



KLM detector for SuperB

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1st Open meeting of the SuperKEKB Collaboration

Motivation for a new KLM design

- **The present RPC design for KLM demonstrated nice performance at Belle**
- However, the efficiency decrease is observed due to high neutron background and large RPC dead time. The effect is not significant at barrel, but large for the endcap KLM.

- Barrel : try to recover efficiency

- **With SuperKEKB luminosity, it is still possible to use RPC in the barrel with moderate modification: streamer/avalanche mode, faster gas mixture, shield in the innermost gap**

efficiency at KEKB

Layer	Barrel	E fwd	E bwd
0	0.91	0.91	0.90
1	0.94	0.93	0.90
2	0.96	0.94	0.90
3	0.98	0.94	0.90
4	0.98	0.94	0.89
5	0.99	0.92	0.88
6	0.99	0.93	0.89
7	0.99	0.92	0.87
8	0.99	0.92	0.86
9	0.99	0.90	0.85
10	0.99	0.87	0.82
11	0.99	0.82	0.80
12	0.99	0.78	0.81
13	0.99	0.77	0.76
14	0.99	N/A	N/A

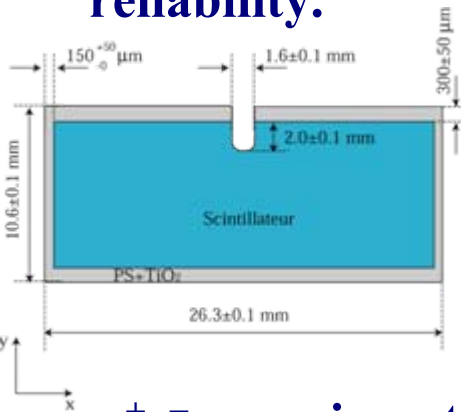
efficiency at SuperKEKB

Layer	Barrel	E fwd	E bwd
0	0.70	0.0	0.0
1	0.81	0.0	0.0
2	0.87	0.0	0.0
3	0.91	0.0	0.0
4	0.94	0.0	0.0
5	0.95	0.0	0.0
6	0.95	0.0	0.0
7	0.96	0.0	0.0
8	0.94	0.0	0.0
9	0.96	0.0	0.0
10	0.98	0.0	0.0
11	0.97	0.0	0.0
12	0.96	0.0	0.0
13	0.97	0.0	0.0
14	0.96	N/A	N/A

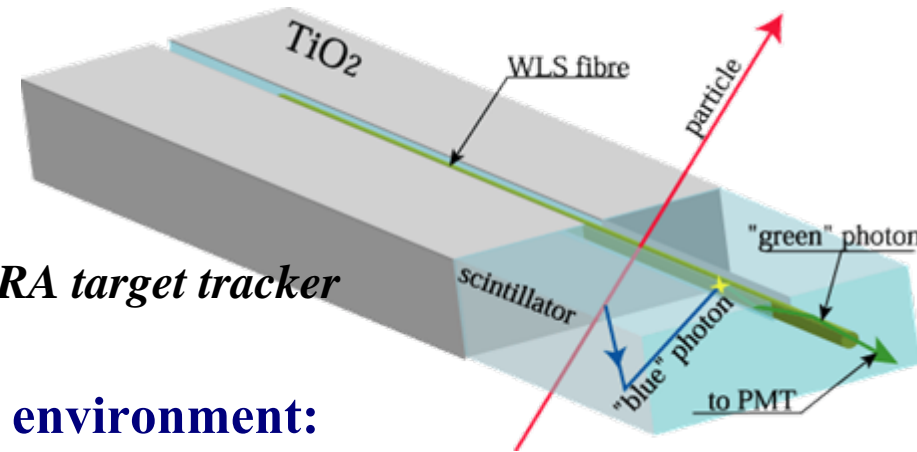
- However, the efficiency of endcap KLM becomes unacceptably low and new fast detector is required.

Scintillator option for endcap KLM

- Plastic scintillator + WLS fiber read out successful in many neutrino experiments (MINOS, MINERva etc) and very popular in the new neutrino experiments (OPERA, T2K near detector), because of relatively low price, high reliability.

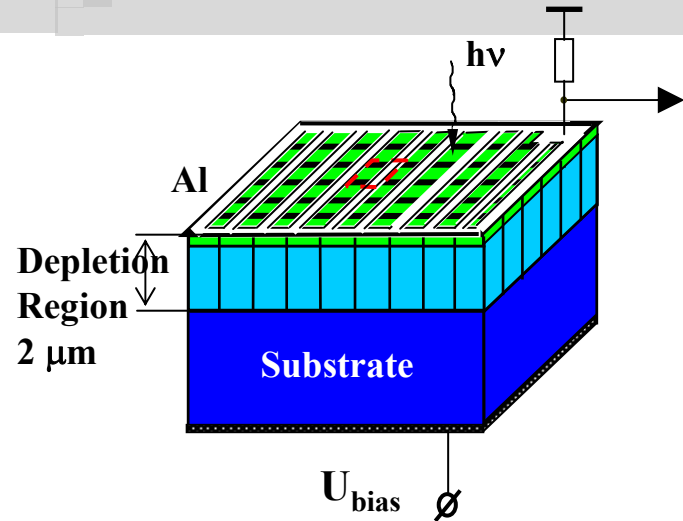


Scintillator strips for OPERA target tracker

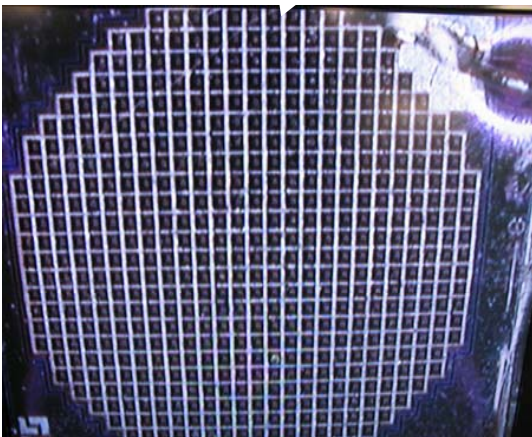
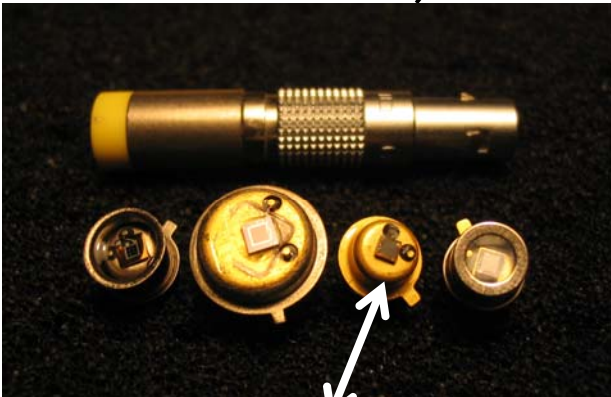


- e^+e^- experiments has (slightly) different environment:
 - Higher occupancies
 - Radiation
 - (Huge) magnetic field
 - Limited space
- The extra requirements due to these new environments are ok for scintillator and WLS fiber;
- The choice of photodetector is the key question:
 - Photomultipliers are not compact and poorly operates in the magnetic field.
 - New multipixel Si photo diodes operating in Geiger mode are tiny and insensitive to the magnetic field.

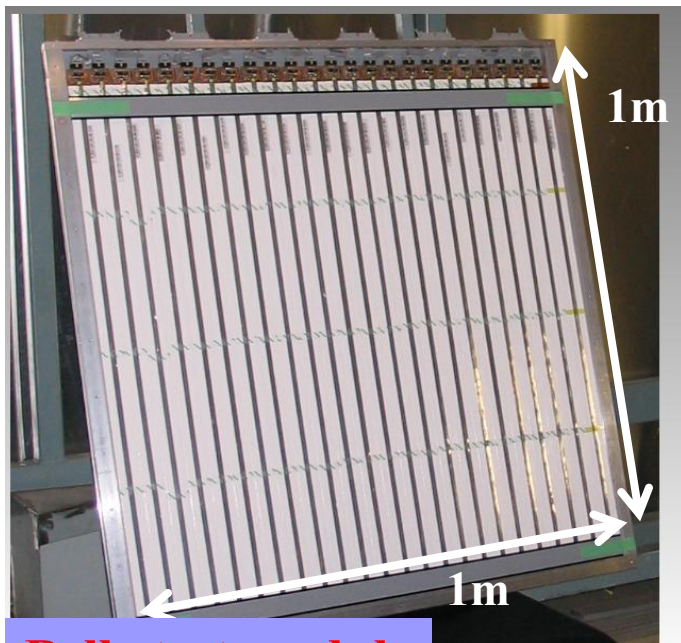
Geiger Photo Diodes



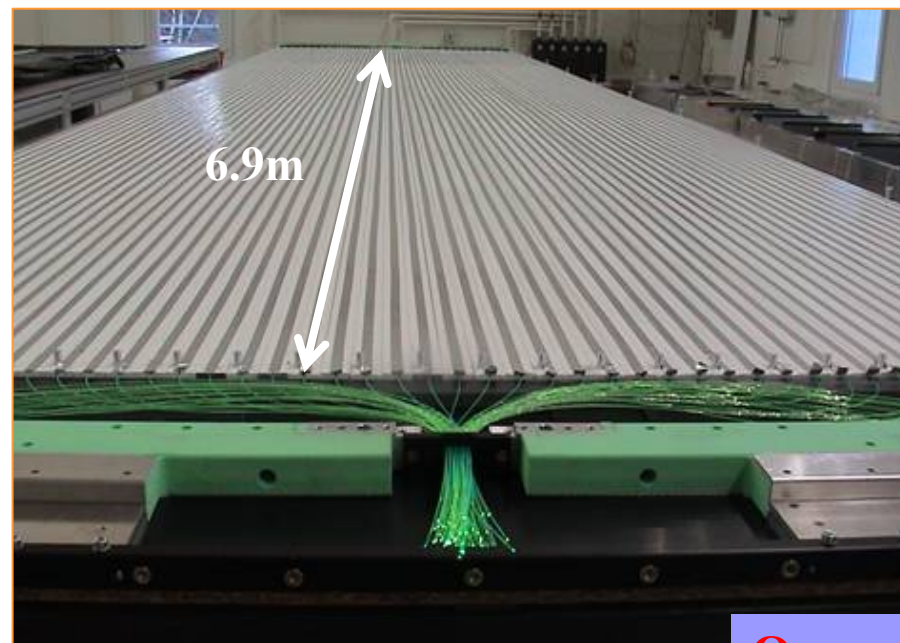
- Matrix of independent tiny pixels arranged on a common substrate (200–2000 pixels).
- Each pixel operates in a self-quenching Geiger mode: gain is $\sim 10^6$.
- Each pixel produces a standard response independent on number of incident photons. *GPD* at whole integrates over all fired pixels.
- Efficiency (including geometrical) to detect photon $\sim 30\%$, higher than typical efficiency of photomultiplier.
- Compact: typical matrix size $\sim 1 \times 1\ \text{mm}^2$.
- Cheap: 20–30\$; cheaper or comparable to one channel of multichannel photomultiplier.
- Not sensitive to magnetic fields.
- Radiation hardness is sufficient for our purposes.
- Internal GPD (one pixel) noise is 100kHz – 2MHz is not a problem: setting threshold at 5 fired pixels reduces the internal noise to $< 1\ \text{kHz}$ and keep the efficiency to MIP 99%.
- Produced by many companies in Russia, Japan, Switzerland, Italy. The russian company CPTA has experience of moderate mass production of few thousand pieces working in real experiment.



- There are several producers for scintillator strips and photodetectors that meet our conditions and have an experience for mass production:
- Scintillator strips:
 - Kharkov (Ukraine) produced scintillator strips for OPERA
 - Fermilab produced scintillator strips for T2K
- Photodetectors:
 - CPTA (Russia)
 - Hamamtsu
- WLS fiber: Kurarai Y11 (no better option)
- Optical glue: St. Petersburg (Russia) or Bicron



Belle test module



Extruded scintillator strips produced by Kharkov

Opera

Strip geometry

We consider now two options of strip width:

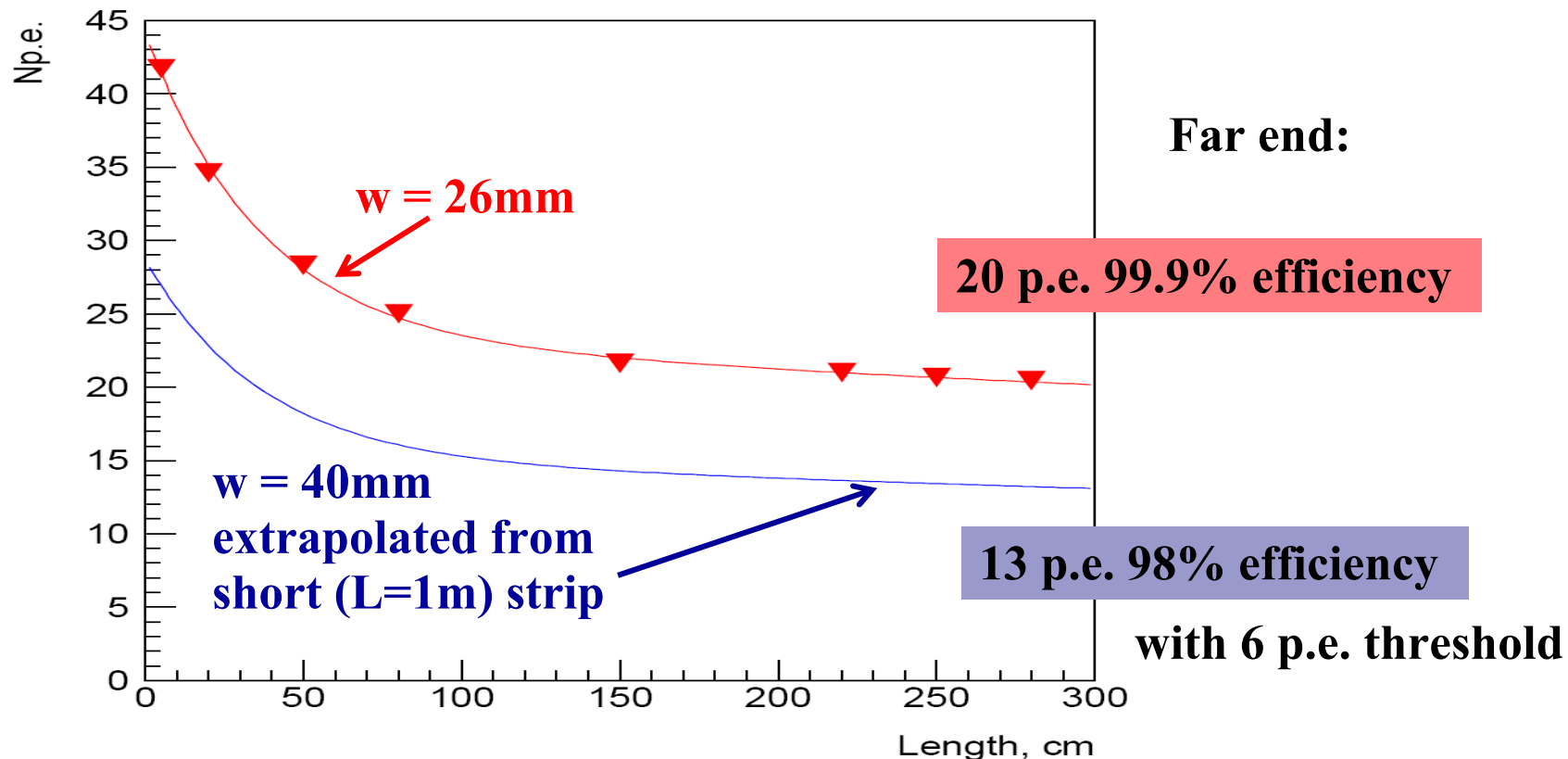
economic option ($w=40\text{mm}$) \approx present
RPC granularity (17k read out
channels)

- 30% cheaper

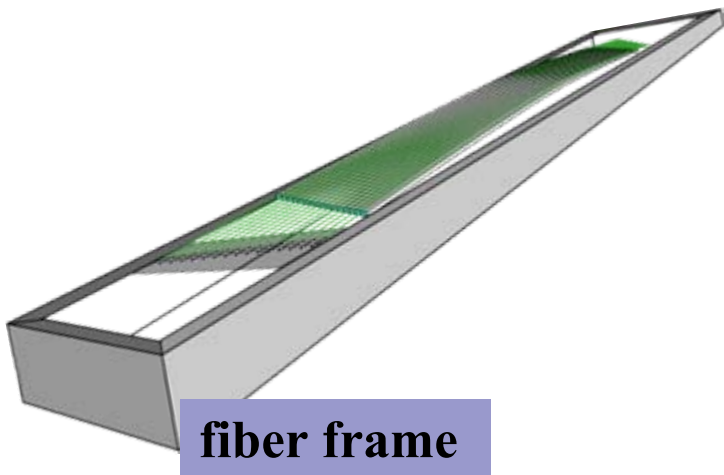
“improved” granularity ($w=26\text{mm}$) \equiv
OPERA strips (27k read out channels)

Advantages:

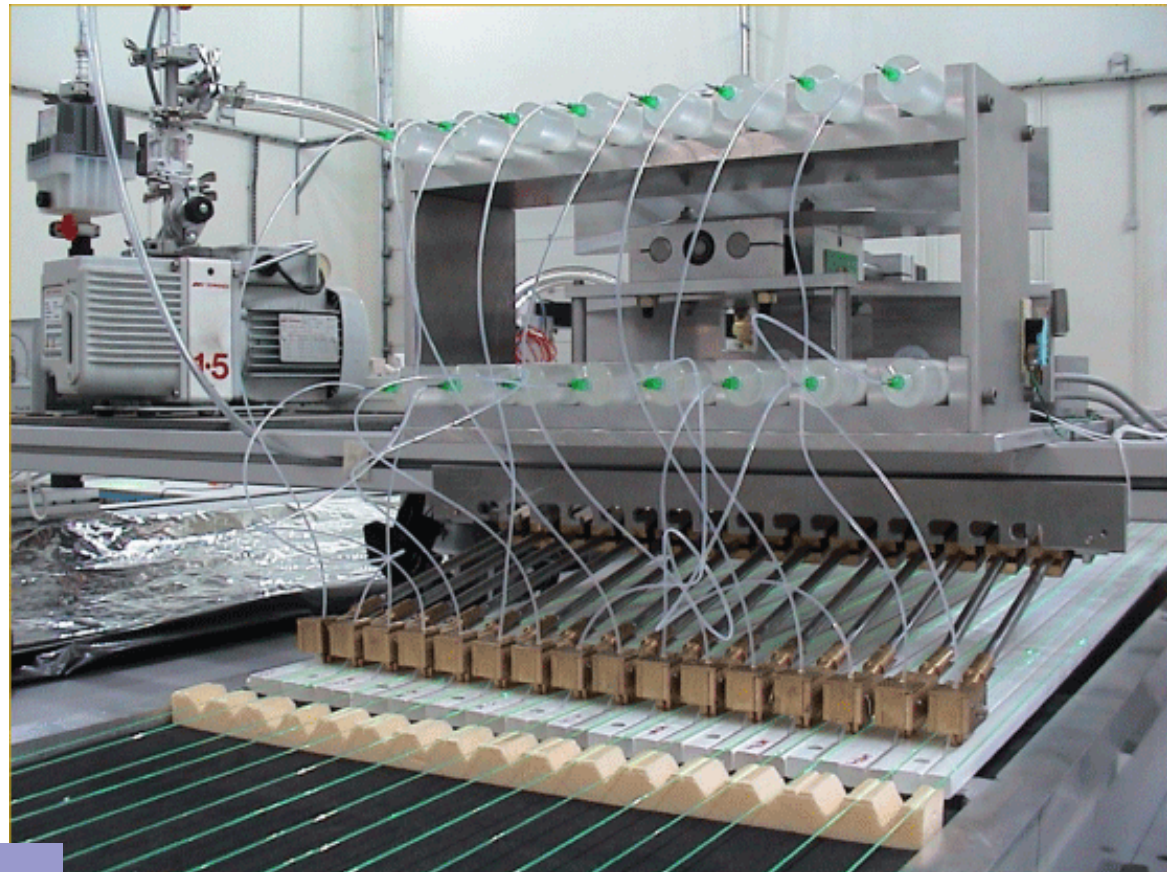
- 30% more light;
- better muon ID (to be confirmed with
GEANT MC)



- **Manual fiber gluing is possible: this was done for the 200 strips of the test module by one person during 30 days. With getting more experience this can be done much faster. Estimated time for production of the whole system is 2 years.**
- **However we can take advantage of experience of neutrino experiments. Some cooperation with Opera/T2K?**



fiber frame



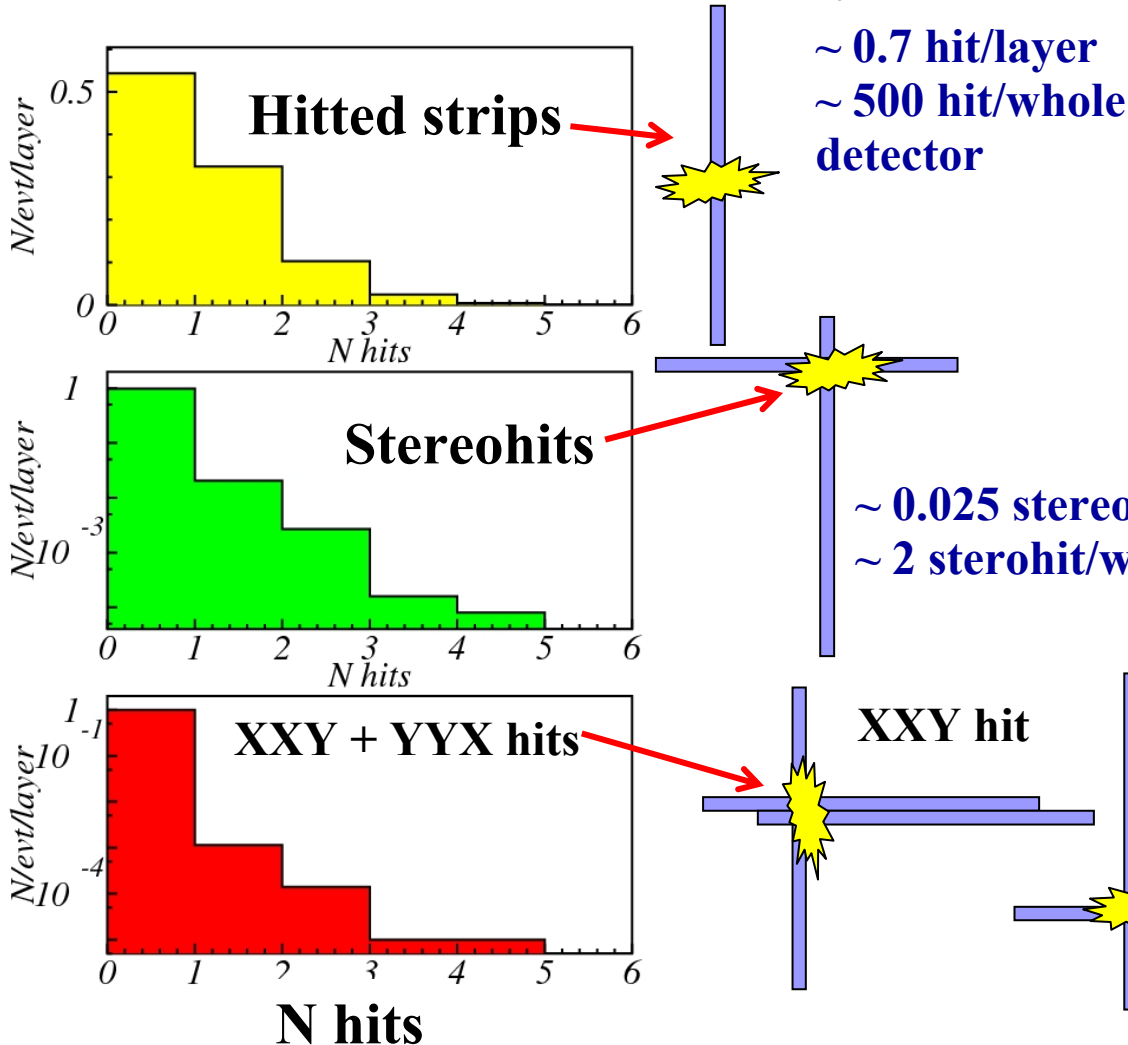
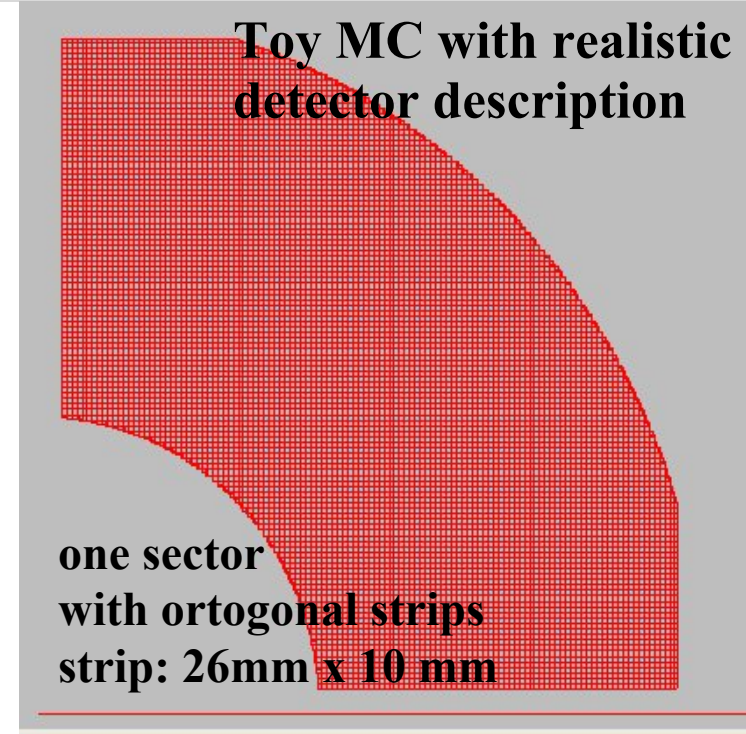
Opera fiber gluing system

Physics performance

- Scintillator detectors are more sensitive to neutrons (due to hydrogen in plastic). The tests in the KEKB tunnels show that neutron rate at scintillator strips is 5 Hz/cm² now; \Rightarrow 70 Hz/cm² at $L=2 \times 10^{35}$ /cm²/s
- Background neutron can produce hits in one strip only (no correlated hits in x and y plane). This allows to have stereohit background rate smaller than at RPC in spite of increased single hit rate.
- Additional suppression is due to good time resolution (measured Strip+GAPD time resolution is ~ 1 ns), therefore x-y coincidence time can be cut at ± 5 ns.
- **K_L detection \Rightarrow now two different tasks:**
 - for reconstruction final states including K_L (e.g. $B \rightarrow J/\psi (\phi) K_L$; $D \rightarrow K_L \pi$): the time gate can be set at ± 5 ns from the expected (calculated time of flight using the known K_L momentum)
 - for K_L veto ($B \rightarrow \tau \nu$; $B \rightarrow h \nu \nu$): the time gate have to be as large as 50 ns from the bunch crossing to accept all K_L momenta (for $p \sim 0.2$ GeV $t \sim 40$ ns)
- **Muon identification** should be better due to better spatial resolution (with 26 mm strips) and higher MIP detection efficiency.

Neutron background estimate

- Neutron hit rate: 100 Hz/cm^2
- Cross-talk between neighboring strips 1%
- Gate 50 ns
- Coincidence time between x and y hits 10 ns

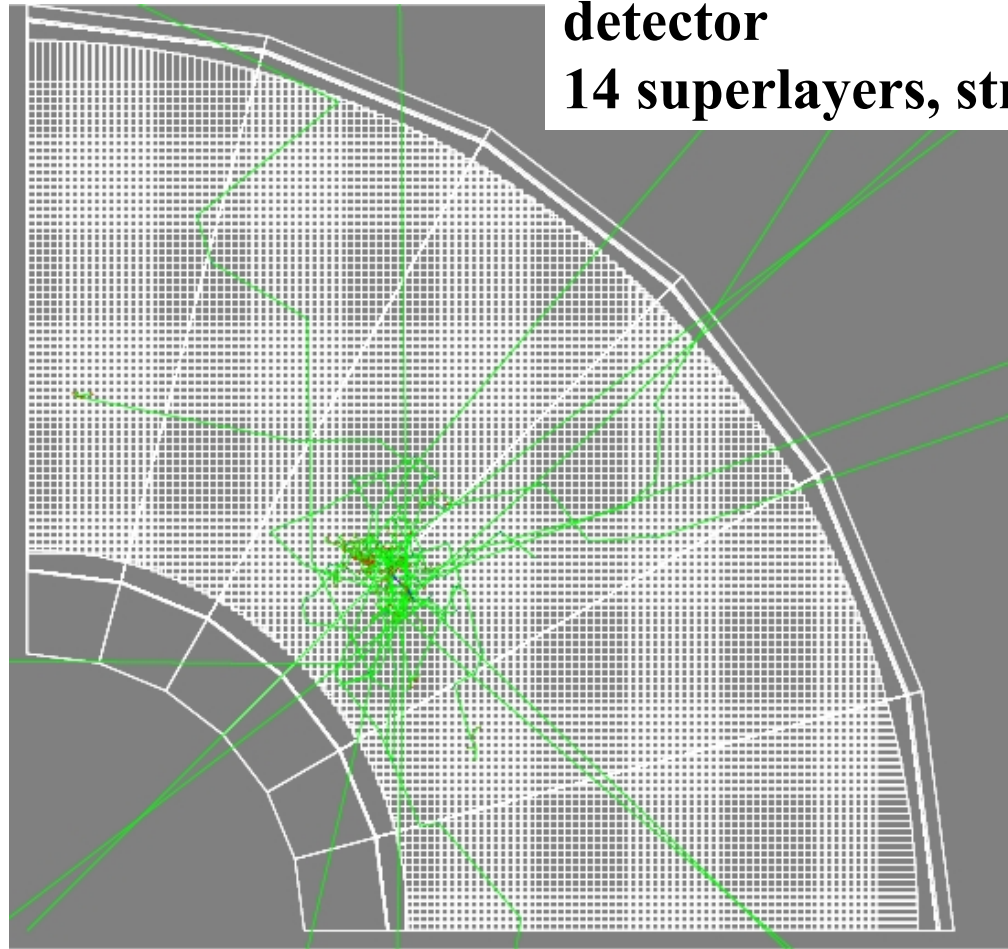
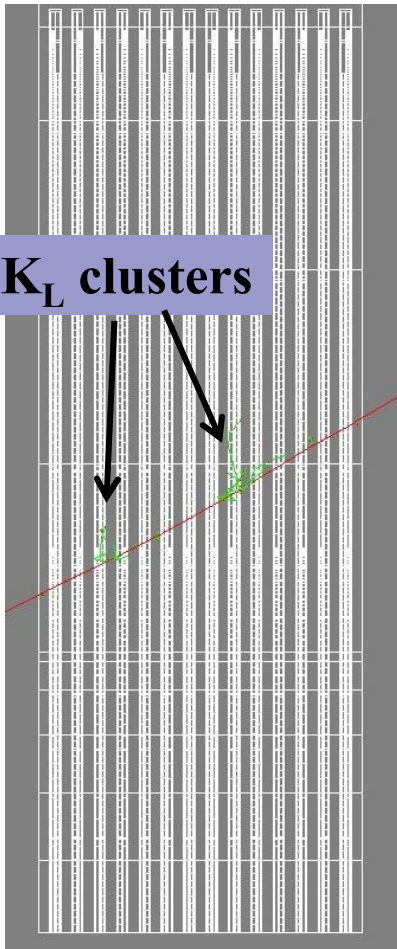


OK for K_L reconstruction
Not OK for K_L veto

OK for K_L veto

Realistic G4-based prototype

Geant4 standalone endcap KIM
detector
14 superlayers, strip width 26mm

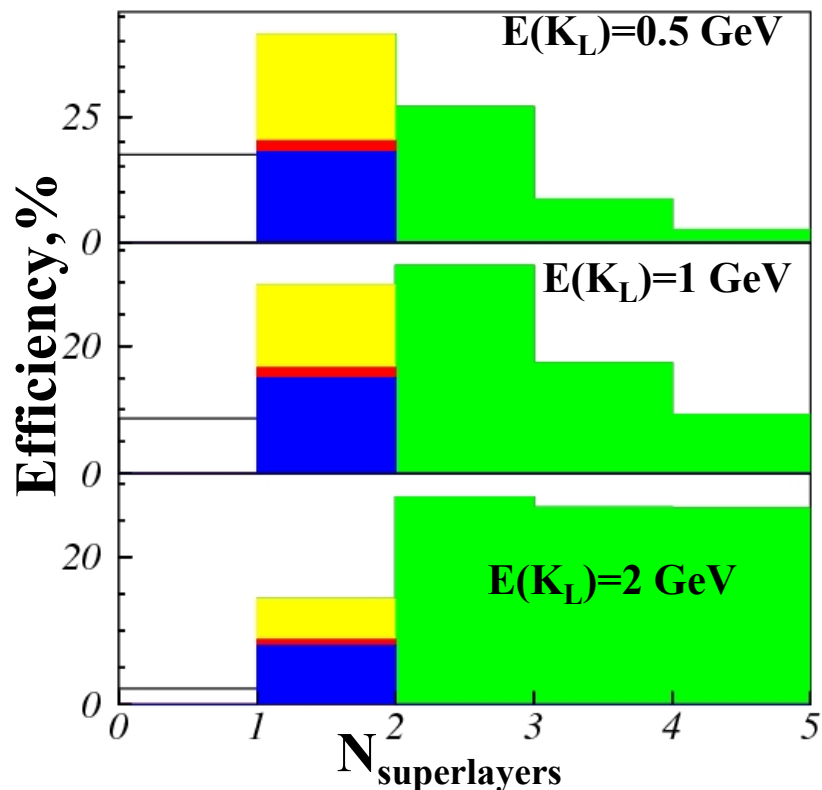


K_L efficiency study

■ GEANT-4 simulation for standalone KLM detector; still no correction for

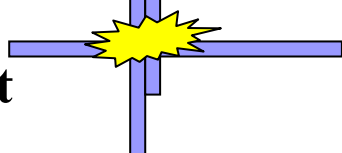
- geometrical efficiency/ light collection efficiency
- ECL

■ Present algorithm: require two superlayers hits or ECL cluster + one superlayer

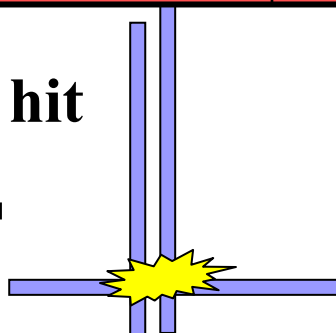


$E(K_L)$, GeV	0.5	1.0	2.0
Present efficiency	38%	59%	81%
Addition			
K_L reconstruction	+40%	+30%	+16%
Veto (option 1)	+18%	+15%	+10%
Veto (option 2)	+20%	+17%	+11%

XYY hit



XY0Y hit



Options to increase efficiency in the case of one superlayer hit

1. use 3hit-cluster XXY+XYY
2. use 3hit-cluster X0XY+XY0Y

- **Another radiation ageing tests is now under way with 10 GAPD(Russia) and 10 MPPC(Hamamtsu). November 6 – December 22, 2008.**
- **Both Fermilab and Kharkov confirmed that they can produce required amount of strips. Their prices are similar (~20\$/kg). November'08 – strips from Fermilab arrived to ITEP for tests.**
- **Electronics: readout electronics is common for all other subdetectors: 16-channels (flashADC/2.5GHz + FPGA – “oscilloscope on chip”), developed and produced at Hawaii. It has been given us for tests in November.**
- **HV and slow control/local run electronics still need to be developed.**
- **Geant4 MC for geometry optimization: the progress is slow. Leo described endcap scKLM in new GEANT MC, with RPC strip geometry. Besides description of new geometry, new reconstruction is required.**

- **Scintillator KLM design is OK for SuperBelle:**
 - the efficiency of MIP detection can be kept at high level (>99% geometrical; thresholds: compromise between efficiency and neutron bg rate)
 - K_L reconstruction: The reconstruction efficiencies can be improved
- **Radiation hardness of *GAPD* is sufficient for SuperBelle for endcap and barrel parts, but we do not have a large safety margin for $L=10^{36}$.**
- **The final optimization of the strip size is to be done with a full GEANT simulation of the whole SuperBelle detector (in progress now).**
- **The negotiations with producers started; Their products have similar characteristics, that are ok for us, and the prices from different producers are similar.**
- **The test with a real prototype in the KEKB tunnel allowed to measure neutron background rate and estimate the radiation hardness of *GAPD* in real conditions.**

Cost estimate for endcap KLM

Item		price	cost
Scintillator strips	28, 000 pc. (14,000 kg)	20 \$/kg	280 k\$
WLS fiber	56 km	1.4 \$/km	80 k\$
Photo-detectors CPTA	28, 000 pc.	20 \$/pc.	560 k\$
Optical glue	300 kg		30 k\$
Electronics	28, 000 ch.	? \$/ch.	? k\$
Miscellaneous			70 k\$
Transportation			40 k\$
Total			1060 k\$

* Cost estimate for electronics will be made after the electronics design

** Cost does not include electronics, labor and R&D

*** Changes in \$ exchange rate can influence the cost