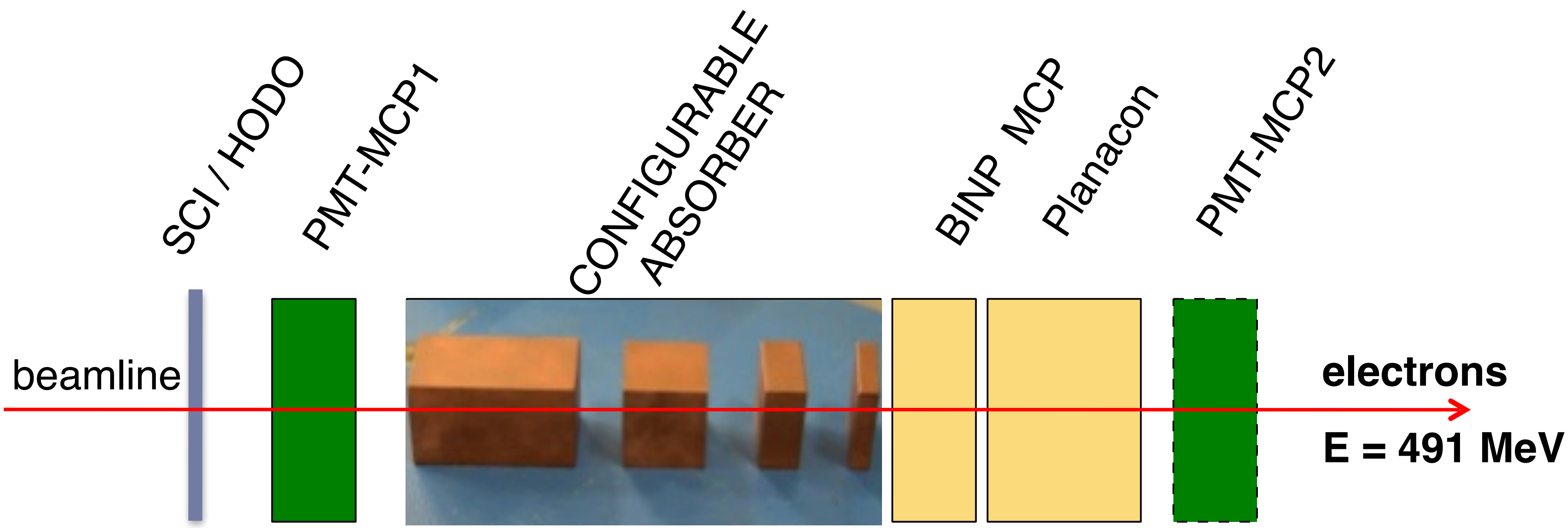


σ~30 ps /PMT-MCP



σ~50 ps for the iMPC

Test beam at the BTF (LNFrascati)

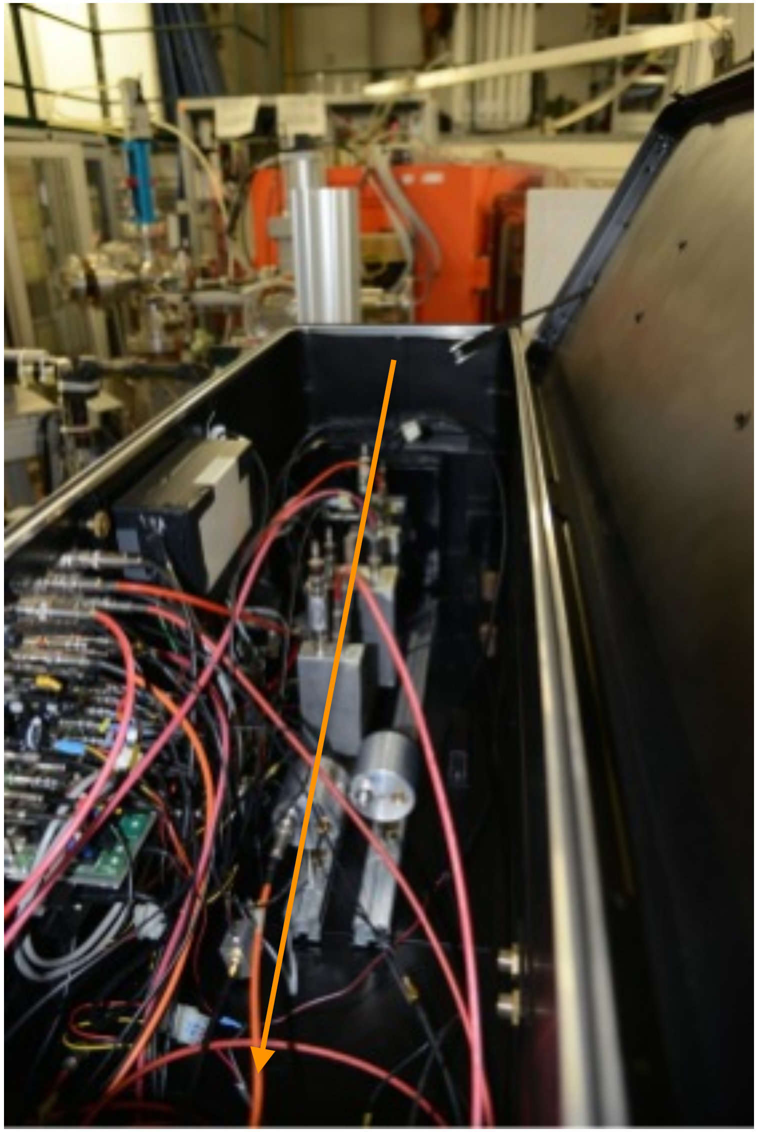


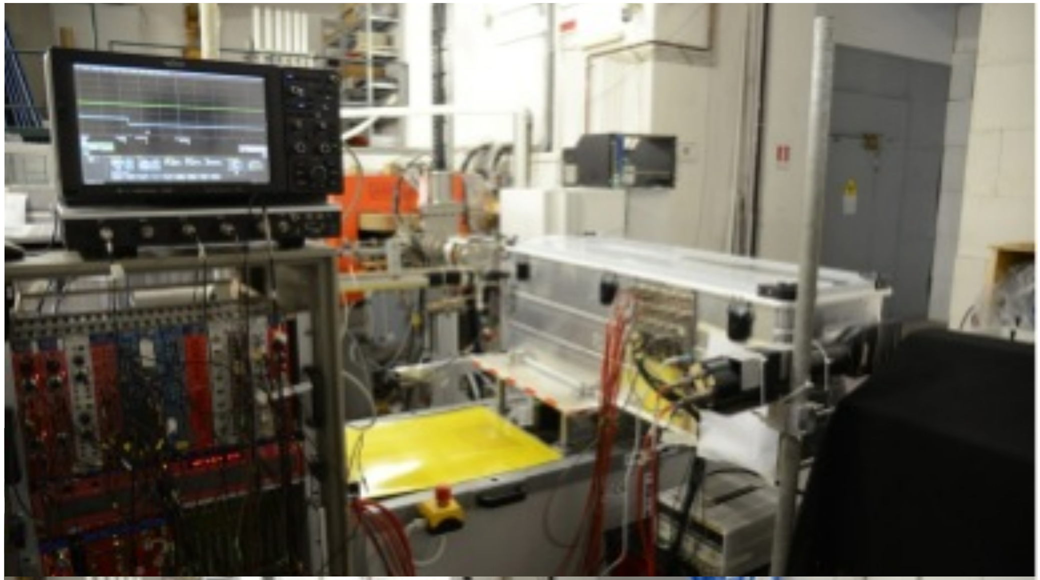
- One (two) PMT-MCP(s) for high resolution time reference
- MCPs to test (w/ and w/o photocathode)

1. **HV scan with no absorber —> response to 'mips'**
2. **X_0 scan for selected HV settings —> response to showers**

- Test beam readout not optimized for time resolution (timing ~60 ps)

Box, setup and selfie

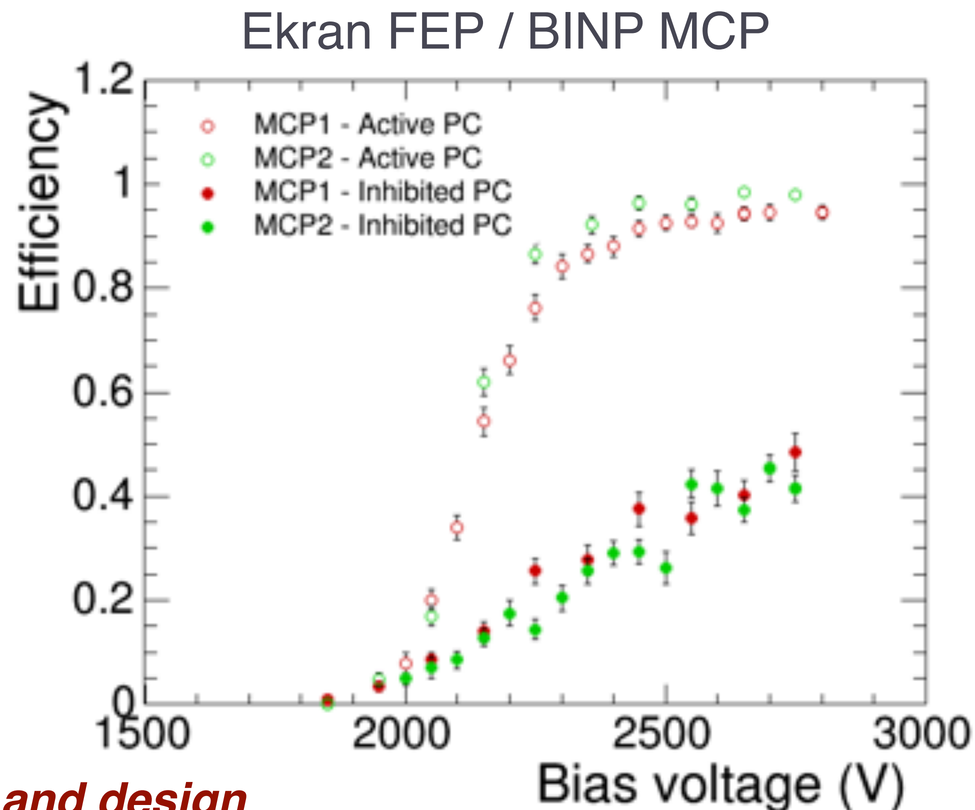




Efficiency scan with single electrons

- **Selections**:
  - Single electron in Sci/Hodo
  - PMT-MCP1 & PMT-MCP2

- **Results on the efficiency:**
  - up to 50% @ HV = 3000 V in ‘ionization-mode’
  - About 100% exploiting Cherenkov emission in the 2 mm optical window



- Preliminary results for BINP MCPs (similar behaviour for Planacon)
- In ‘ionization mode’ efficiency still raising; HV beyond 3000 V not tested

- ***Interpretation of efficiency curves and design consideration for high efficiency i-MCPs in the attached document***

Scan in absorber thickness

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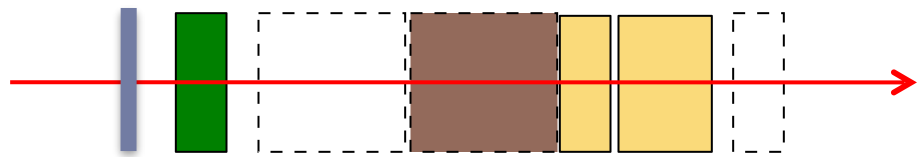
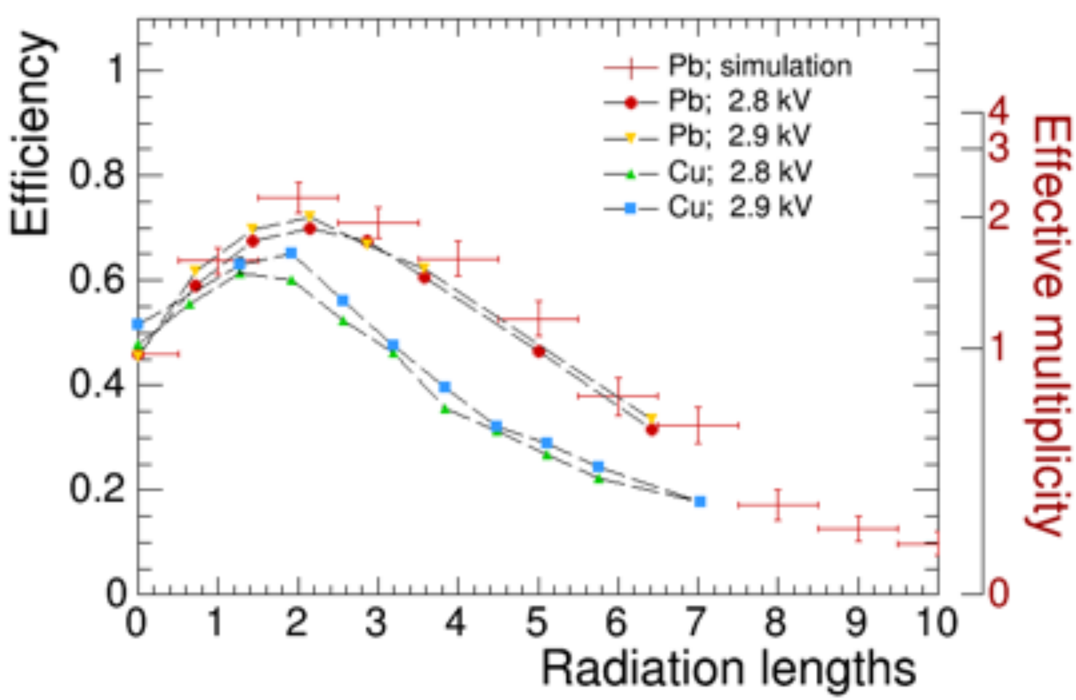
- **Selections**:
  - Single electron in Sci/Hodo
  - PMT-MCP1



- **Results on the efficiency:**
  - up to 70% @ shower max in 'ionization mode' [100% exploiting the Cherenkov window]

Ekran FEP / BINP MCP



- Data in fair agreement with a preliminary simulation
  - $\mathcal{E}(t) = < 1 - (1-\mathcal{E}_0)^{n(t)} >$
  - $n(t)$ = event track multiplicit at depth t from Geant4

Preliminary projections to shower timing

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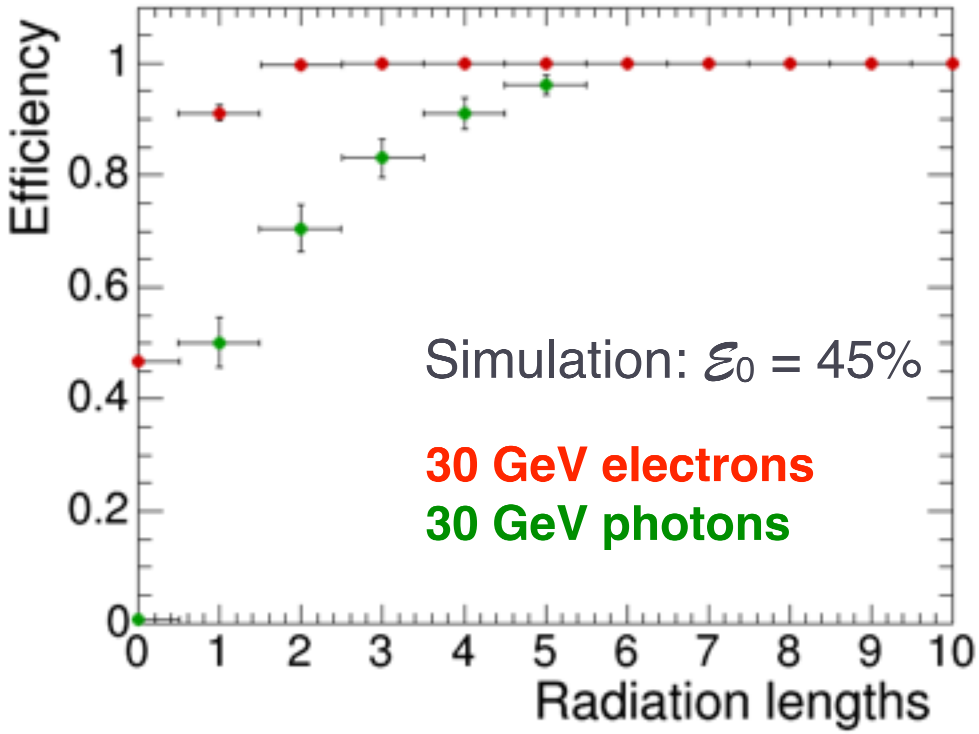
- Estimate response to 30 GeV electrons and photons in lead using the MC simulation shown to match data
  - Charged track multiplicity in the MCP layers from Geant4
- [Efficiency to electrons ~ 1]
- **Efficiency to photons**
  - ~80% at $3X_0$ for 45% efficiency to mips
  - Efficiency ~90% in a preshower with two samplings at $1X_0$ and $3X_0$
  - >90% at $3X_0$ for 70% efficiency to mips (**)



- (**) Efficiency of 70% achieved in with three MCP layers [M.Bondila et al., NIM A] Design consideration for high-efficiency i-MCPs in the attached document

Summary and prospects

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- **MCPs in 'ionization-mode' (i-MCP): viable option for shower fast timing**
  - Efficiency to photons in excess of 90% possible with existing MCPs
  - *A potential configuration with optimized response identified: a two-stage MCPs stack (optimized for secondary emission, and devoted to amplification respectively)*
- PMT-MCPs with Cherenkov emission in the optical window —> baseline solution, if proven sufficiently rad hard
- **Future studies include:**
  - Identification of i-MCP configurations of high efficiency
  - Radiation hardness study of i-MPC *[also vs PMT-MCP]*
  - Rate capability of MCPs and response in high B-field
    - (contacts established with RAL/Brunel for tests up to 4 T)
  - Optimization of the readout for fast time response
    - Close collaboration with G.Pessina and C.Gotti (MiB)
- Additional information on the R&D plan provided in the proposal, and in the presentation to CNS V - in October 2013

Result dissemination

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- **Students involved in the project:**
  - Laurea triennale: 5
  - Laurea magistrale: 2
- **Contacts with external collaborators**
  - BINP, Novosibirsk - secondary emission studies in thin foils replacing the photocathode (with Ekran)
  - RAL/Brunel - Immunity to magnetic field
  - Work on fast timing at HL-LHC within CMS (with Caltech, Princeton, CERN)
- **Publications**:
  - Test beam results may be shaped into a report to a conference

- *Other projects on fast timing: Caltech (Studies on MCPs), Saclay (fast Micromegas), Princeton at al. (silicon devices), NIKHEF (Tipsy with MEMS)*