AMADEUS: Status of hardware and analysis of K^-He data

Oton Vázquez Doce

37th LNF Scientific Committee
December 1, 2008

Summary

AMADEUS: status of hardware

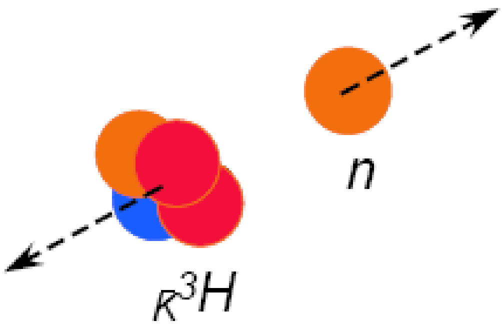
- Introduction
- Setup
  - Target
  - Trigger System: SiPM+ scintilliating fibers
  - Inner tracker: TPG tests
- DAQ + slow control

The AMADEUS Collaboration

- **LNF**: beam-pipe definition; Slow Controls and DAQ; trigger; SiPM electronics; inner tracker (GEM); mechanics
- **SMI-Vienna**: target system; SiPM; inner tracker (TPG, GEM); Monte Carlo simulations
- **ITEP Moscow**: SiPM tests
- **Moscow Engineering Physics Institute, Moscow**: electronics for inner tracker
- **JINR**: trigger definition, data analyses algorithm
- **TU Munich**: inner tracker (TPG) system
- **Inst. Physics Cracow**: trigger and DAQ
- **IFIN-HH Bucharest**: Slow Control System (target) and SiPM electronics
- **Ist. Superiore Sanita' Roma**: SiPM development
- **Isfahan Univ., Iran**: Monte Carlo simulations
- **Poli Milano, Italy**: front-end electronics (SiPM, inner tracker)
- **TRIUMF Canada**: target system
- **GSI**: SiPM system
- **RIKEN, Japan**: target definition
- **University of Zagreb, Croatia**

The AMADEUS experiment

- **Letter of Intend, March 2006**
- **Day 1 proporsal, November 2007**



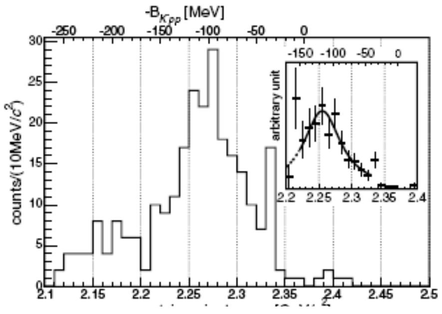
The main aim of AMADEUS is to confirm or deny the existance of Kaonic Clusters, studying it in the formation and decay processes

Either situations: EXISTENCE or NON-EXISTENCE of the deeply bound kaonic nuclear clusters will have strong impact in kaon-nucleon/nuclei physics

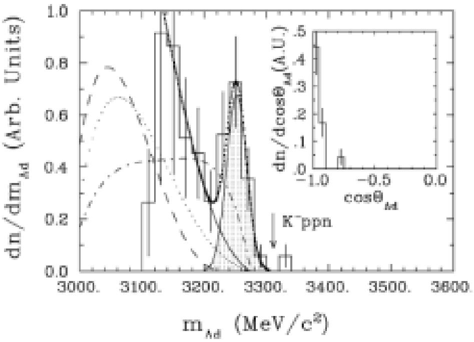
Framework

Experimental results from **FINUDA**

K- stopped in light nuclei
Invariant mass spectroscopy



Λp

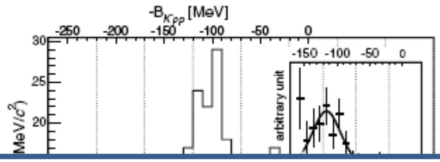


Λd

Framework

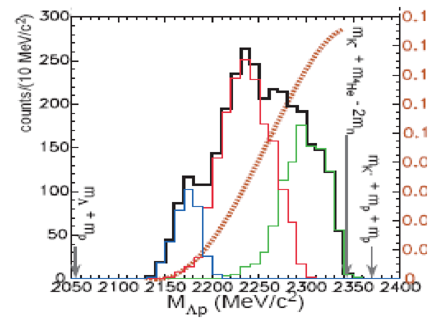
Experimental resu
from **FINUDA**

K- stopped in light nuc
Invariant mass spectro

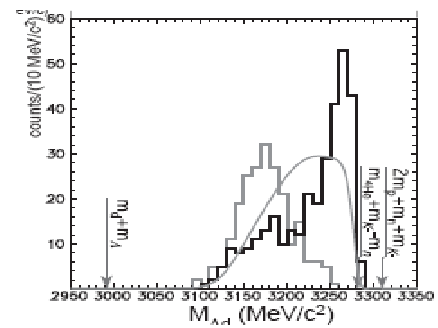


Results from **KEK**:

K- stopped in 4He
Invariant mass spectroscopy

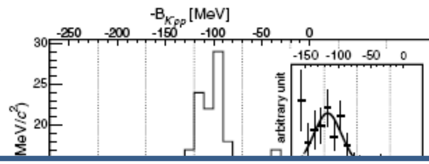


Λp



Λd

Framework



Λp

Experimental resu
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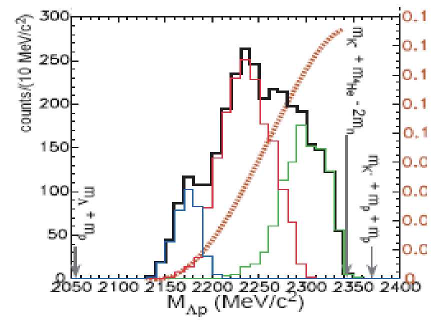
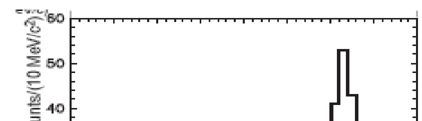


Λp

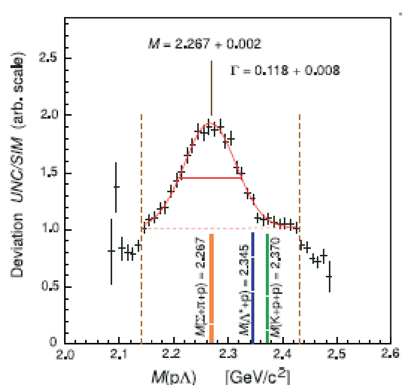


Λd

K- stopped in 4He
Invariant mass spectroscopy

DISTO

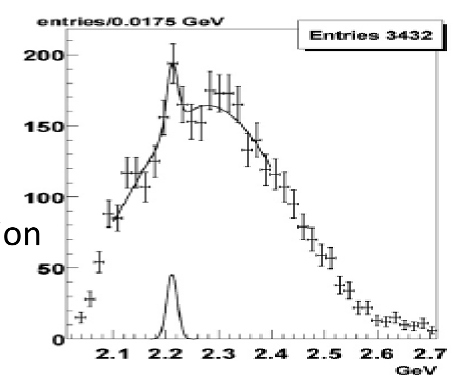
p+p → K⁺+X



Λp

OBELIX

p̄⁴He annihilation



Λp

(Λd)

The AMADEUS experiment

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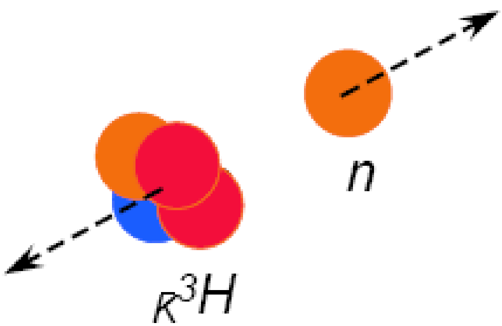

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Either situations: EXISTENCE or NON-EXISTENCE of the deeply bound kaonic nuclear clusters will have strong impact in kaon-nucleon/nuclei physics

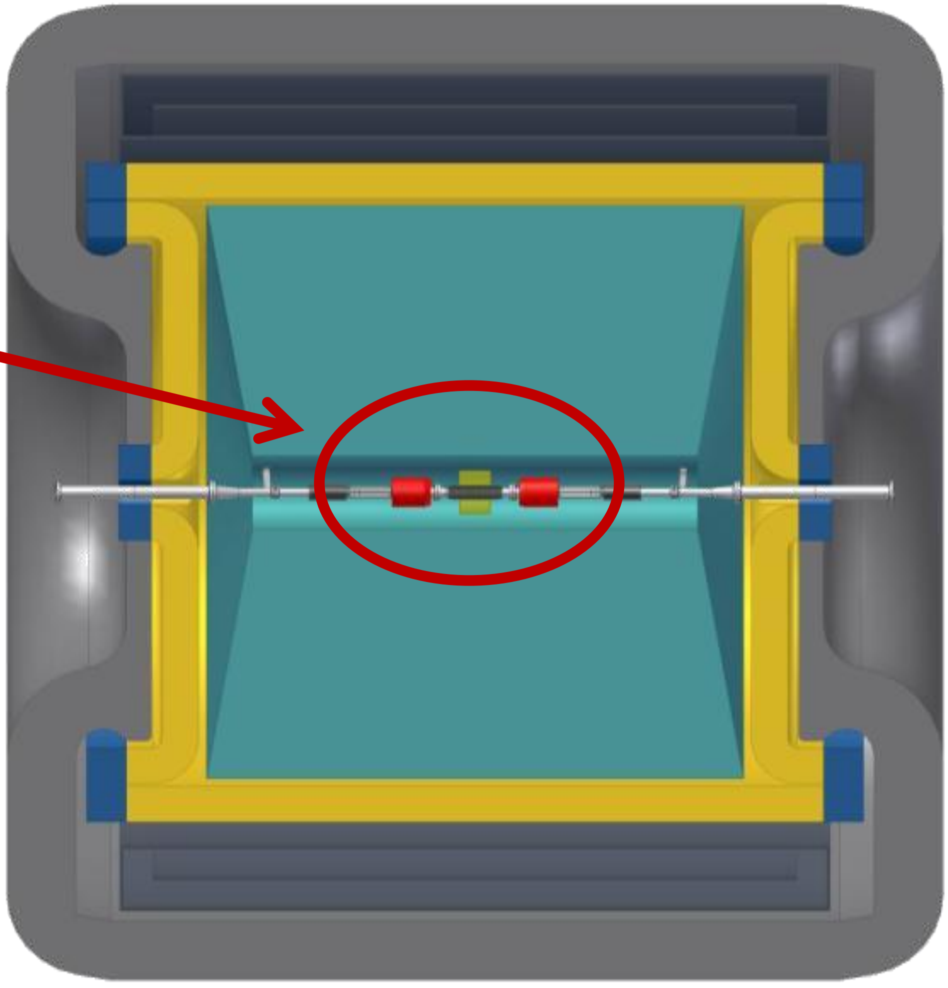
AMADEUS phase-1: start in 2010/2011 (after KLOE2 step-0), study di- and tri – baryon kaonic nuclei and low-energy kaon-nucleon/nuclei interactions

AMADEUS phase-2: after 2012, higher integrated luminosity, refined study; extend to other nuclei (kaonic nuclei spectroscopy along the periodic table)

The experimental setup of AMADEUS

Full acceptance and high precision measurements will be made by **implementing the KLOE detector with an inner AMADEUS setup**

•The AMADEUS setup will be implemented in the 50 cm. gap in KLOE DC around the beam pipe:



•**Target** (A gaseous He target for a first phase of study)

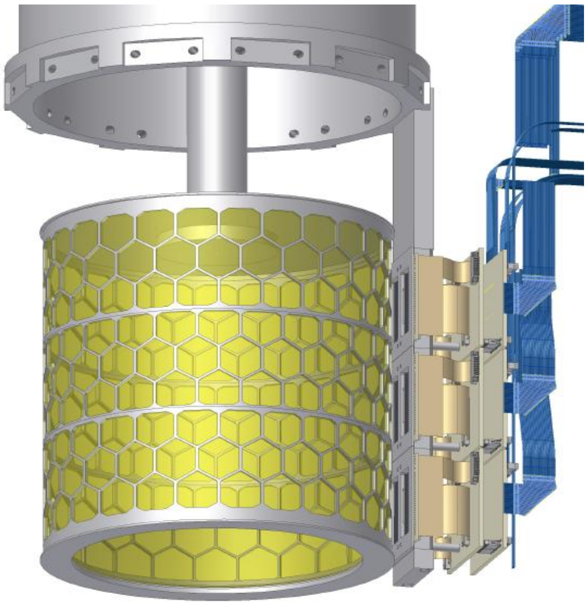
•**Trigger** (1 or 2 layers of ScFi surrounding the interaction point)

•**Inner tracker** (eventually, a first tracking stage before the DC)

Target

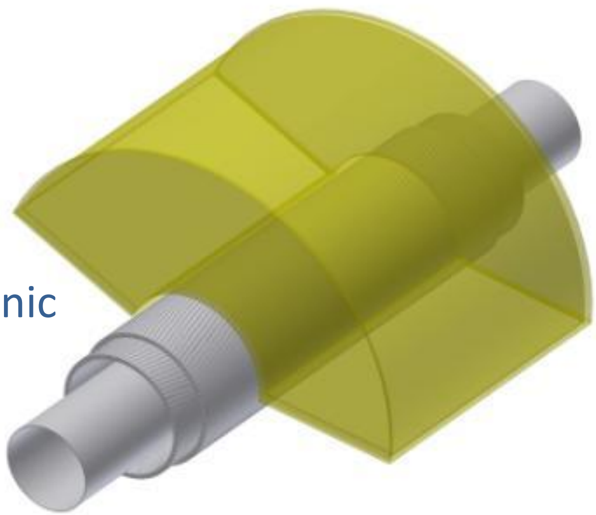
- **Current target installed in Daphne** for SIDDHARTA experiment
- **Stopping power optimization:**
  - combination with different degraders
  - Position-dependent study of x-ray signal of SDD's
  - Monte Carlo simulations

SIDDHARTA



working T 22 K working P 1.5 bar
Alu-grid
Side wall: Kapton 50 μm
Entrance window: Kapton 50 μm

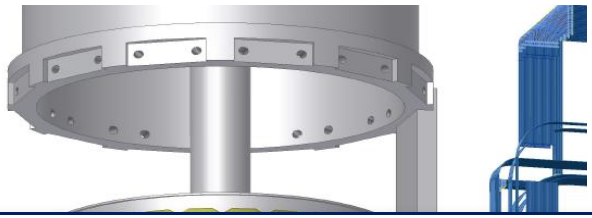
AMADEUS



Low-mass cryogenic gas target cell:
T = 10 K
P = 1.0 bar
Rin = 5 cm
Rout = 15 cm
L = 20 cm

Target

SIDDHARTA



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- **Stopping power optimization:**
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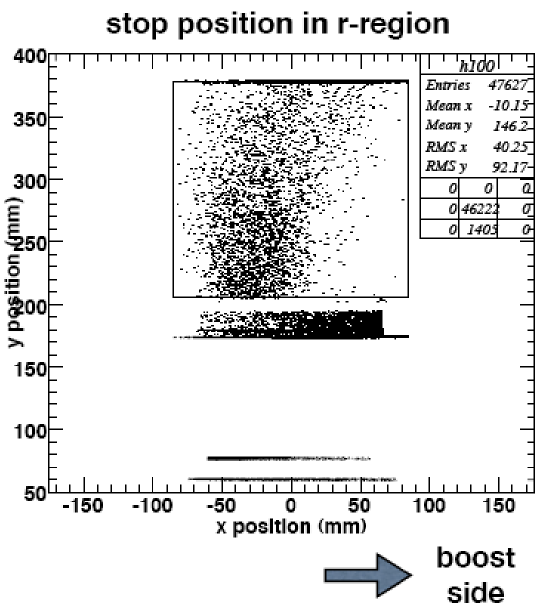
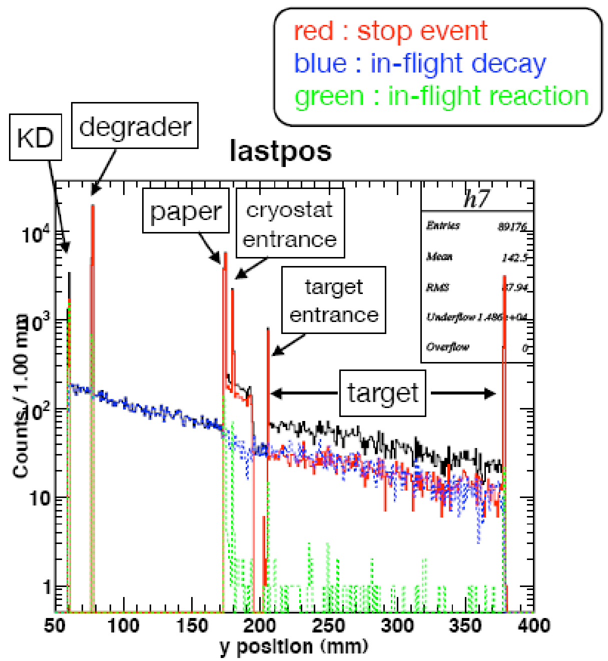
ulations

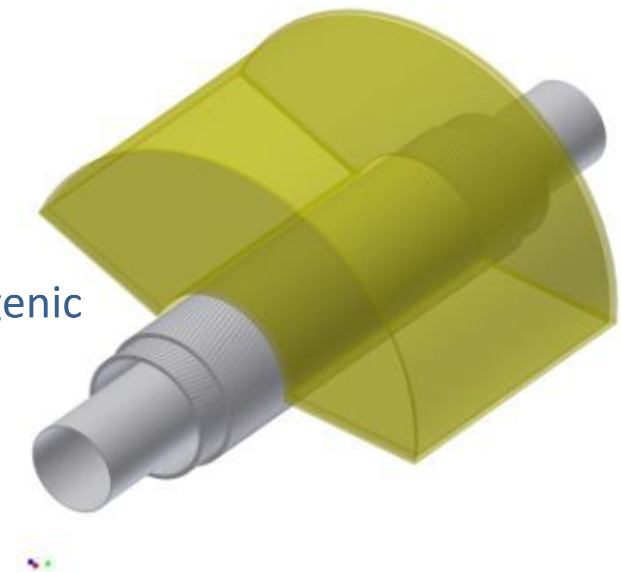
genic

SIDDHARTA Monte Carlo

selected target radius







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- **Current target installed in Daphne** for SIDDHARTA experiment
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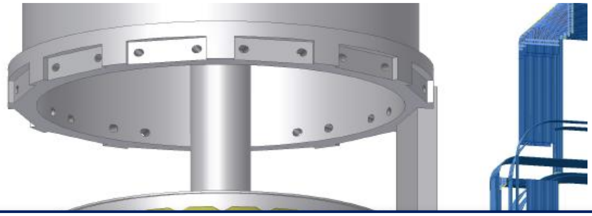
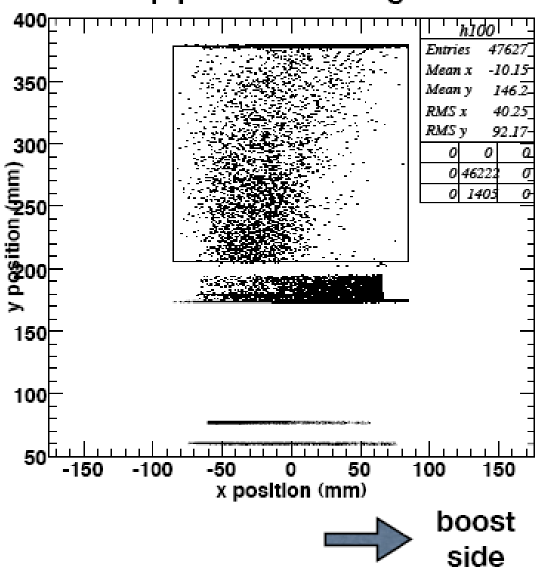
SIDDHARTA

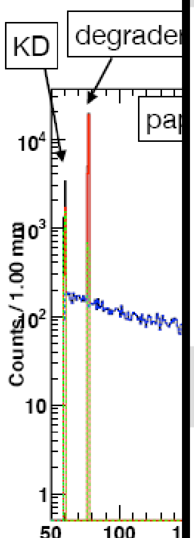


SIDDHARTA Monte Carlo

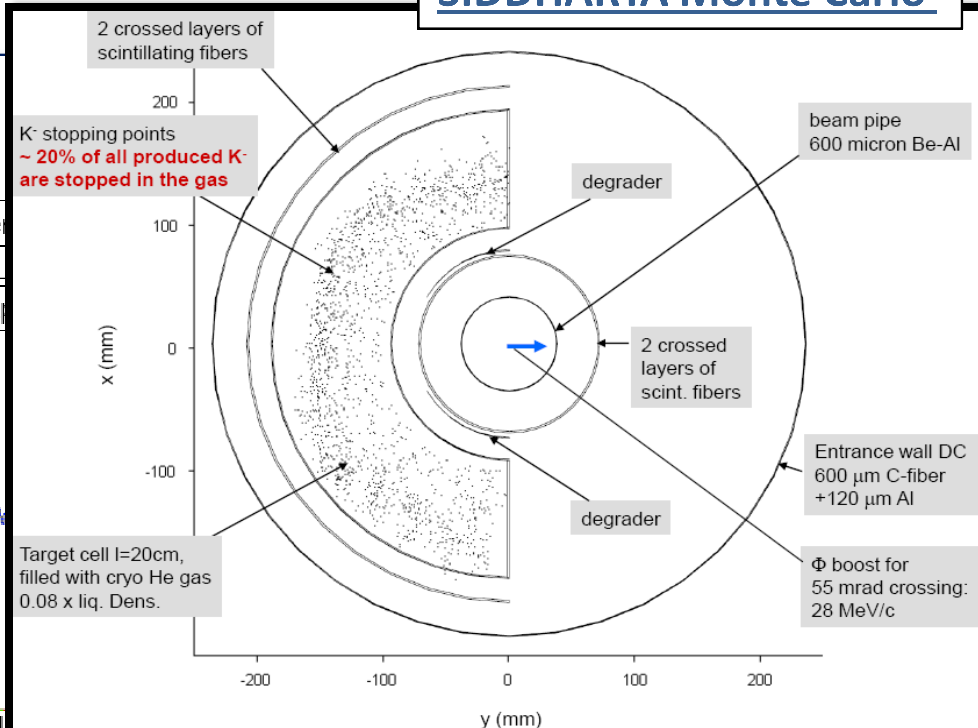
selected target radius

stop position in r-region





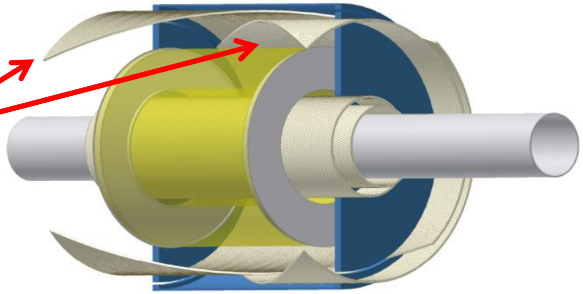
SIDDHARTA Monte Carlo



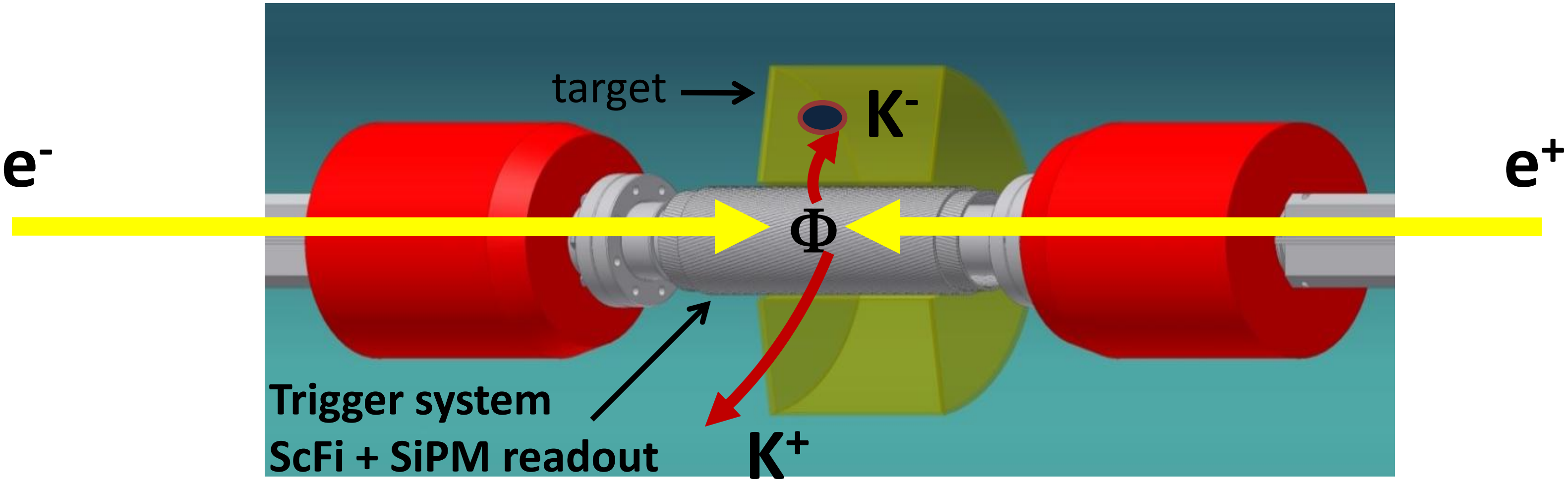
Trigger system

- **Cilindrical layer of scintillating fibers** surrounding the beam pipe to **trigger K^+ K^- in opposite directions**
- Single or double layer

In this case possibility of perform tracking as well: X-Y measurement with high granularity layers



- Readout to be done by **SiPM (silicon photo-multipliers)**



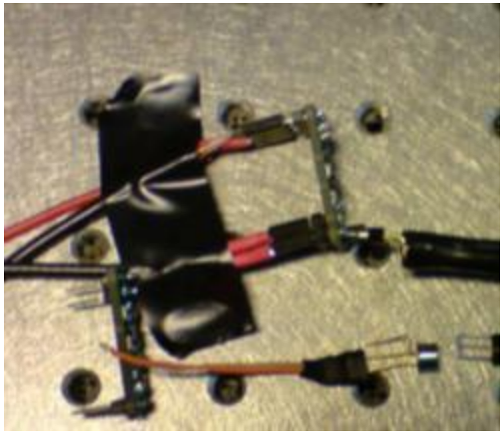
SiPM tests

- Array of single Geiger Mode APD.
- Photon counting depending on the PIXEL size
- **Ideal for:**
  - **ScFi coupling**
  - **High granularity detector**
- **Time resolution below 1 ns**
- **Insensitive to strong magnetic fields**
- High gain (>10^6) and quantum efficiency

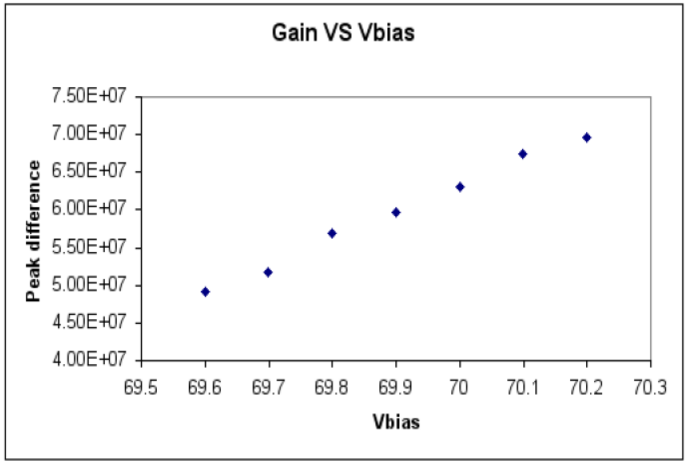
Different options available in the market, becoming a standard light readout system (Hamamatsu, Photonique, etc)

<u>SiPM Hamamatsu S10362-11-050U</u>

efective area 1mm^2
400 pixel
λ = 270-900 nm
working biases ~ 70 V .



SiPM tests: New electronics



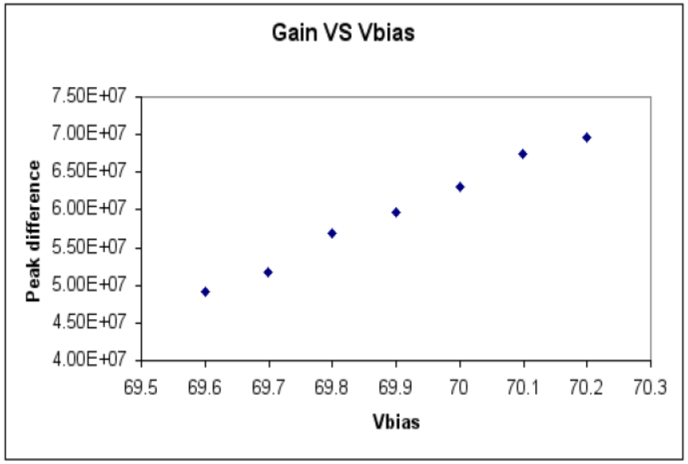
- The Geiger mode of SiPM makes **gain extremely dependent of applied V_{bias}**

-A characterization of this dependency based on the peak distance of intrinsic noise:

$$G = \frac{\Delta N \times ADC_{conv.rate}}{e}$$

- For a good behavior stability in the applied voltage with great precision is needed for every single detector.

SiPM tests: New electronics



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Electronics: New CAMAC modules providing:

• Variable V_{bias} for 5 channels with a **stability for nominal voltages below 10 mV**

•2 output / channel:

-Amplified (x50-x100) signal

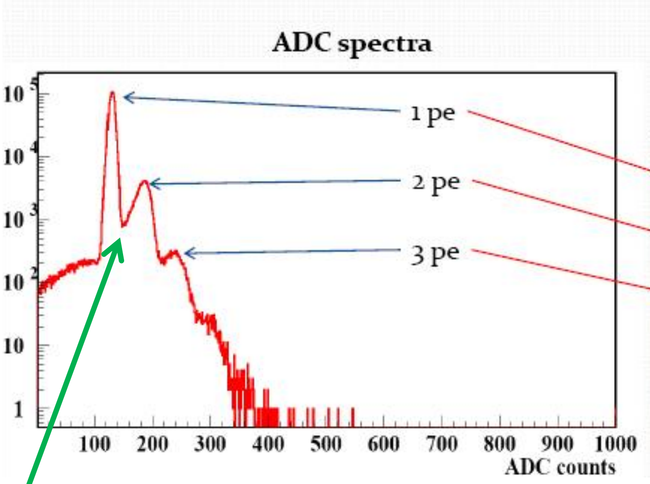
-Discriminated signal (variable threshold)

Designed by G. Corradi, D. Tagnani, C. Paglia

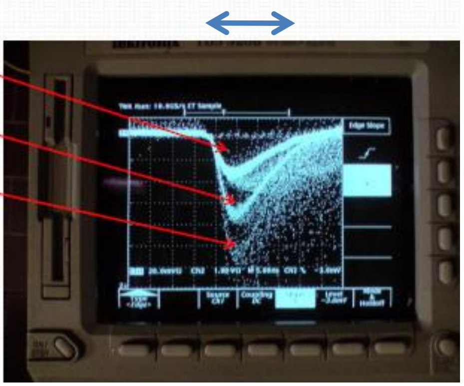
SiPM tests: Dark Noise

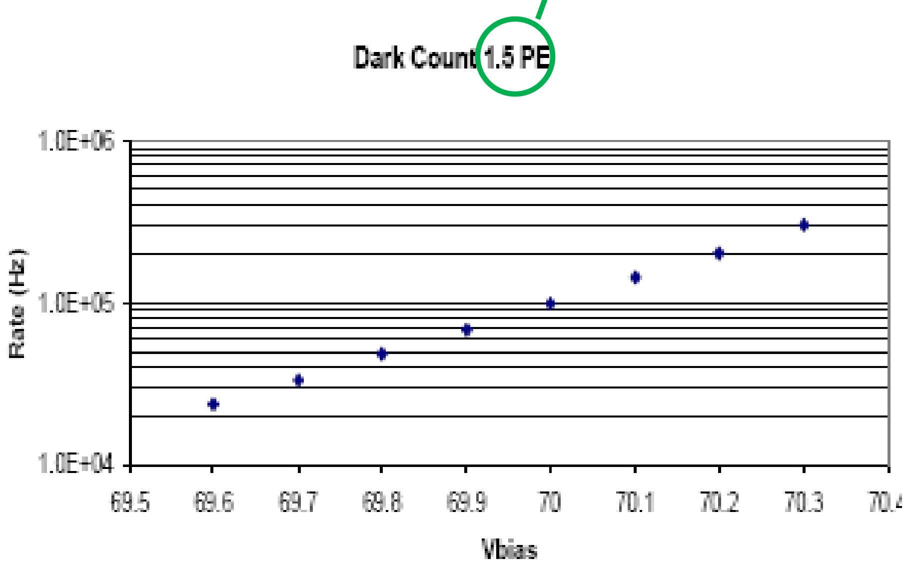
-Spureous signals appear with **high rate** due to internal **thermal noise**

-Practically **absent for > 3 phe signals**



Rise Time ~ 3 ns
Fall Time ~ 50 ns

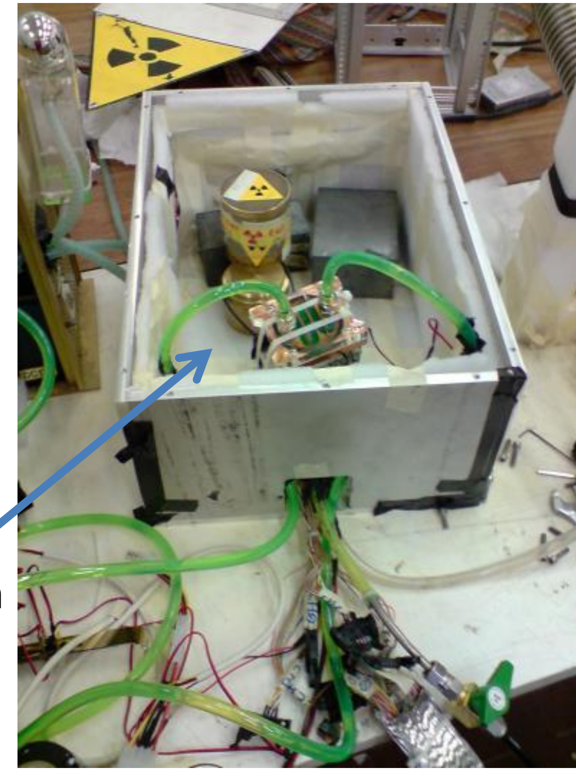




-Dark noise rate exponentially increased with Vbias

SiPM tests: Dark Noise

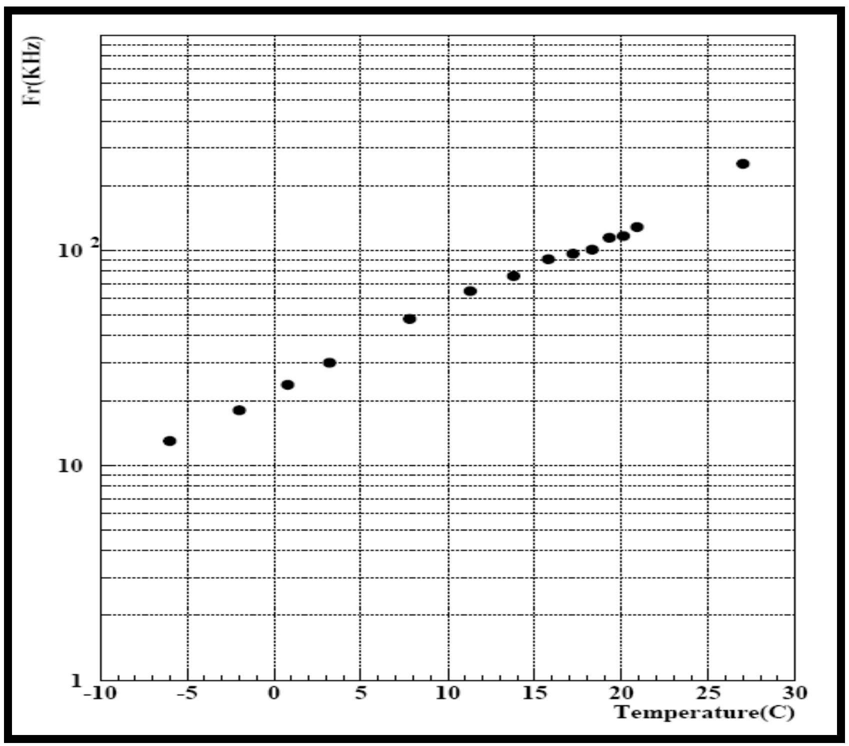
-Dark count rate is **evaluated in function of the temperature**



Peltier cell

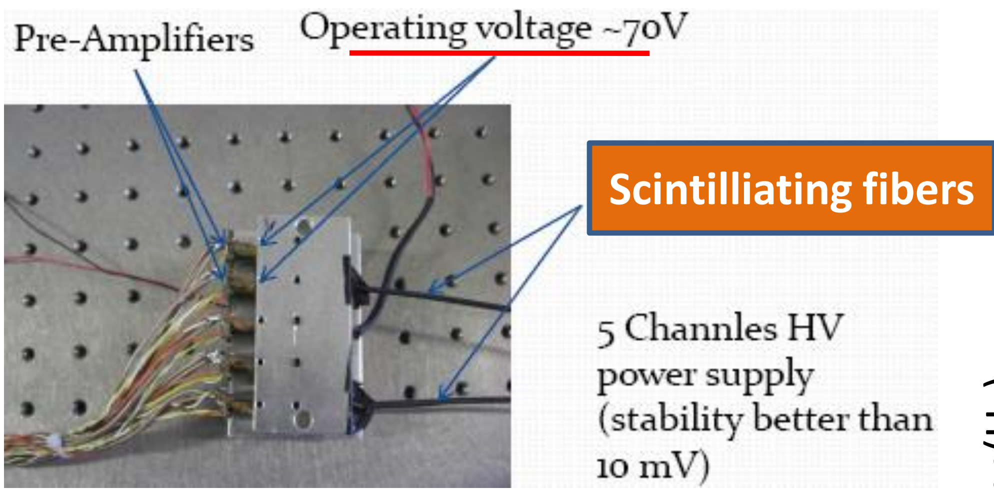
+

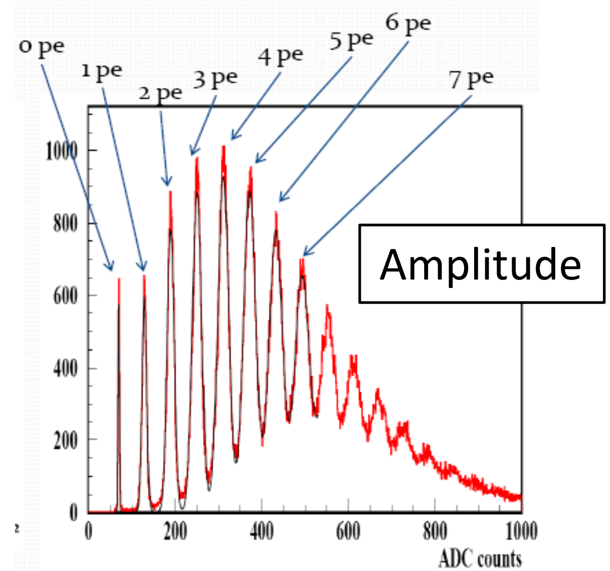
cooling system



ScFi + SiPM tests

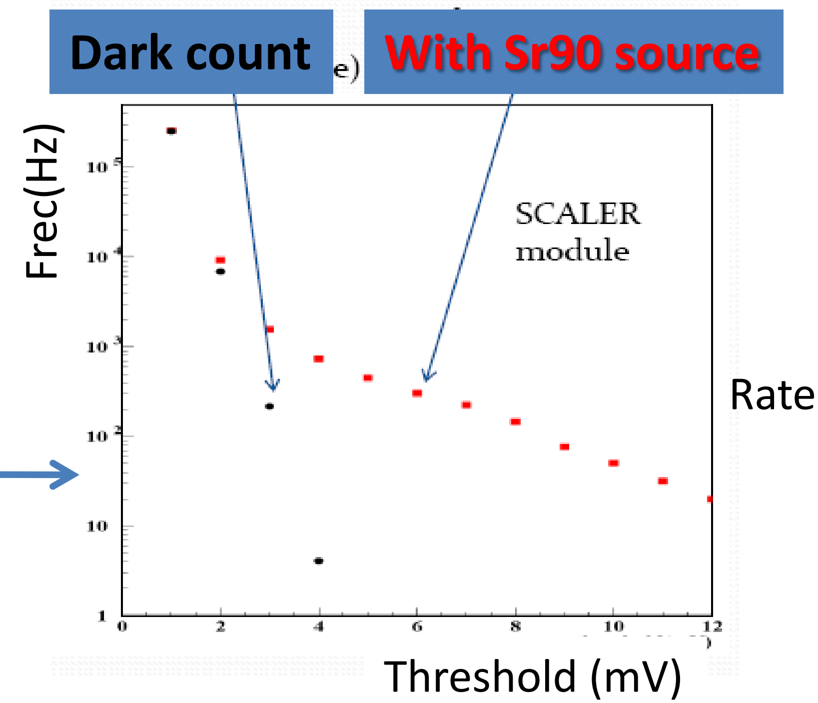
Signal in **fibers** with **Sr90 β source** (e$^-$ ~2.2 MeV)





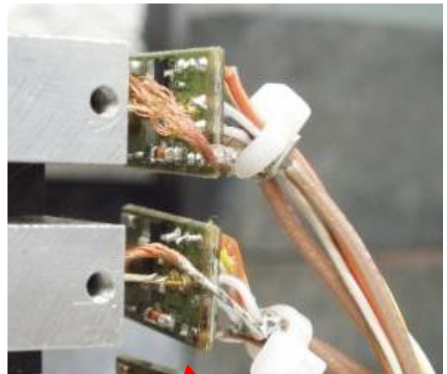
-Dark noise rate practically **absent for > 3 phe signals**

-Signal un-masked by dark noise from 4 ph.e.

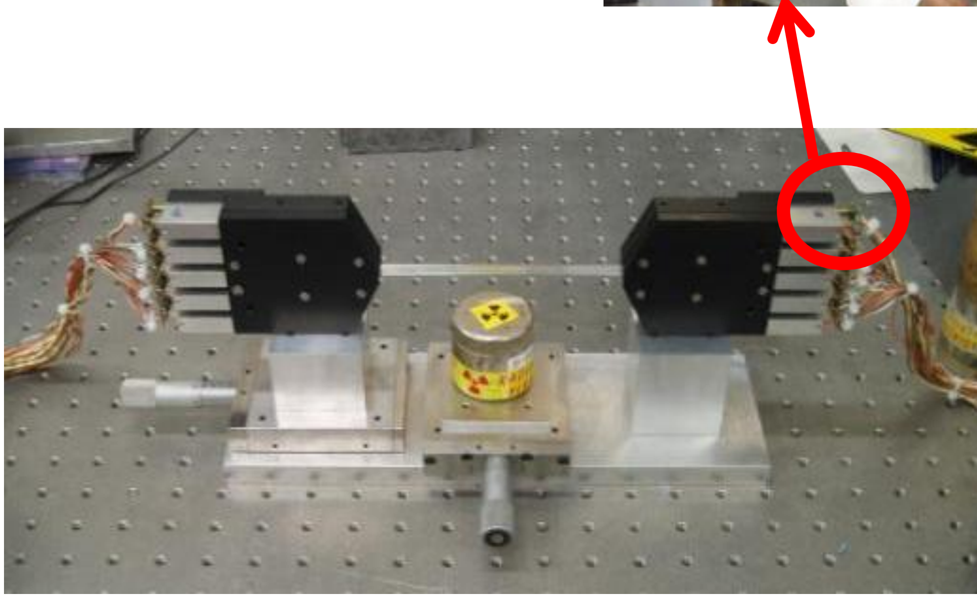


ScFi + SiPM tests

New mechanical support for
5 ScFi read from both sides
10 SiPM + readout card



Precission support for efficiencies studies

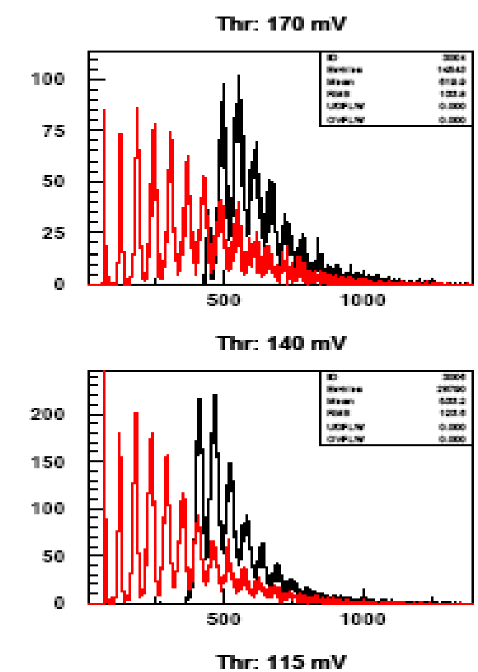


November, 2008

Instrumented fibers:

- Pol.Hi.Tech 46 (Blue)
- Saint Gobain BCF- 10 single cladding:
    - -Emission peak 432 nm
    - -Decay time 2,7 ns
    - -1/e 2.2 m
    - -80000 ph./MeV

Trigger SiPM
Signal SiPM



ScFi + SiPM next tasks

- Atenuation of signal with long fibers
- Absolute efficiency of fiber+SiPM coupling
- Response to no-MIP particles
- Monte Carlo simulation of # ph.e. / E.loss
- Time resolution:
  - Laser
- Signal separation in time
  - Laser + mirrors
- Collaboration with SMI group testing SiPM for FOPI: results + Hardware sharing
  - SMI-group has tested behaviour of SiPM under strong magnetid fields (up to 4T)

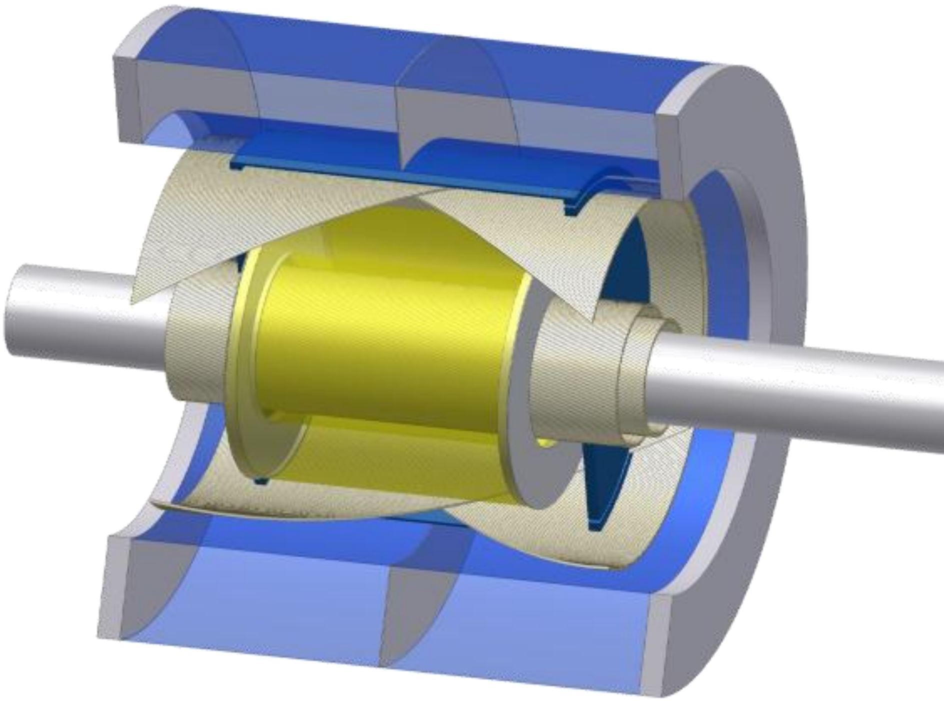
Inner tracker

- **TPG**

  - Time projection chamber with Gem readout

  - Multi-layer gem

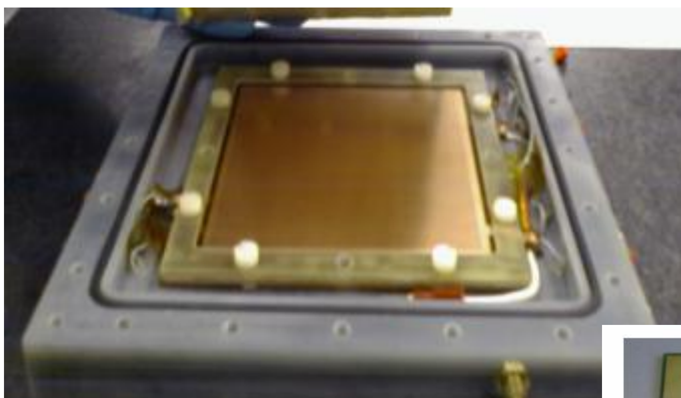
  - Vertex detector near to the interaction point



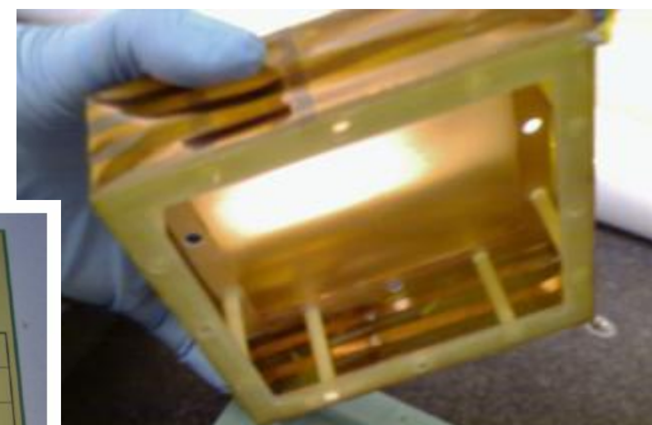
TPG

The TPG chamber has been constructed by F. Murtas in the framework of experiment IMAGEM – INFN – CSN5 for beam diagnostic purpose

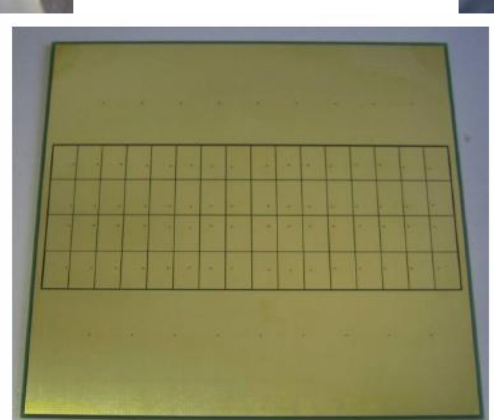
The detector was realized with standard 10x10 cm^2 GEMs inside a G10 gas-tightness box



A drift gap of 4 cm was built to increase the uniformity of the drift field, a field cage was built using 3 copper strips on kapton foil

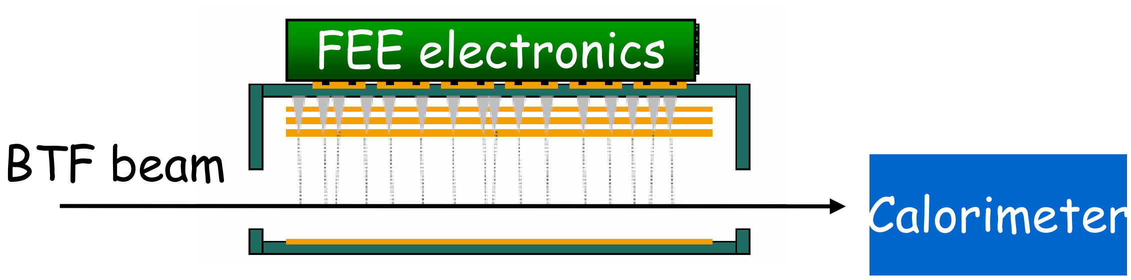


The pad readout was organized in 4 rows with 16 pads each



TPG tests: BTF run

16 channels for each board



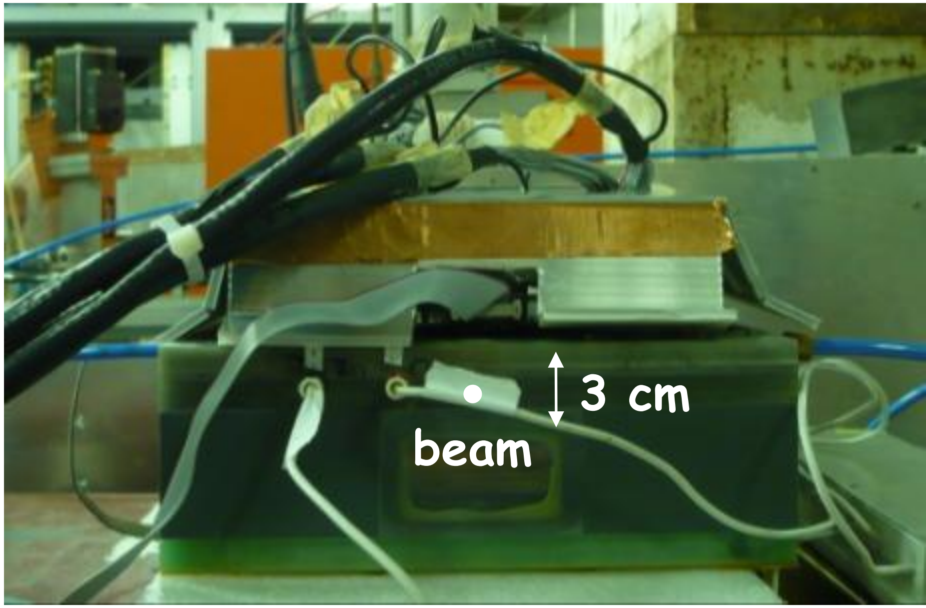
box cross section

- Multi-hit TDC record the leading edge (time hit) and the width of each signal

The noise rate < 100 Hz @ thr=200 mV on the whole detector (64 pads)

The calorimeter signal used to discriminate the number of electrons

Tests by M. Poli Lener, A. Rizzo
October / November 2008



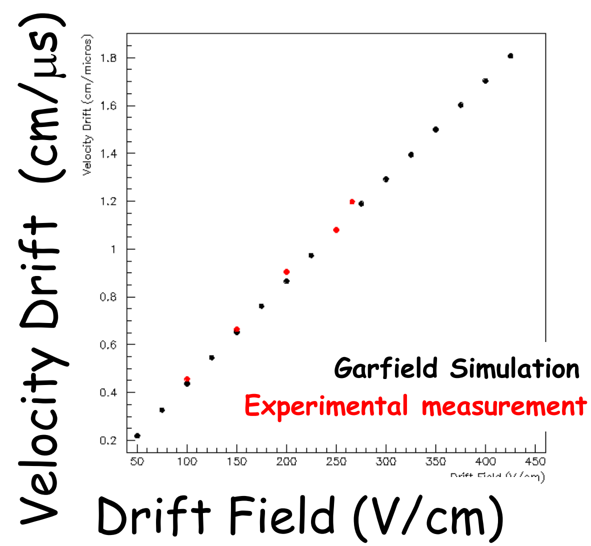
TPG tests: BTF run

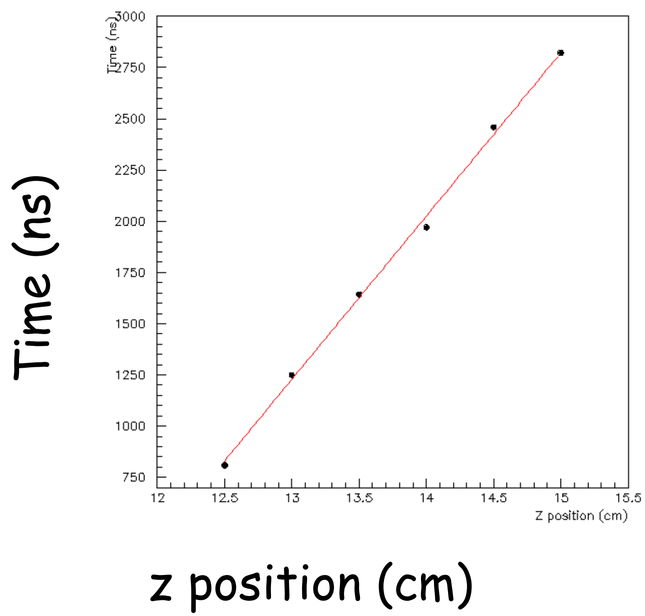
Meeasurement of the **velocity drift** for the **$Ar/CO_2/CF_4$ (45/15/40)** gas mixture.

moving the detector in **z** and changing **drift field**

The results agree with **Garfield simulation**

Drift velocity estimated by Garfield = (1.29 ± 0.01) cm/μs
@ 300 V/cm, T=24 °C, P= 993 mbar





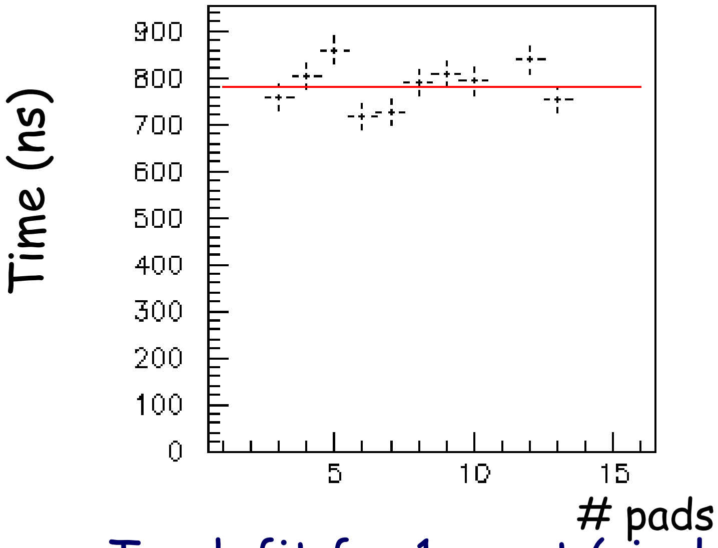
V_d = (1.25 ± 0.03) cm/μs

@ 300 V/cm, T=24 °C, P= 993 mbar

TPG tests: BTF run

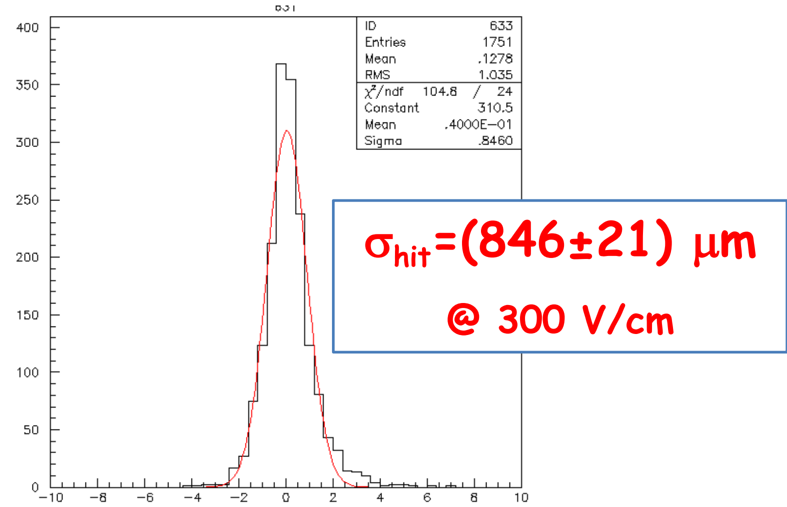
Time calibration run performed to take into account drift field dis-uniformity and ambient parameters variation.

- T0 measurements applied on each channel
- fit track procedure



Track fit for 1 event (single e-)

The distance of each hit from the estimated track allow to measure the single hit resolution in z for the **$Ar/CO_2/CF_4$ (45/15/40)** gas mixture



Residual on z-track (mm)

TPG tests: BTF run

Time calibration run performed to take into account drift field dis-uniformity and ambient parameters variation.

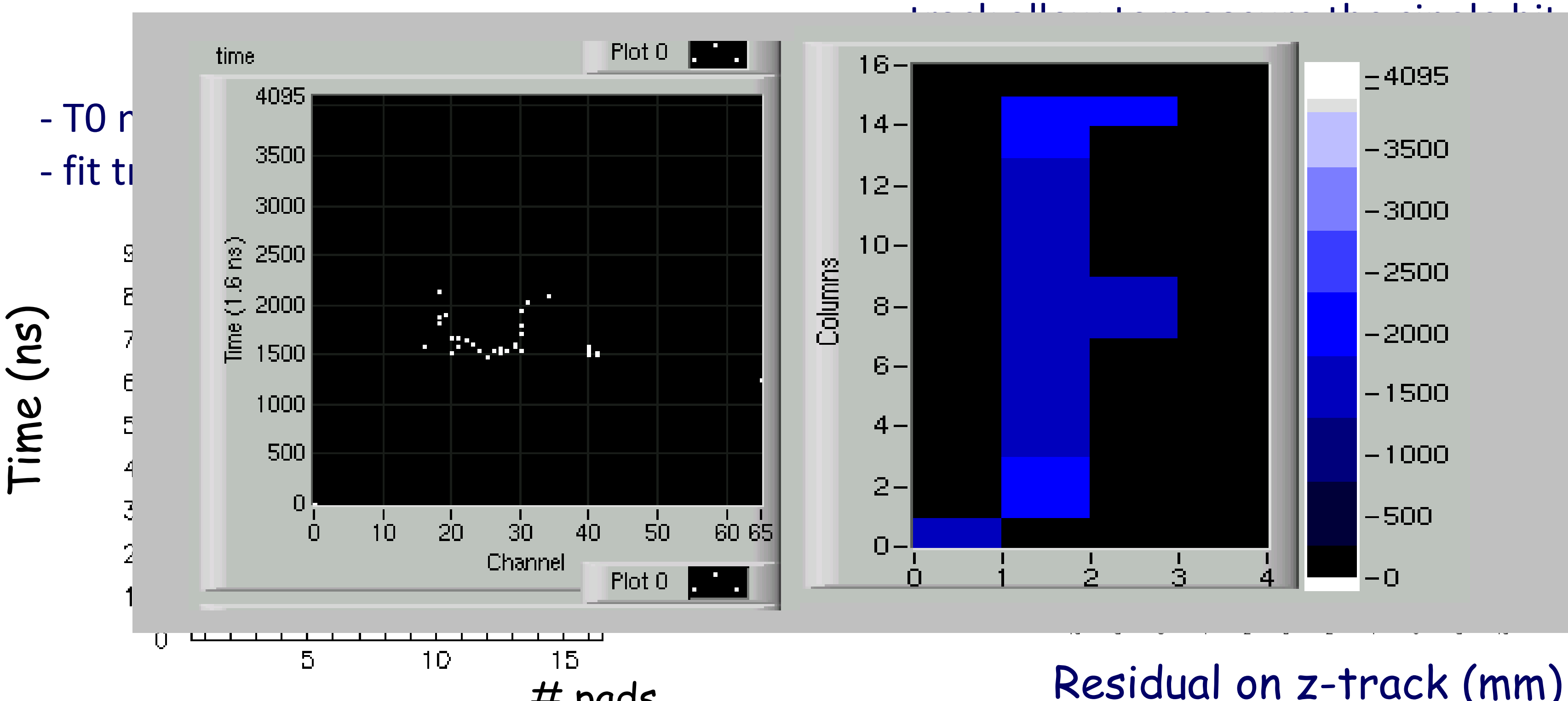
The distance of each hit from the estimated

- T0 r
- fit tr

/15/40)

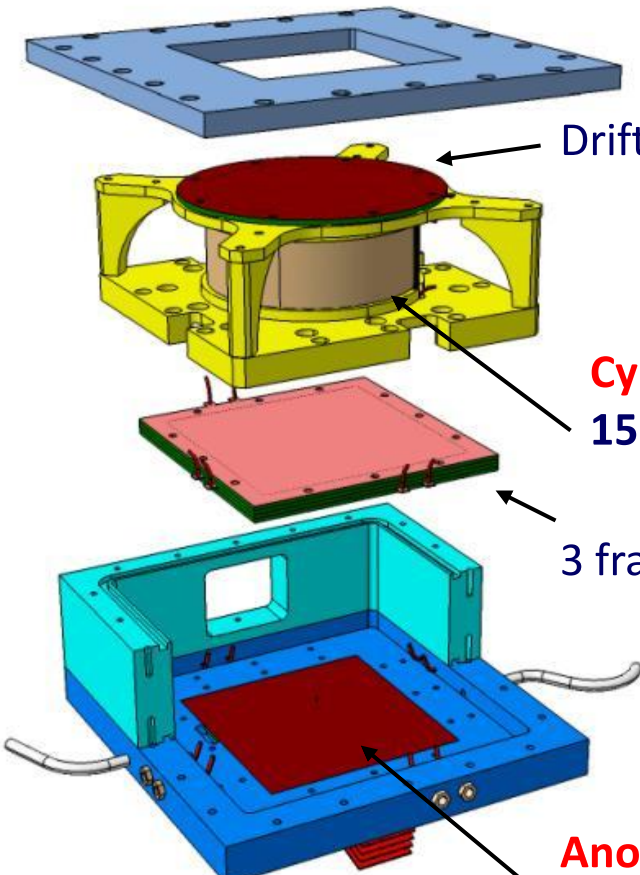
21) µm

/cm



Track fit for 1 event (single e⁻)

TPG: Next steps



Drift electrode

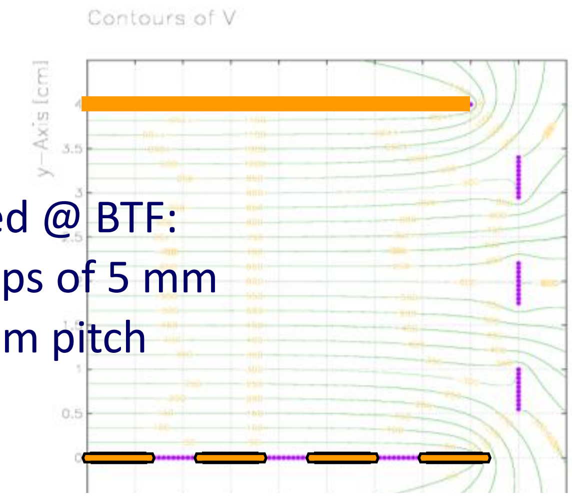
Cylindrical Field Cage
15 strips

3 framed GEM

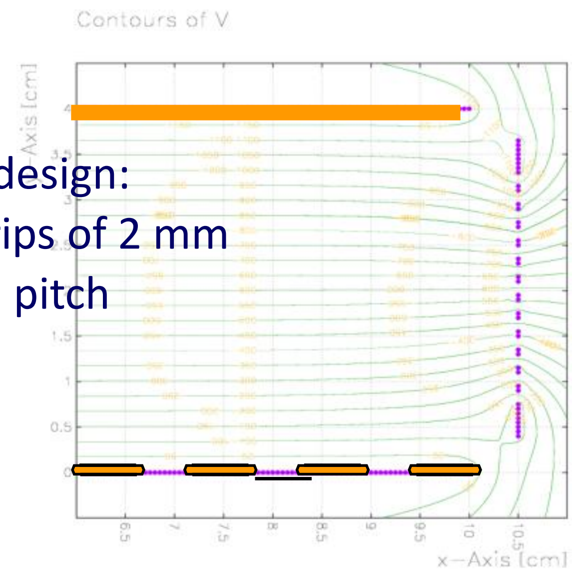
Anode Read-out
(pads / strip X-Y)

Drawing by C. Capoccia

Field Cage Simulation



Tested @ BTF:
3 strips of 5 mm
10 mm pitch



New design:
14 strips of 2 mm
3 mm pitch

Simulation by Fan Ruirui

- Detector performances with different gas mixtures (Ar/CO_2, Ar/CH_4, Ar/CF_4) will be studied

Slow controls and DAQ

- ***Alessandro D'Uffizi*** – from AMADEUS team: works with KLOE team for both:
  - -> Slow Controls
  - -> DAQ

Development of an C++ language online monitoring via CAENET for all the working parameters of the EMC and DC of KLOE (high and low voltages).

Coordination of the AMADEUS specific integration in the online monitoring

Luminosity request

The luminosity request for AMADEUS Phase-1 is:

- 2 fb^{-1} of integrated luminosity with **He^4** target in order to study the tribaryon DBKNS
- 1-2 fb^{-1} of integrated luminosity with **He^3** target in order to study the dibaryon DBKNS
- 0.5 fb^{-1} of integrated luminosity for **low-energy kaon-nuclear** dedicated measurements

overall integrated luminosity of 3.5 - 4 fb^{-1} with 500 pb^{-1}/month, 10 months

AMADEUS Phase-2 (after 2012)

- increase the statistics for di- tri-baryon DBKNS
- study DBKNS produced in heavier targets as: Li, B, Be, C …
- complete the physics program by:

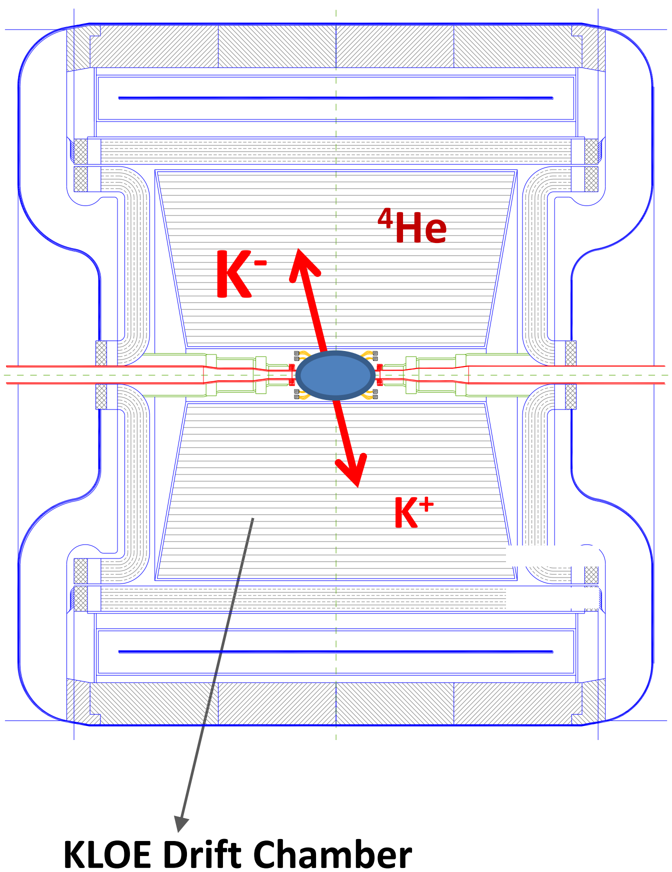
binding energies, decay widths and – determination of quantum numbers of all states, including excited ones, measurement of the spin-orbit interaction, determination of partial widths of kaonic nuclear states by observation of all decay channels, Dalitz plots

-Continue studies of kaon-nucleon/nuclei interaction

Integrated luminosity request of about 10-20 fb^{-1}

Analysis of K^{-}He KLOE data

Analysis of kloe data



•Statistics:

•Total amount of data analyzed up to an integrated luminosity of ~**1,1 fb^{-1}** from KLOE data (K-charged group).

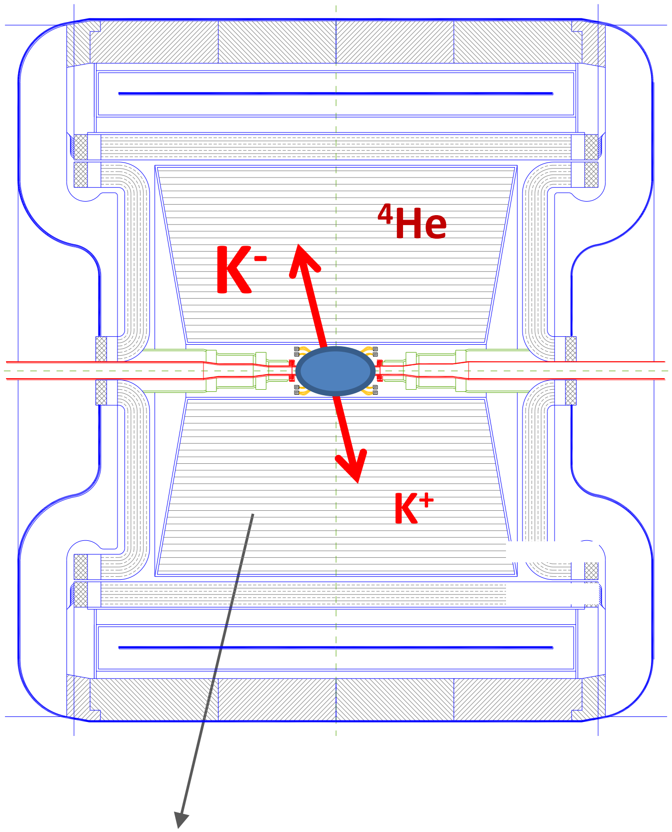
•Special ntuples of KLOE data were created, with kaons tagged by **2-body decay** or by the **dE/dx** signature in the DC gas.

•Strategy:

Search for hadronic interactions with Λ(1115) as products:

- **$\Lambda \rightarrow p + \pi^-$** (64% BR) vertex made by KLOE reconstruction
- Construct a vertex with **Λ + an extra particle**

Analysis of kloe data

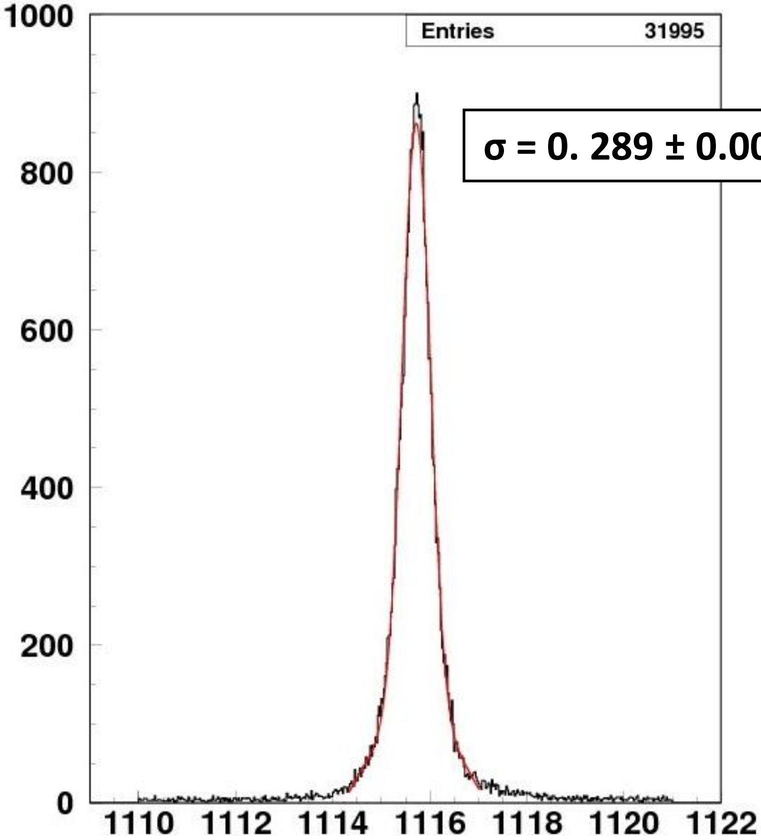


KLOE Drift Chamber

- **Lambda mass determination**
- **Lambda momentum spectra (comparison with FINUDA)**
- **Lambda-d correlations**
- **Sigma0-pi0 correlations**

Lambda invariant mass

$\Lambda \longrightarrow p + \pi^-$



M_{inv} pπ (MeV/c2)

σ = 0. 289 ± 0.003 MeV/c²

-Dedicated event selection to avoid Eloss in the DC wall

- Best $\chi 2$ tracks and vertices

KLOE:

M_{inv} = 1115,723 ± 0. 003 stat (MeV/c²)

PDG: M_Λ = 1115,683 ± 0.006 stat ± 0.006 syst **(MeV/c²)**

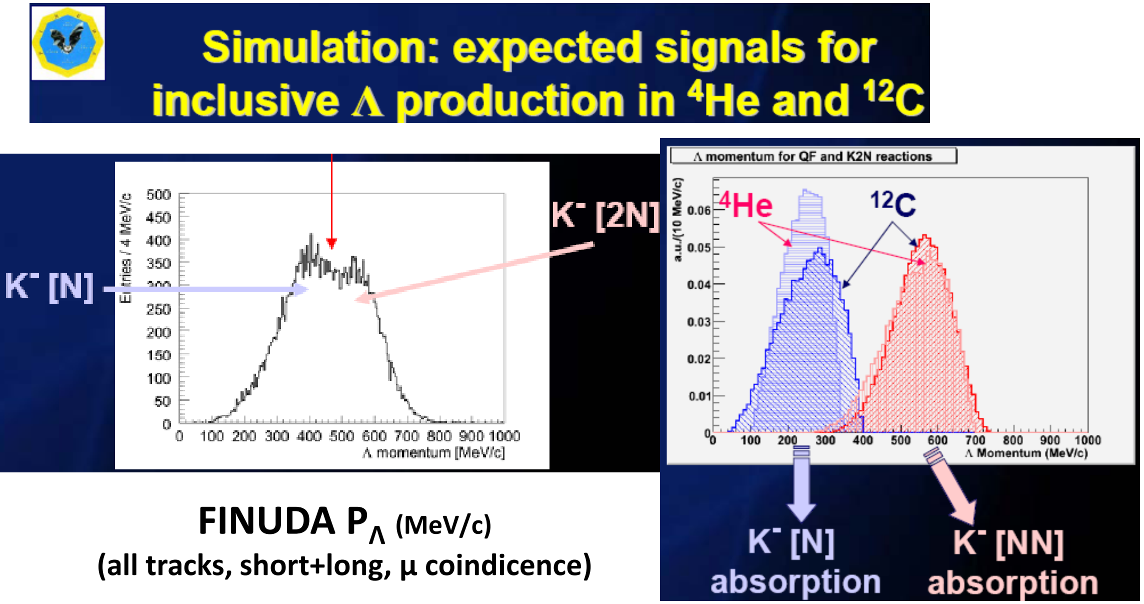
-Sistematics dependent of momentum calibration

-Evaluated by 2-body decay of $K^\pm$:

$K^\pm \rightarrow \mu^\pm \nu$

$K^\pm \rightarrow \pi^\pm \pi^0$

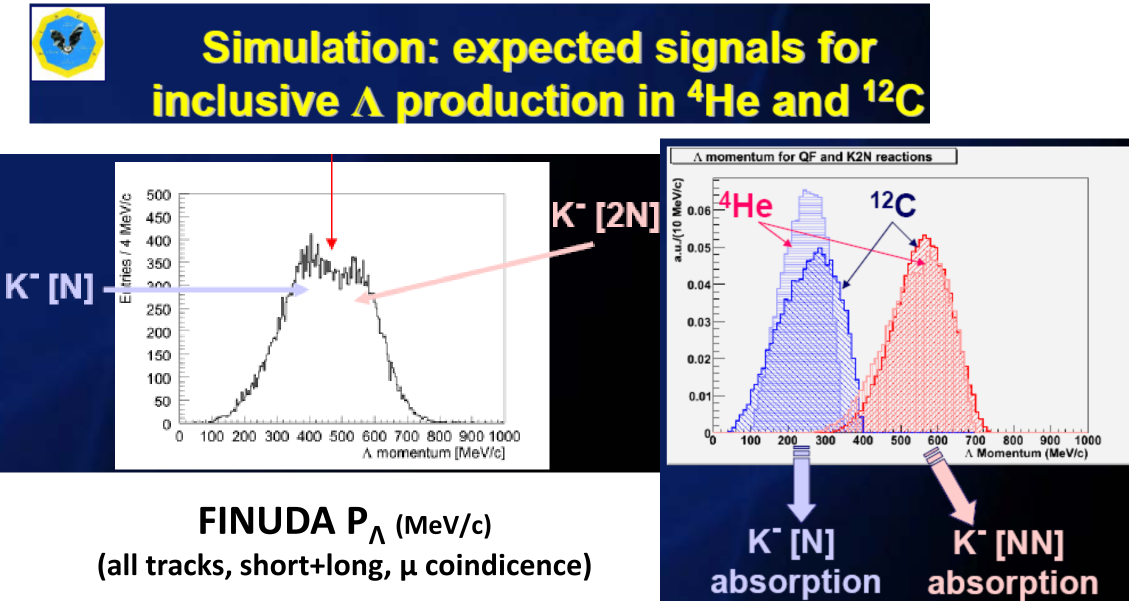
Lambda momentum



FINUDA P_{Λ} (MeV/c)
(all tracks, short+long, μ coindicence)

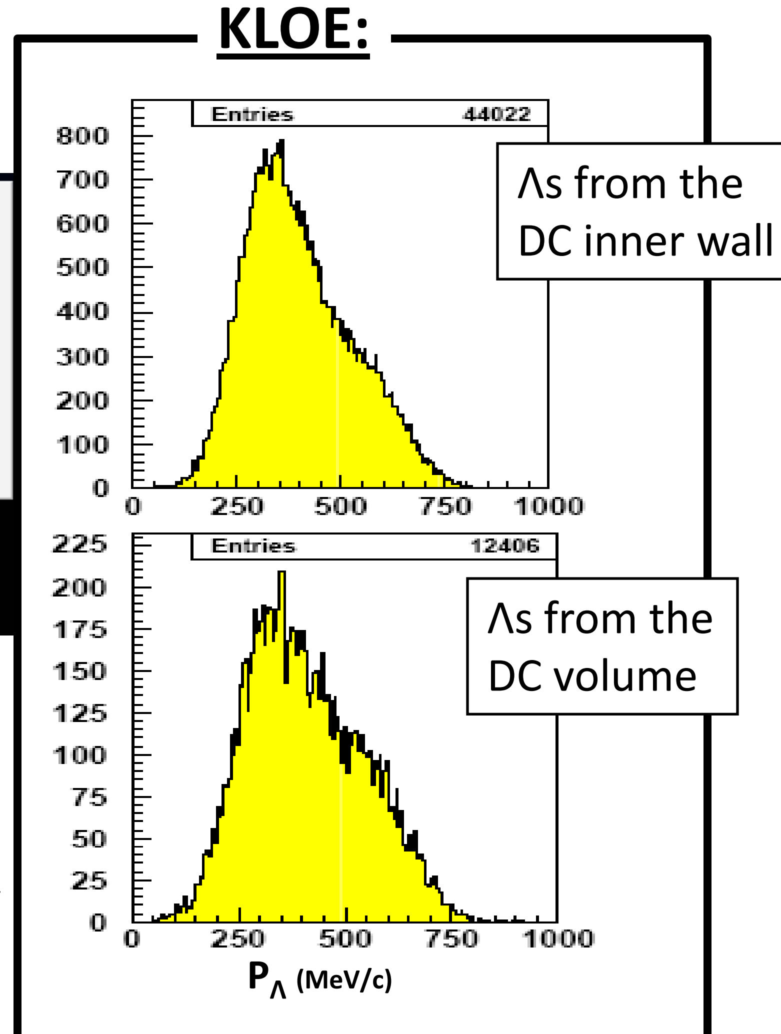
Thanks to S. Piano, A. Filippi

Lambda momentum



FINUDA P_Λ (MeV/c)
(all tracks, short+long, μ coindicence)

Thanks to S. Piano, A. Filippi



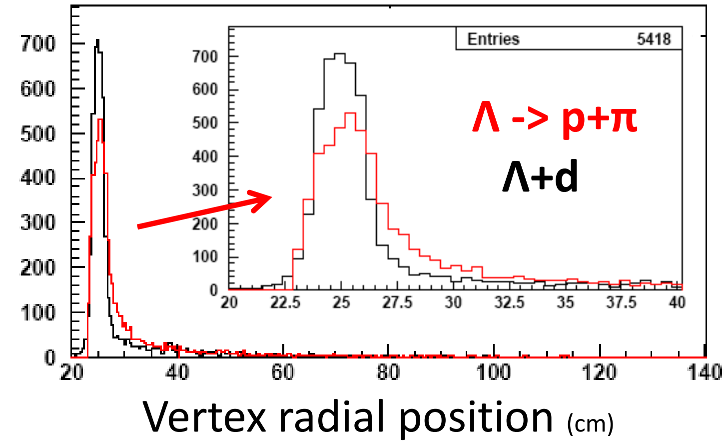
-Well defined double structure in both cases
-Similar momentum range
-Differences at lower momentum due to acceptancy
-**Perfectly compatible!!!**

Correlations: Lambda-d vertices

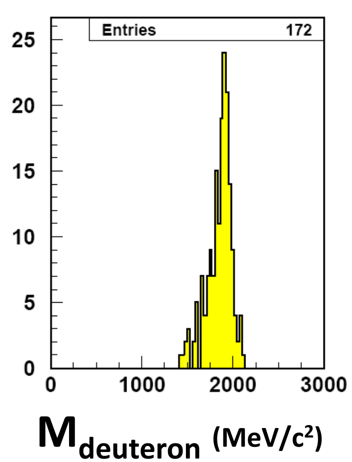
Improved Λd vertex reconstruction

Improved mass recognition (PID) of deuterons and protons

Improved selection of events in DC-gas

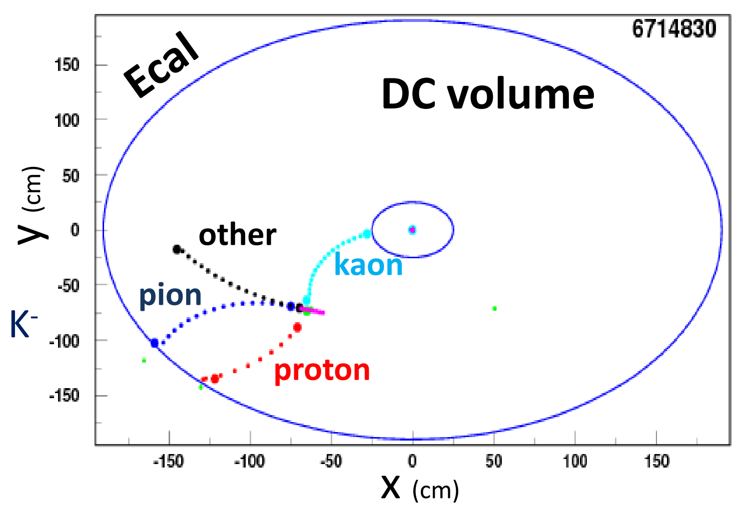


- Proton/deuteron candidates are required to have an associated cluster in the EMC and its mass is measured by **time of flight.**



-Require the presence of the tracked/extrapolated K⁻

-Check event display

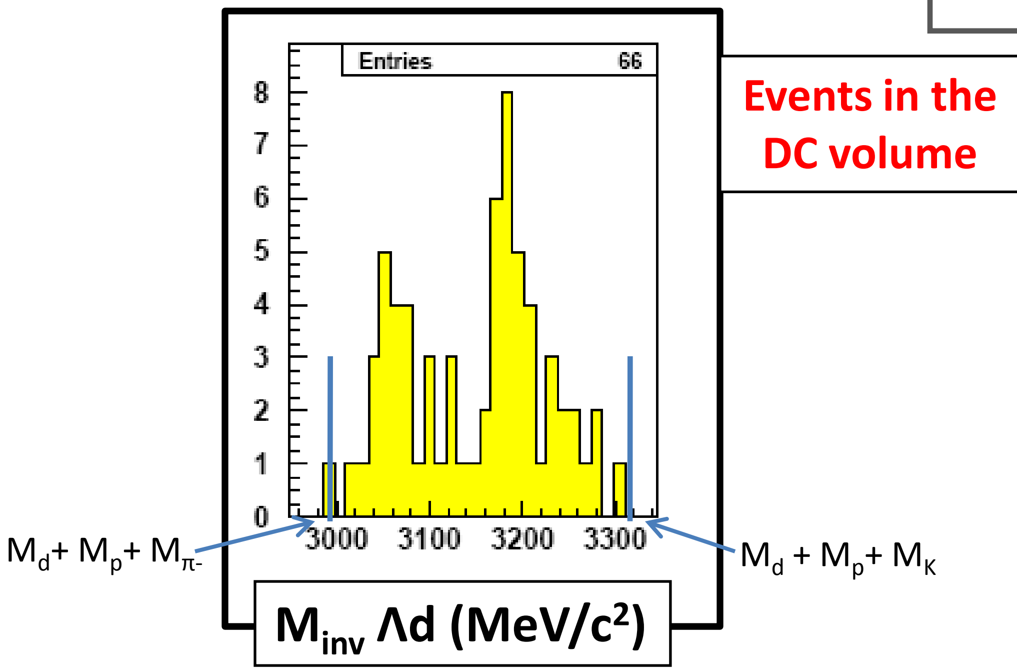


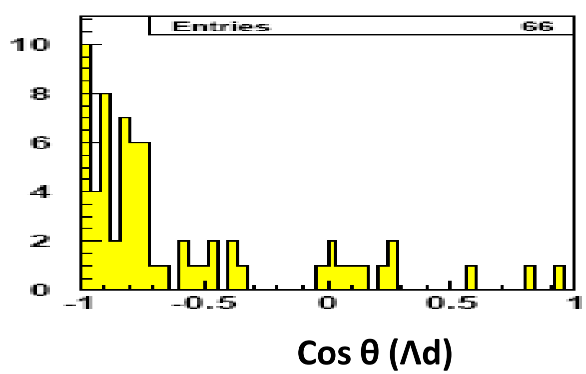
Lambda-d

$$K^-_{stopped} + {}^4He \rightarrow n + (\underline{K^- ppn})$$

$$\downarrow$$

$$\Lambda + d$$

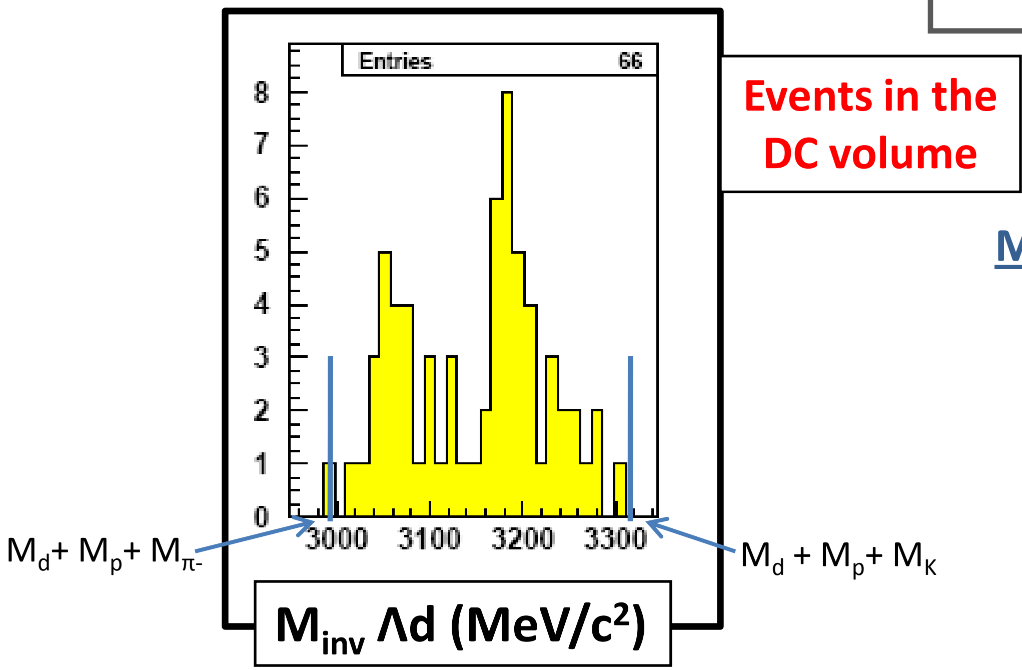


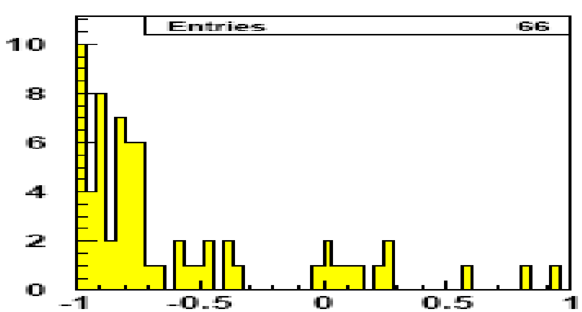


Lambda-d

$K^{-}_{stopped} + {}^{4}He \rightarrow n + (K^{-}ppn)$

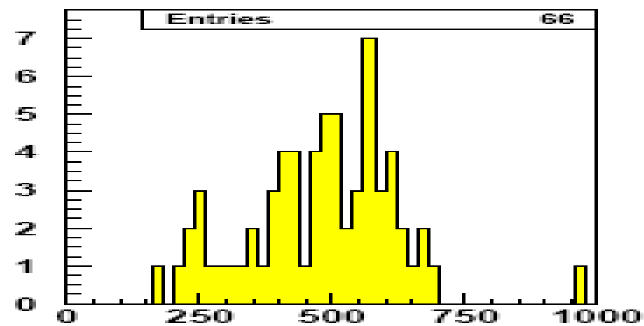
$(K^{-}ppn) \rightarrow \Lambda + d$



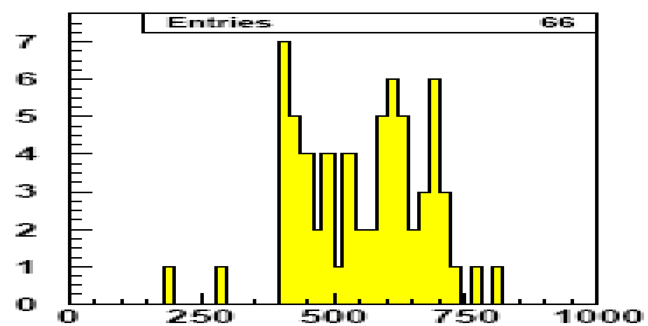


Cos θ (Λd)

Momentum of lambda and deuteron:



P_Λ (MeV/c)



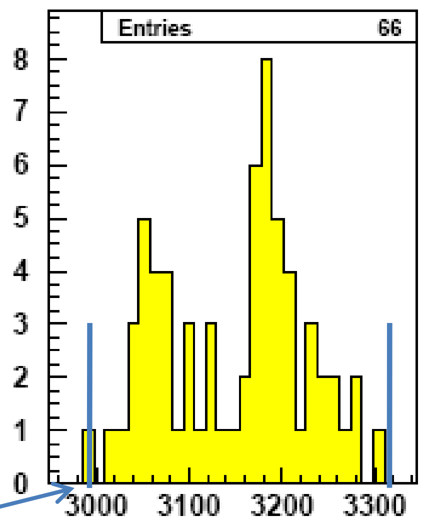
P_d (MeV/c)

Lambda-d

$K^-_{stopped} + {}^4He \rightarrow n + (K^-ppn)$

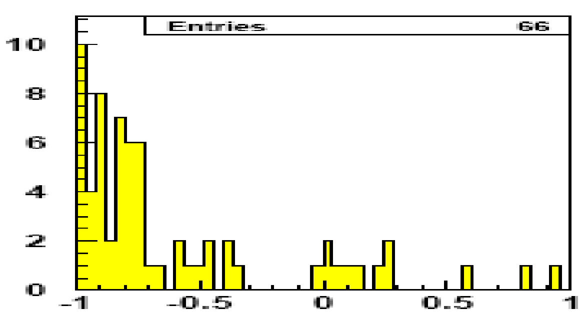
$\Lambda + d$

Events in the DC volume



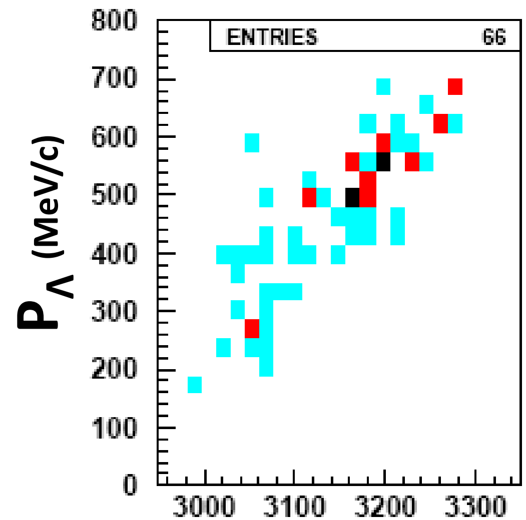
$M_d + M_p + M_{\pi^-}$

M_{inv} Λd (MeV/c^2)

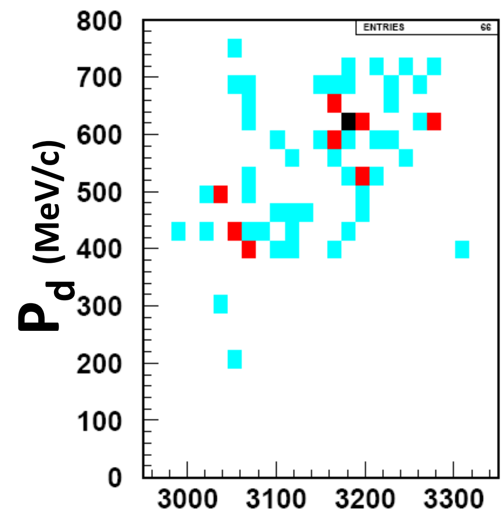


Cos θ (Λd)

lambda momentum vs. Minv



deuteron momentum vs. Minv

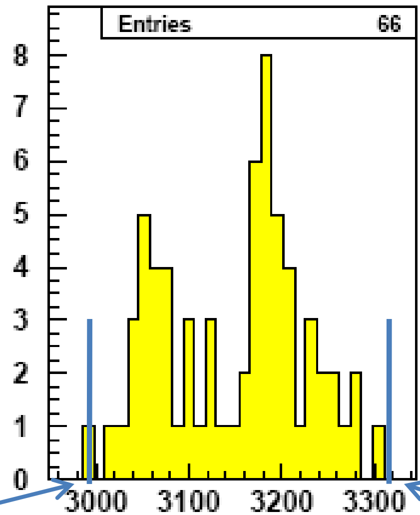


M_{inv} Λd (MeV/c^2)

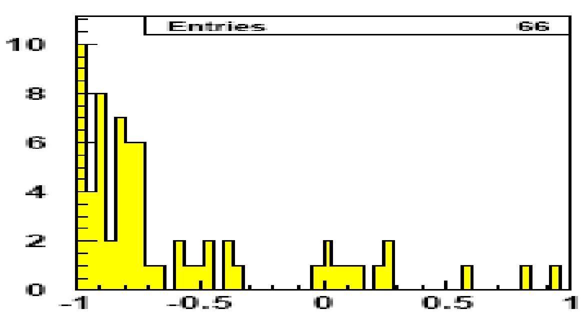
Lambda-d

$K^-_{stopped} + {}^4He \rightarrow n + (\underline{K^-ppn})$

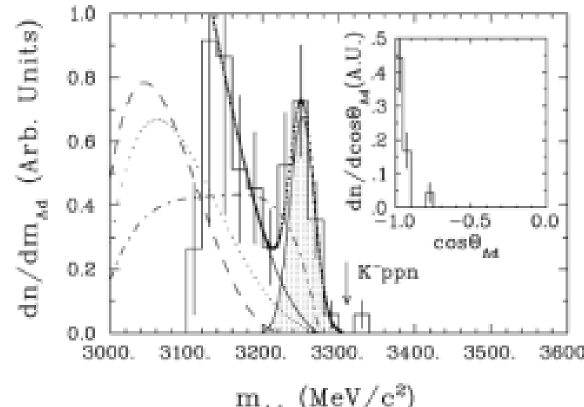
$\Lambda + d$



M_{inv} Λd (MeV/c²)

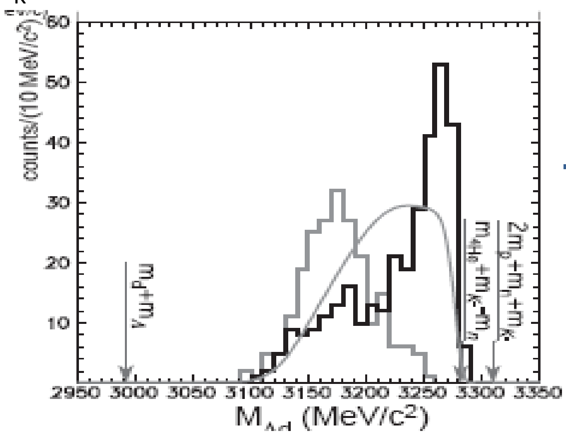


Cos θ (Λd)



FINUDA

K- stopped in light nuclei



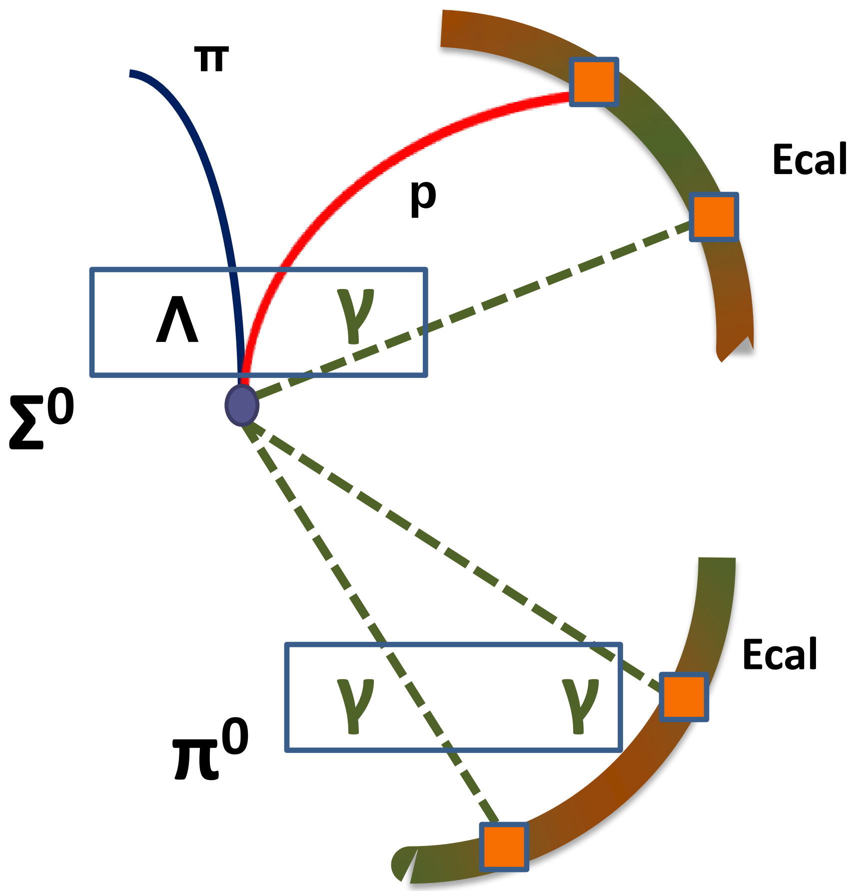
KEK

K- stopped in 4He

Sigma0-pi0

Λ(1405)/Λ(1420) search

- **Strongly related with the deeply bound kaonic states prediction**
- **Lack of experimental data**



Kinematic fit:

- $\chi 2$ computing:
  - -momentum of proton and pion
  - -Covariance matrix elements for every track
  - -time and positions plus resolutions for photons
- **Allows to reject background selecting the right combination of photons**
- Constraints: Δt for the arrival time of photons
- No mass assumption -> unbiased mass spectras

Sigma0-pi0

Λ(1405)/Λ(1420) search

- **Strongly related with the deeply bound kaonic states prediction**
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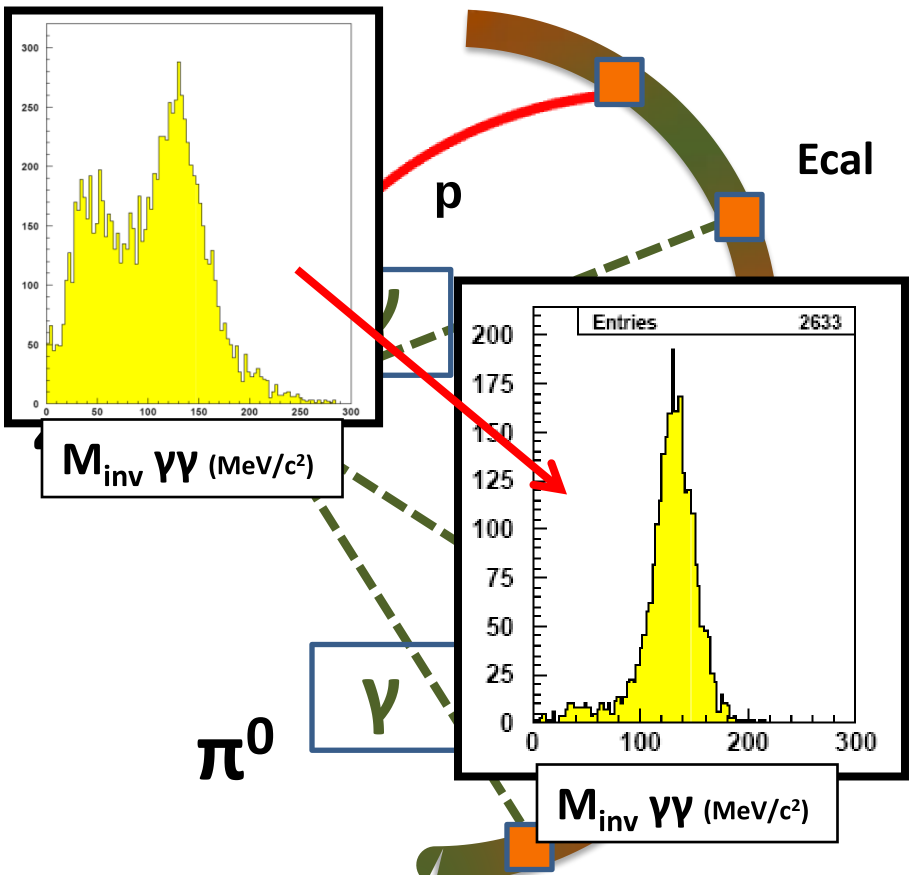

Kinematic fit:

- χ2 computing:
  - -momentum of proton and pion
  - -Covariance matrix elements for every track
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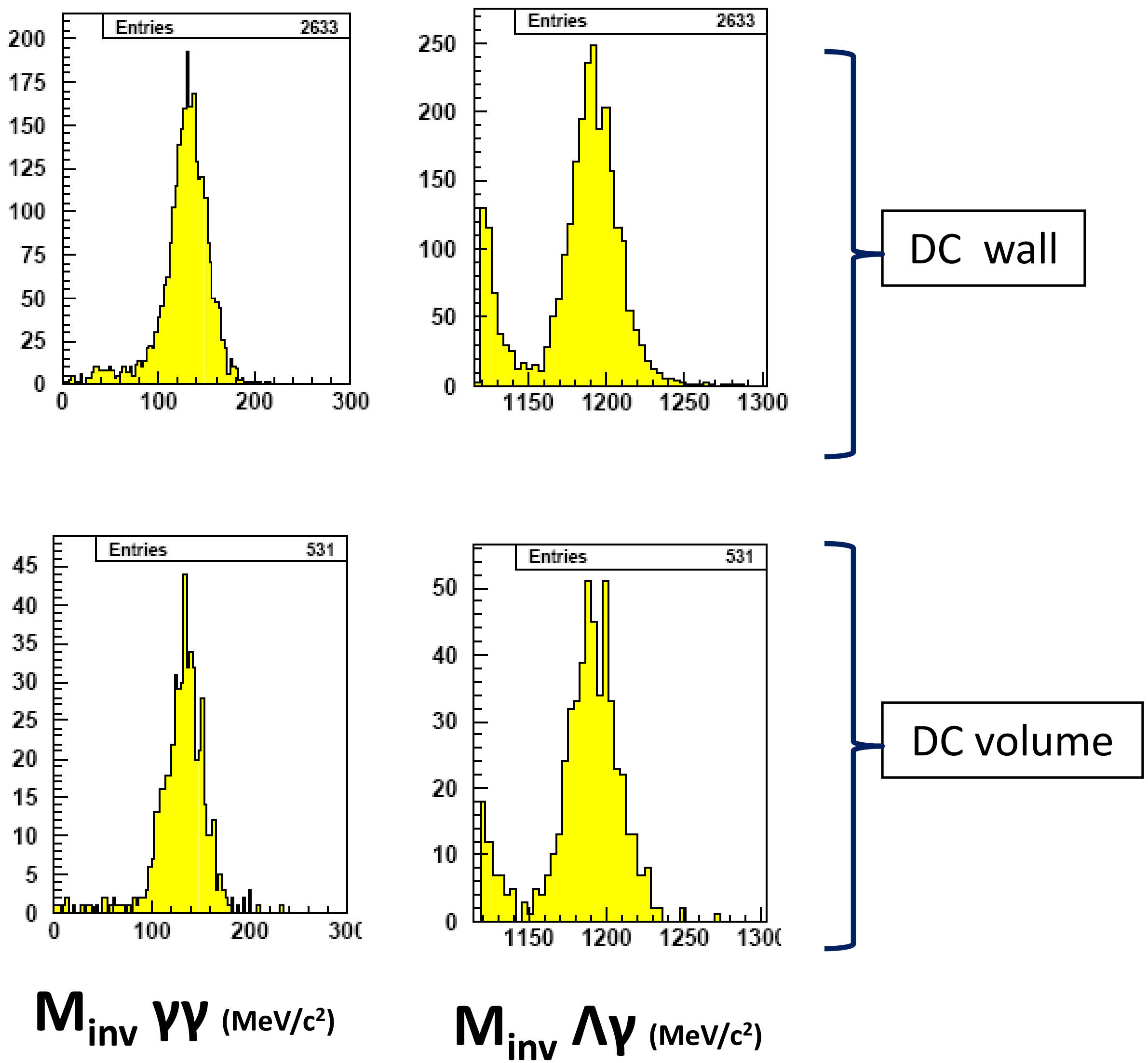
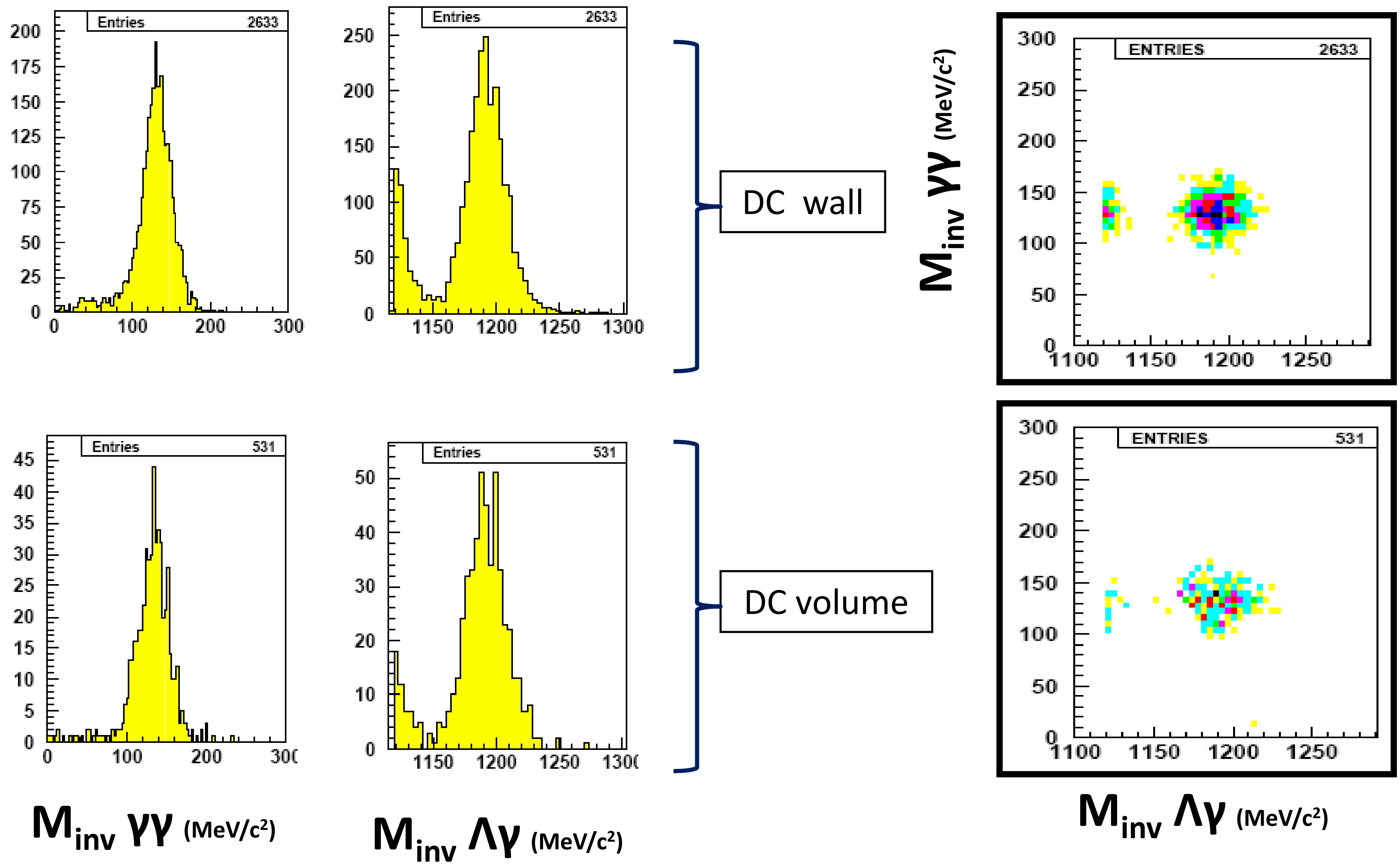
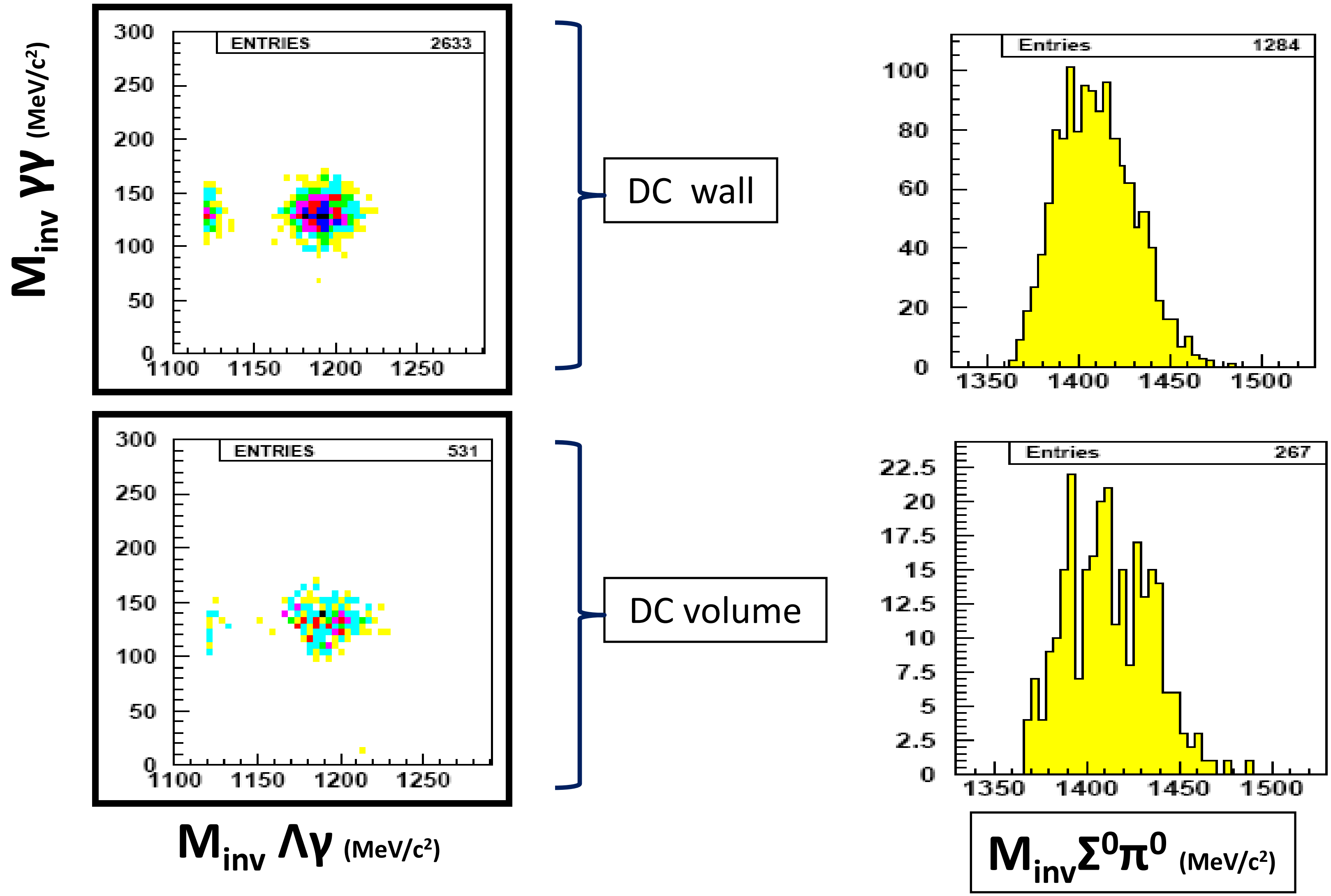
Sigma0-pi0


Entries 2633
Entries 2633
DC wall
Entries 531
Entries 531
DC volume
M_{inv} γγ (MeV/c²)
M_{inv} Λγ (MeV/c²)

Sigma0-pi0


Entries 2633
Entries 2633
DC wall
ENTRIES 2633
Entries 531
Entries 531
DC volume
ENTRIES 531
M_{inv} γγ (MeV/c²)
M_{inv} Λγ (MeV/c²)
M_{inv} γγ (MeV/c²)
M_{inv} Λγ (MeV/c²)

Sigma0-pi0


ENTRIES 2633
ENTRIES 531
Entries 1284
Entries 267
DC wall
DC volume
M_{inv} γγ (MeV/c²)
M_{inv} Λγ (MeV/c²)
$M_{inv} \Sigma^0 \pi^0$ (MeV/c²)

Sigma0-pi0

$\pi^- p \rightarrow K^0 \Sigma^0 \pi^0$ (solid line) PDG

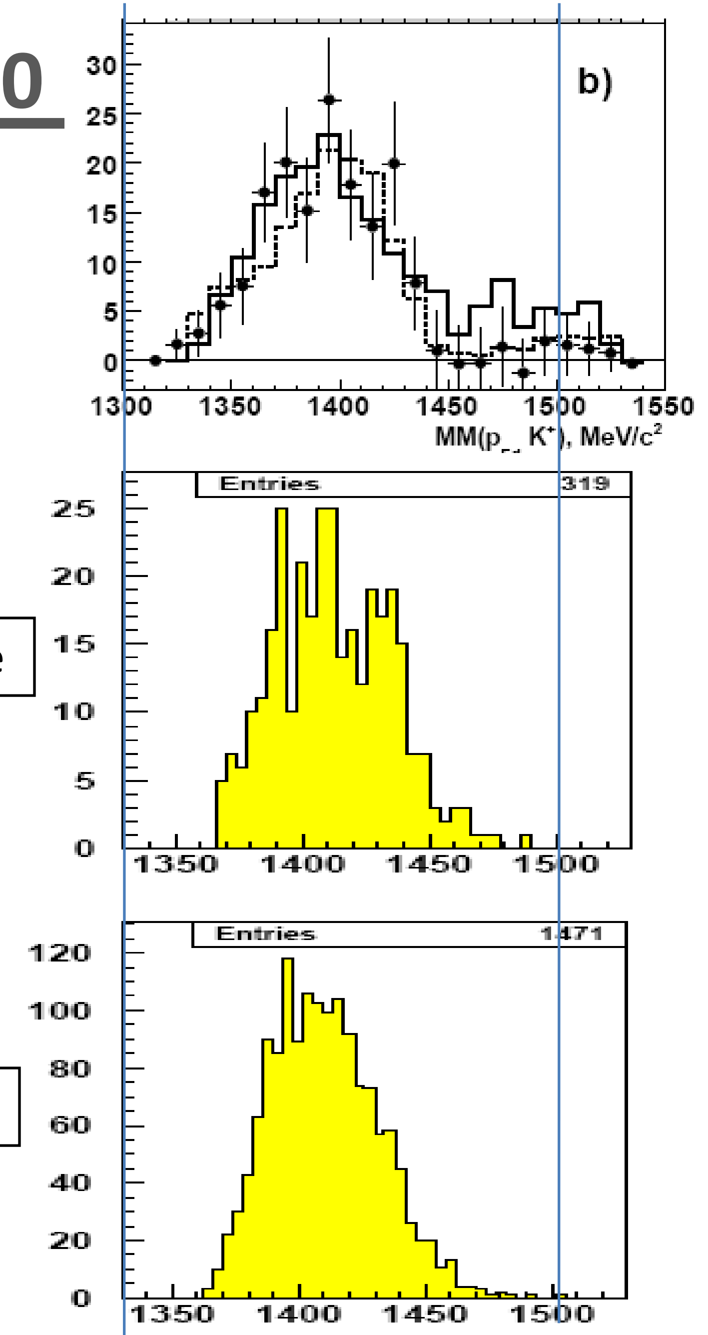
$K^- p \rightarrow \pi^+ \pi^- \Sigma^+ \pi^-$ (dotted line) PDG

$pp \rightarrow p K^+ Y^0$ (points with errors) 2007

Comparison with available experimental data

DC volume

DC wall



Future goals

* Complete the analysis and publish the results for:

-Lambda invariant mass
-Lambda-p
-Lambda-d
-Lambda-t
-Sigma0-pi0

Thanks to the KLOE collaboration and the KLOE K-charged group,
Specially to E. de Lucia, V. Patera, A. de Santis

Many thanks from the electronic part to G. Corradi, D. Tagnani, C. Paglia

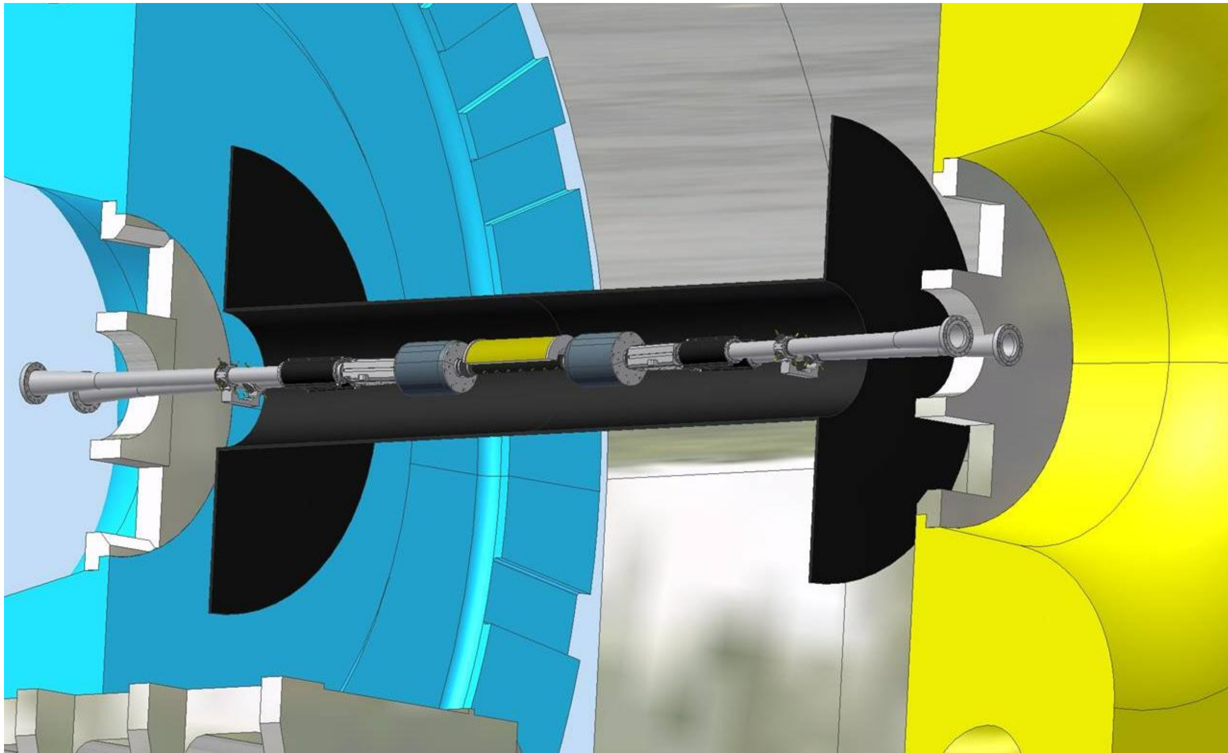
Many thanks as well to C. Capoccia

Beam pipe

Technical items needing special attention

(35th LNF Scientific Committee)

- **The beam pipe**: we plan to develop (with KLOE and DAFNE) a technical solution which should be easy to extract/implement.



Preparation, implementation plan and roll-in proposal

- **2009 and 2010:** take part to KLOE maintenance, roll-in and data taking (training)

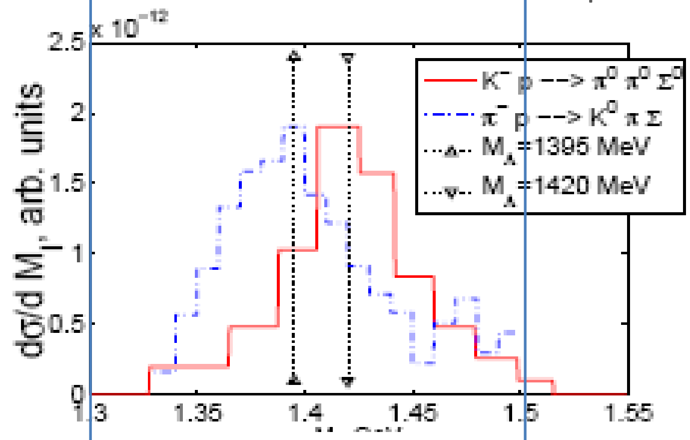
• **AMADEUS construction and assembly:** the AMADEUS inner setup - the specific one - will be built, assembled and tested in 2009/2010 so as to be ready for:

• **roll-in of AMADEUS:** roll-in in 2010/2011, compatible with KLOE end of step 0.

• **AMADEUS DAQ:** for an integrated luminosity of about 4 fb^{-1} in 2011.

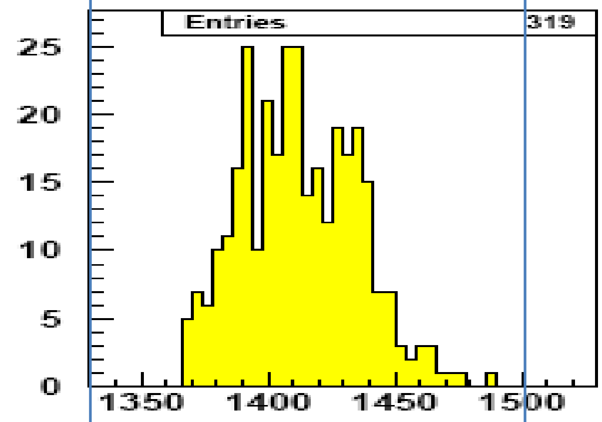
In parallel – AMADEUS phase2

Sigma0-pi0



Comparison with available experimental data

DC volume



DC wall