

MRPC meeting

2021/7/28

1. Status and Schedule
2. EMPHATIC RPC test at LEPS-II
3. $\phi \rightarrow KK$ Proposal and PAC
4. Plan for E16 MRPC

Status and Schedule

- 7/24-26 J-PARC PAC
- 7/23-26 EMPHATIC-RPC beam test (LEPS)
- 7/27 E16エリアステージ下のLV電源等取り出し (完了)
- ~8/17 JAEA→筑波大へMRPC、ガスボンベ移送 (窒素減圧弁届き次第)

EMPHATIC MRPC Test

- EMPHATICのconventional typeは準備が間に合わなかったため、Ship-type RPCのみのテストとなった。EMPHATICとしてはShip-typeで進めたいとのこと
- 70psを切る高時間分解能が出た(TOT slewing補正後)
- 閾値は5.5V以上(=193mV)で時間分解能が一番よくなる
- ノイズレベル (typically ~20mV peak-to-peak) w/o attenuator
→E16-RPC試作機：30-90mV

- 7/23 Ship-RPC preparation, BGOegg RPC beam test (予備機)
- 7/24 BGOegg RPC beam test, Ship-RPC beam test
- 7/25 Ship-RPC beam test

Ship-type RPC

- よい時間分解能ができれば、E16で是非採用すべき
- ガラスはアクリルボックスで封入（気密）
 - 1段（6枚のガラス）ずつ2個のアクリルボックスを使用
 - 透明アクリルボックスなのでガラスの損傷が目視で確認できる
 - ガラスが割れても1/2のみ作り替えればよい
 - レート耐性向上のため、アンプを温めずにガラスのみ温めることが可能！
- Anode, Cathode PCBはアクリルボックスと完全に独立
 - コネクタの気密を気にする必要がない
 - 自由に様々なPCBを組み合わせられる
- 全体をアルミ筐体に入れる
 - 気密である必要が無い
 - 様々な筐体を試すことが可能。ノイズ抑制の改良が行いやすい

Ship-type RPCの改善すべき点

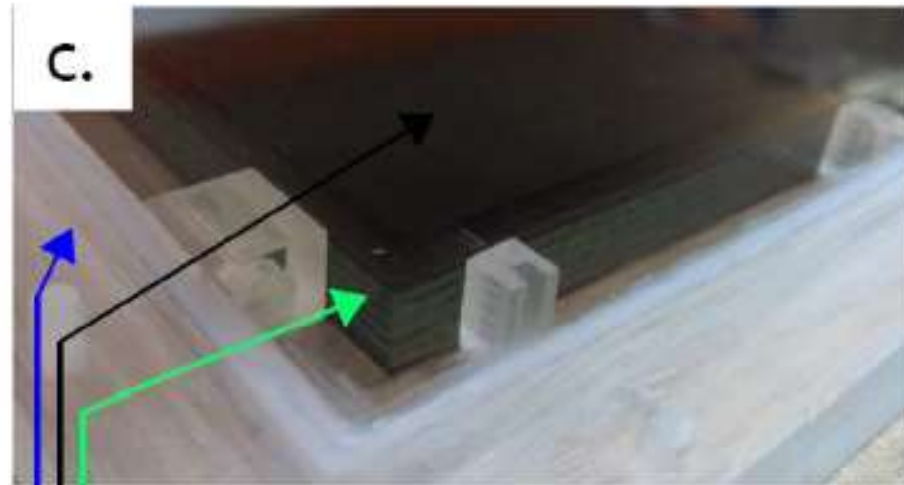
- アクリルボックスの厚さは4mmしかないため、コネクタが横に付けられない。横に付けられないと全体の厚さが熱くなってしまい、E16ではスペースがないため困る
- Amp-anode PCB間のUFLコネクタの接続が不安定（コネクタの接続がよく外れる、基板とコネクタのはんだ付けも外れやすい）→はんだ付けの方が良い？

方針と予定

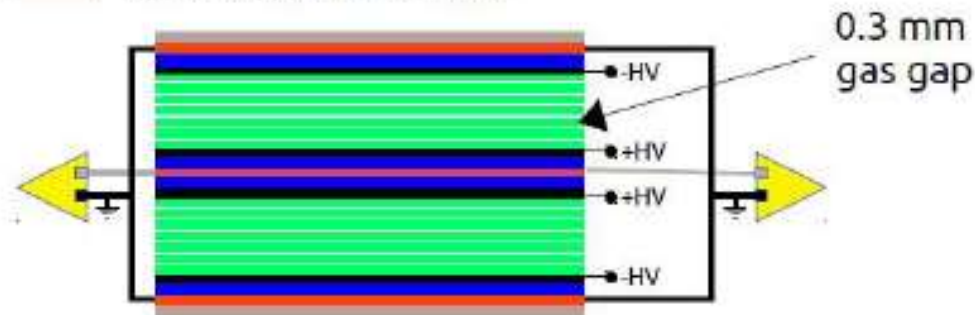
- 今年度2台のship-type RPCを作る
- EMPHATIC RPC (～7台) を今年度中に製作しLEPSで試験を行う。そのスケジュールに合わせて2台製作、ビーム試験を行いたい。
- ガラスを温めるヒーターの設計 (アクリルボックス内)。温度制御、インターロック機構
- PCB、アクリルボックス、筐体はEMPHATIC typeをベースで作る
- AMPはEMPHATICと同じ

SHiP RPC

JINST 15 C10017



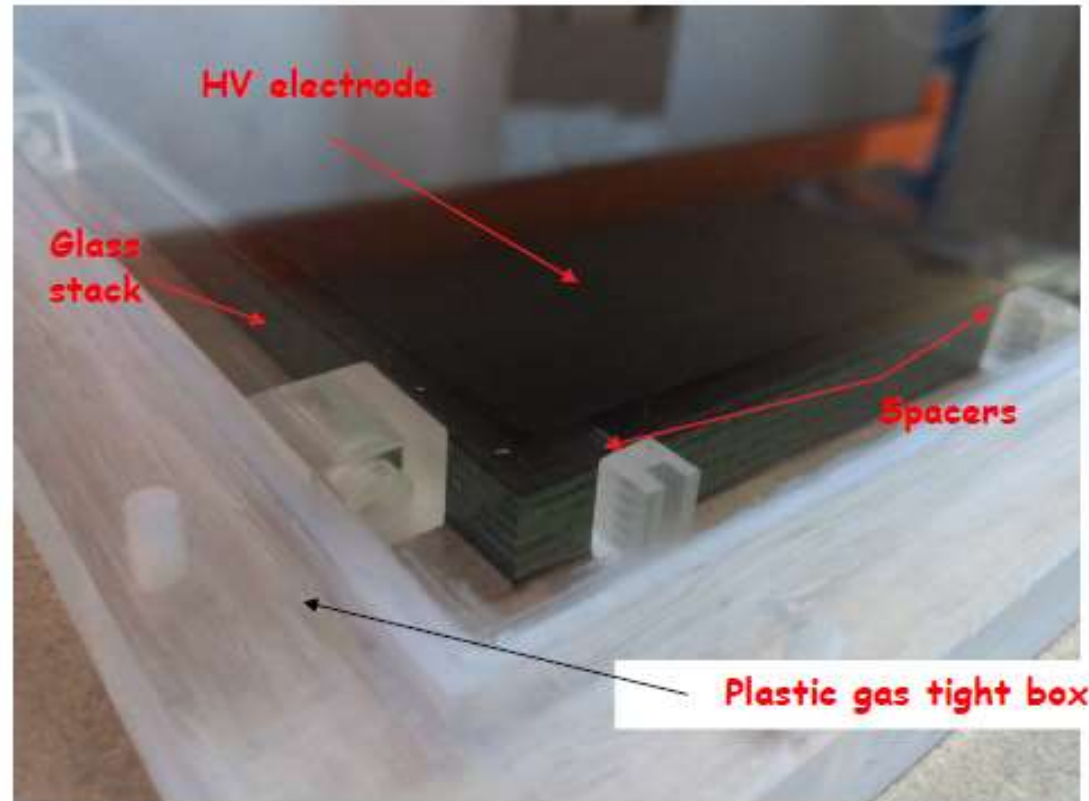
- 1 mm thick float glass with $\sim 4 \times 10^{12} \Omega \text{cm}$ at 25 °C.
- HV electrodes. Based on a acrylic artistic paint with $100 \text{M}\Omega/\square$.
- 1 mm thick polycarbonate cover.
- 1.6 mm thick FR-4 PCB readout strips/ground plane.
- 3 mm thick aluminum box.



- Glass + carbon are in plastic gas container (glue)
- PCBs are outside of the gas container
- Easier amp connection
- We can check glasses after transportation (?)
- Smaller gas flow (no honeycomb)

The TD implementation. MRPC Sealed glass stack

- Modules composed of two 6 (0.3 mm) gaps sealed glass stacks (SGS).



A **sealed glass stack** contains the glass and HV electrodes enclosed in a plastic gas tight box with feed-throughs for gas and High Voltage.

Easy to build
completely gas tight,
no gas leaks, robust. Low gas
consumption

Decouples the gas and HV from
the rest, specifically readout
electrodes

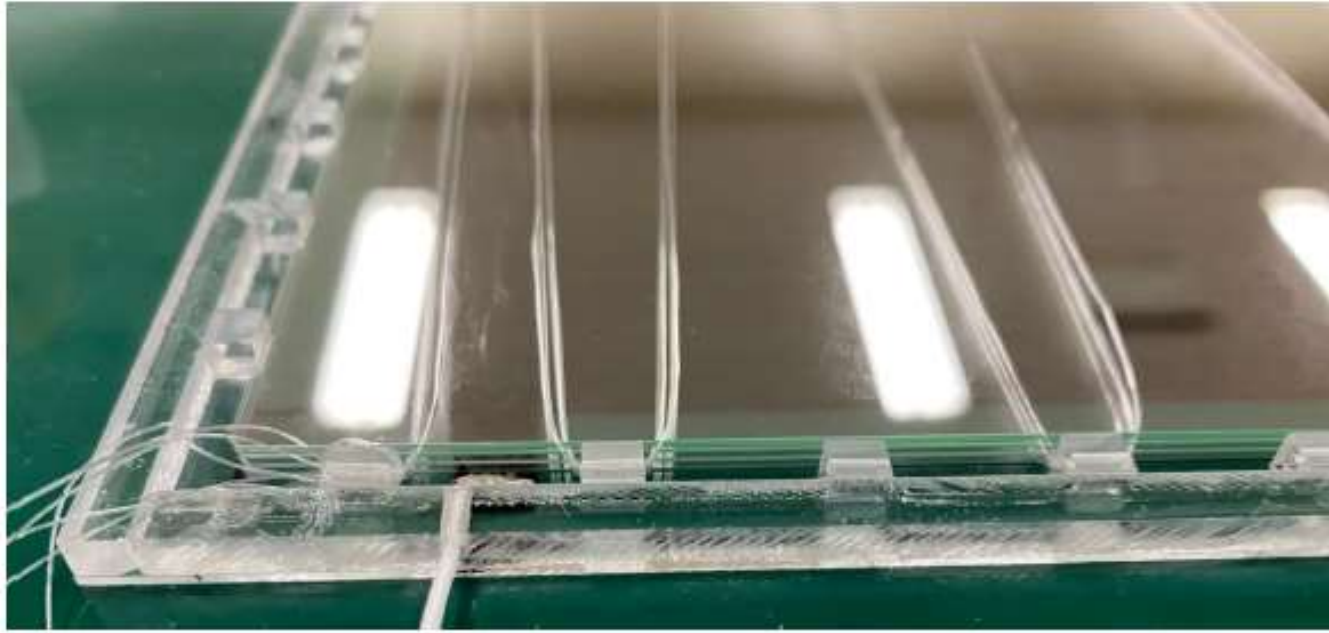
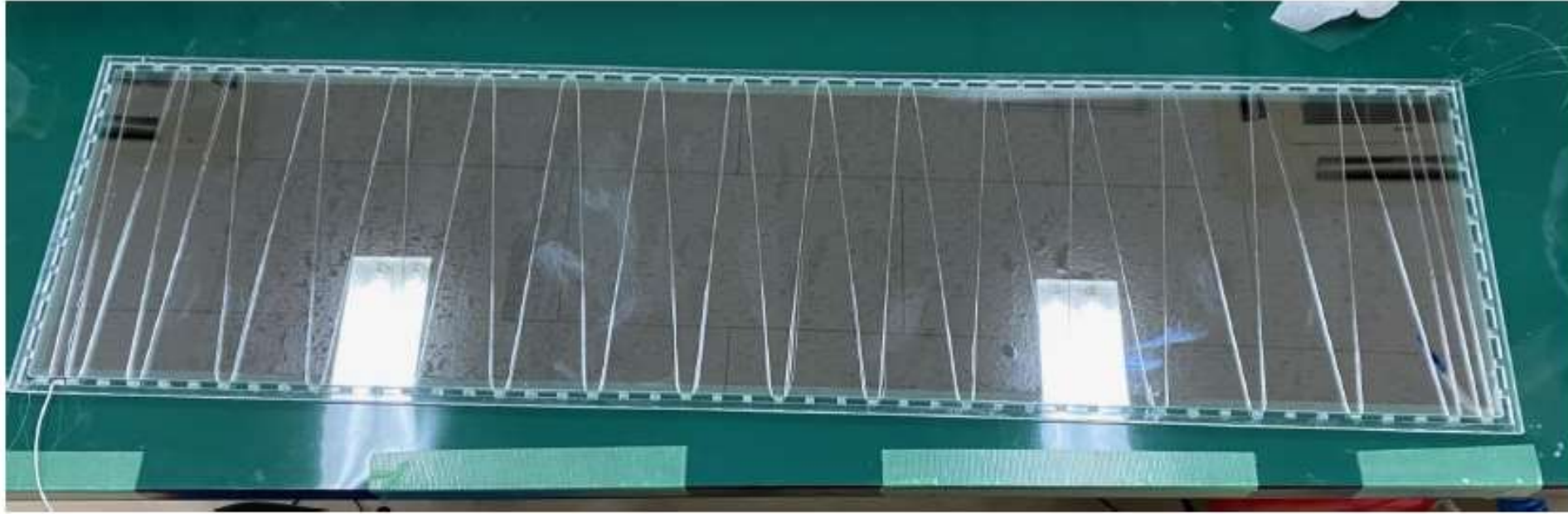
In competition with a scintillator based approach

SHiP RPC

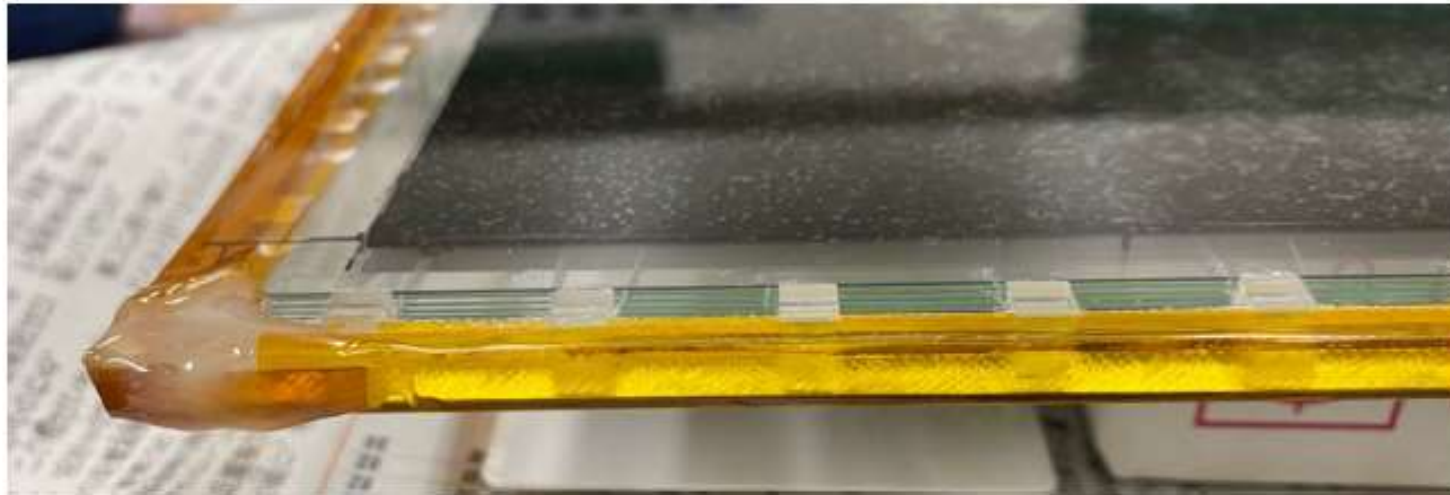
Photo from Yi Wang



SHiP type



SHiP type gas tight



- Gas tight using capton tapes
- Except for the edges
- Re-tape => Removed with gas pressure

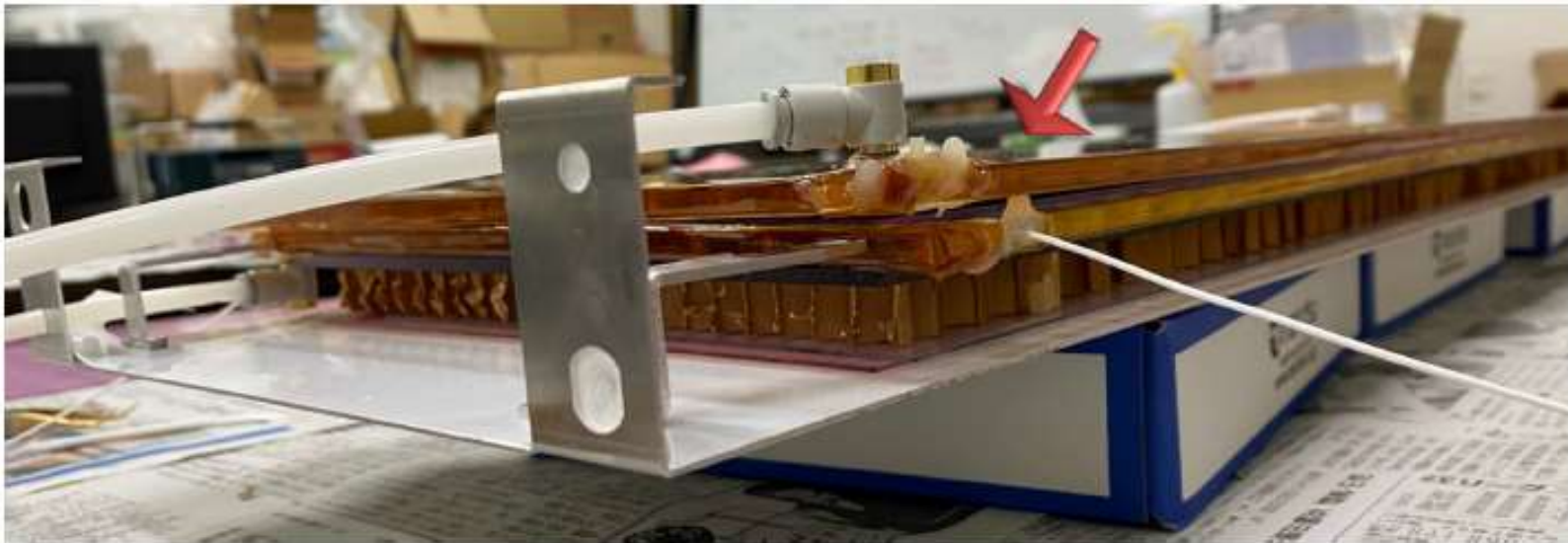
Shopping list

Material	supplier / contact
Gas box	Suzuno, CI kogyo, SHiP group
glass	Mitsuru Kogaku, Hiraoka glass
carbon	EEEE, Tanimura
strip PCB	Academia Sinica (gerber), Tsinghua univ., G-Tech (import)
Amp	Academia Sinica, export paper work
Honeycomb	Suzuei
Fishing line board	Suzuno
U.FL-MCX cable	Almic
Gas-tight MCX	Almic
Air duster	

Amp

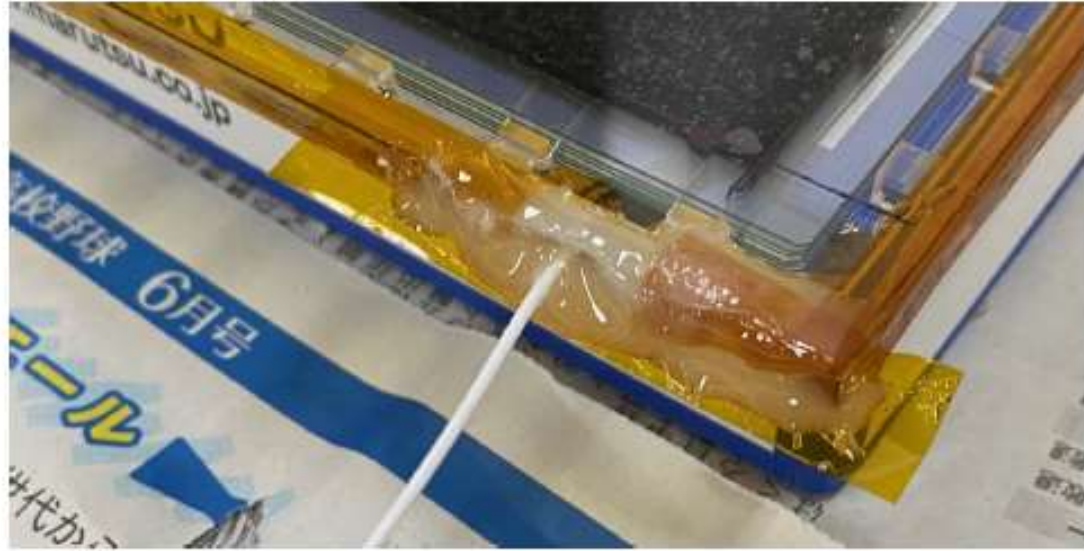
- 26-mm pitch, 8ch (EMPHATIC, E50) x 20
 - **Without** impedance matching resistor
 - **Without** attenuator
 - Output : **U.FL**
 - Input : ordinally soldering x 14
 - x6 EMPHATIC/RCNP
 - x8 ELPH
 - Input : U.FL x 6
 - x6 EMPHATIC/RCNP
- 26-mm pitch, 12ch (LEPS2) x 10
 - **With** impedance matching resistor (200Ω)
 - **With** attenuator (10dB)
 - Output : **LEMO** • We need to send connectors ?
 - Same geometry (input soldering, hole) as Ken's amp
- 5-mm pitch (tracker)

SHiP type



- Bent because of glue => Need to fix

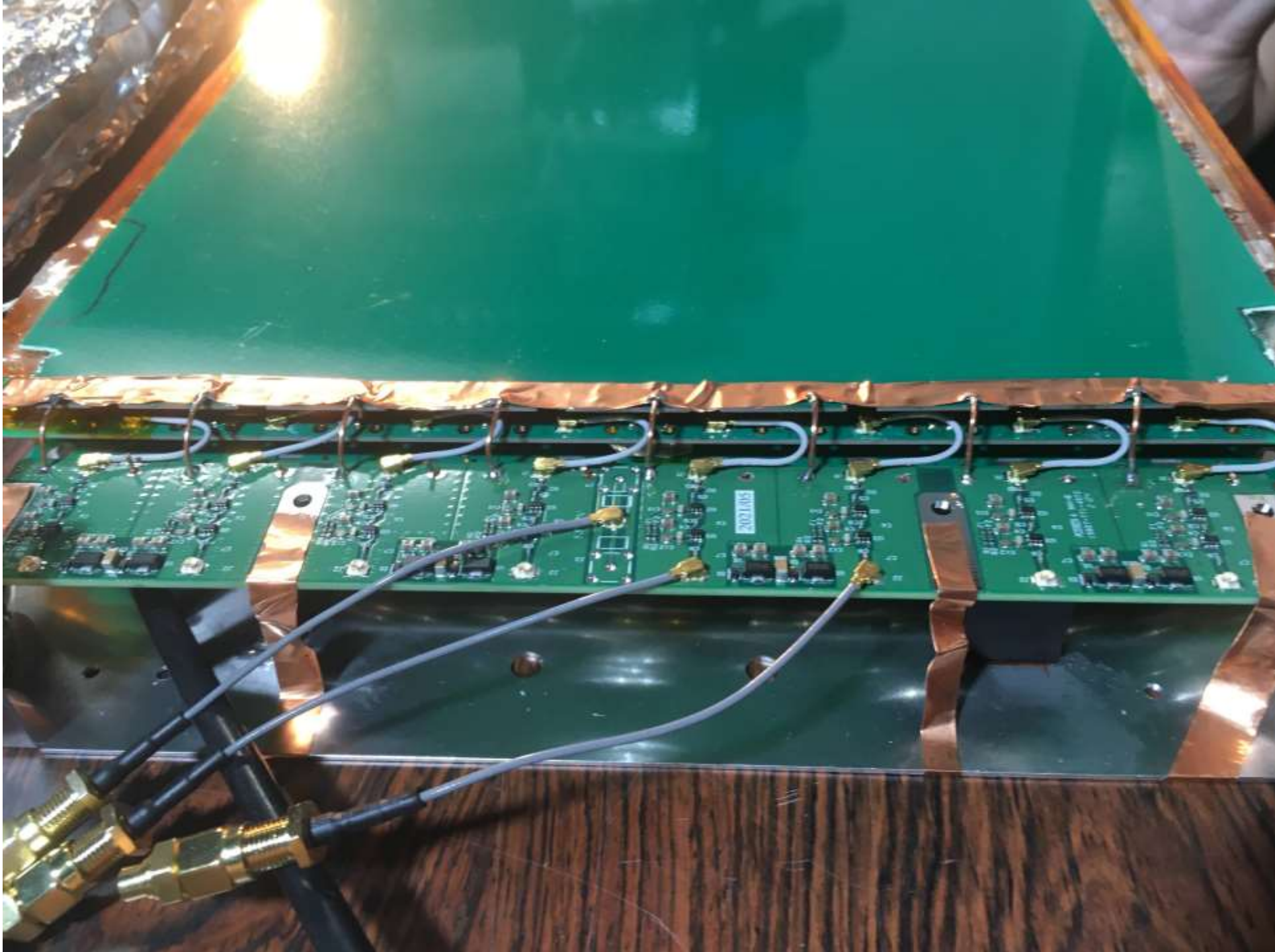
SHiP type

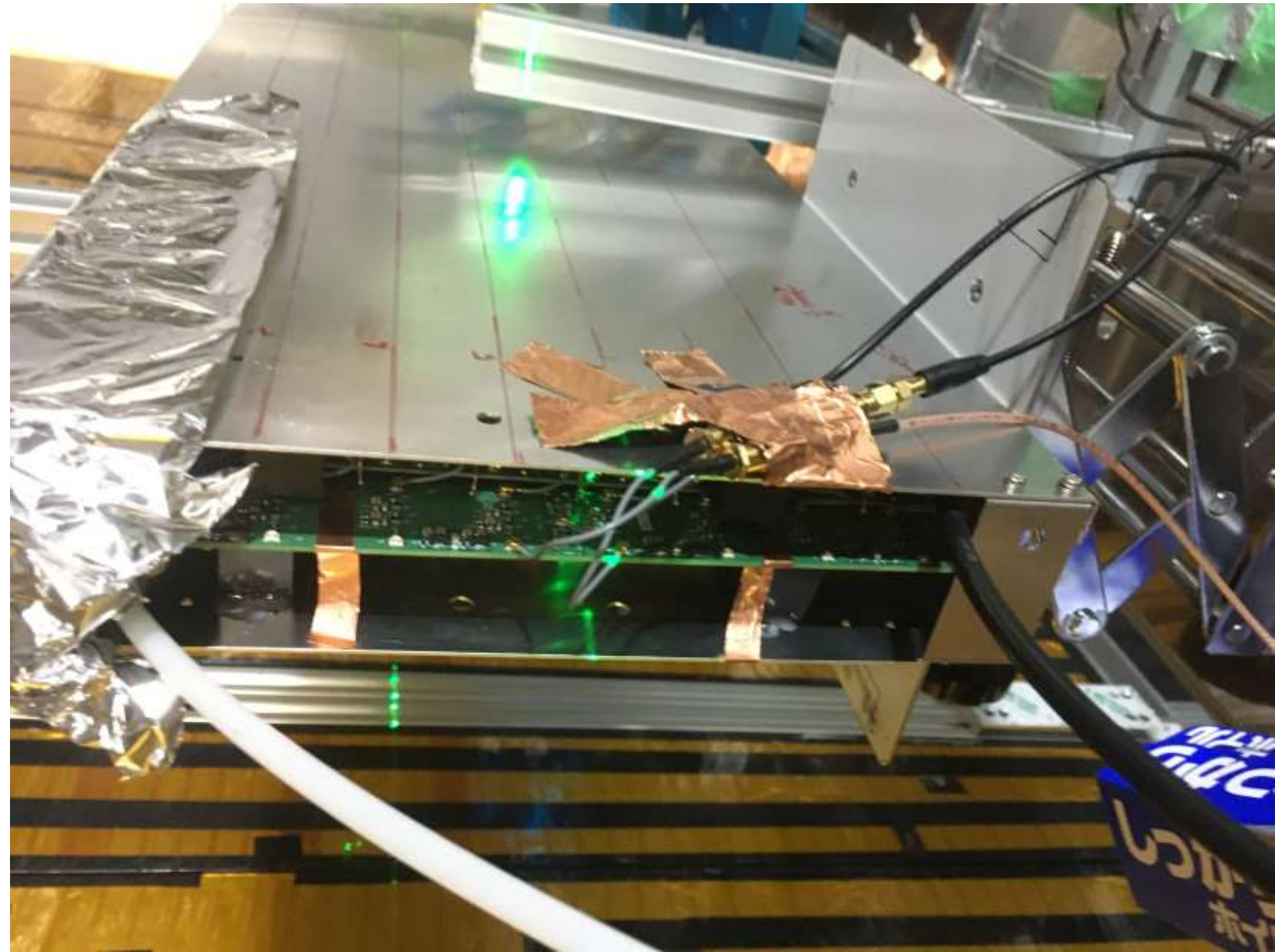


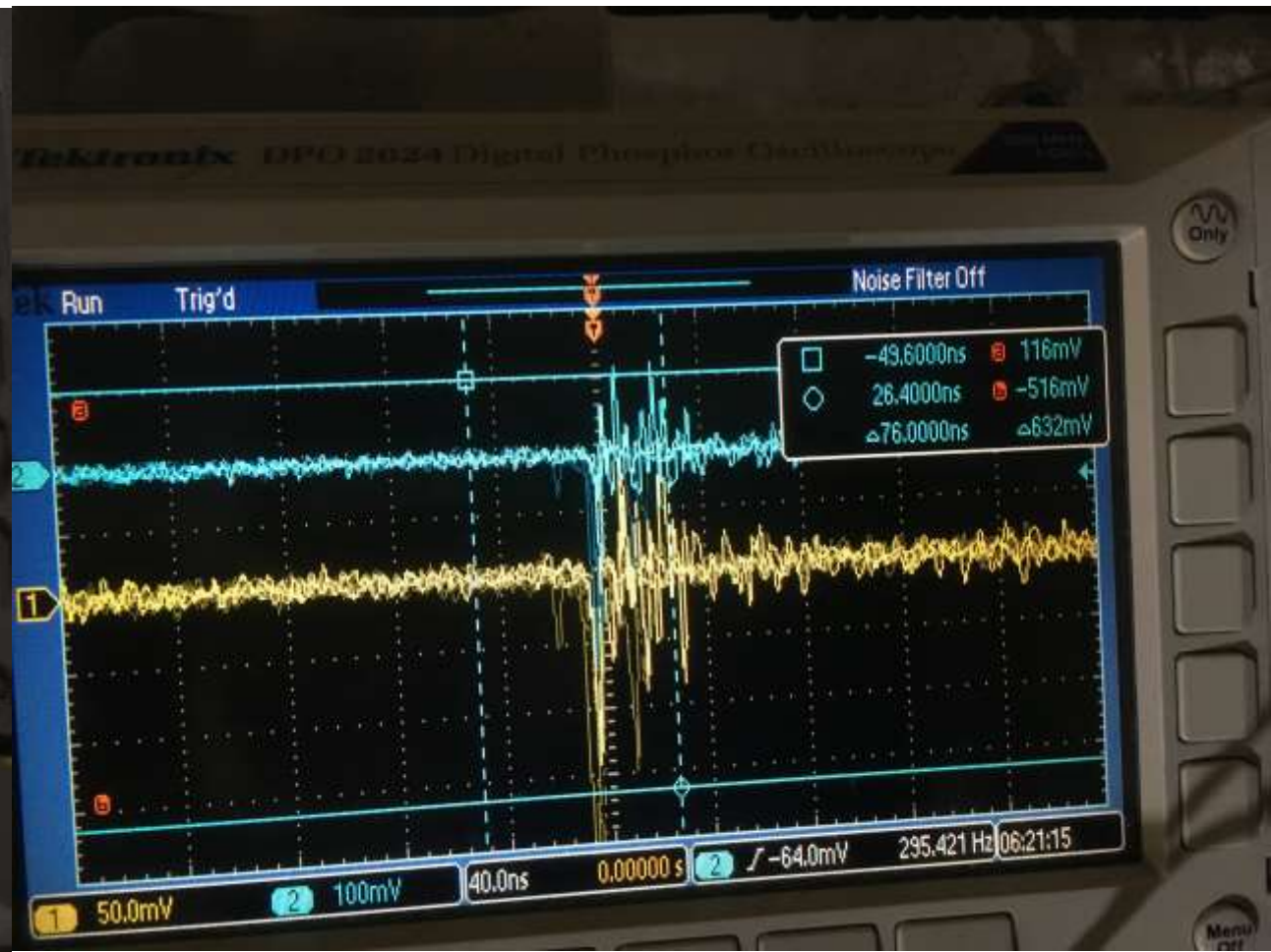
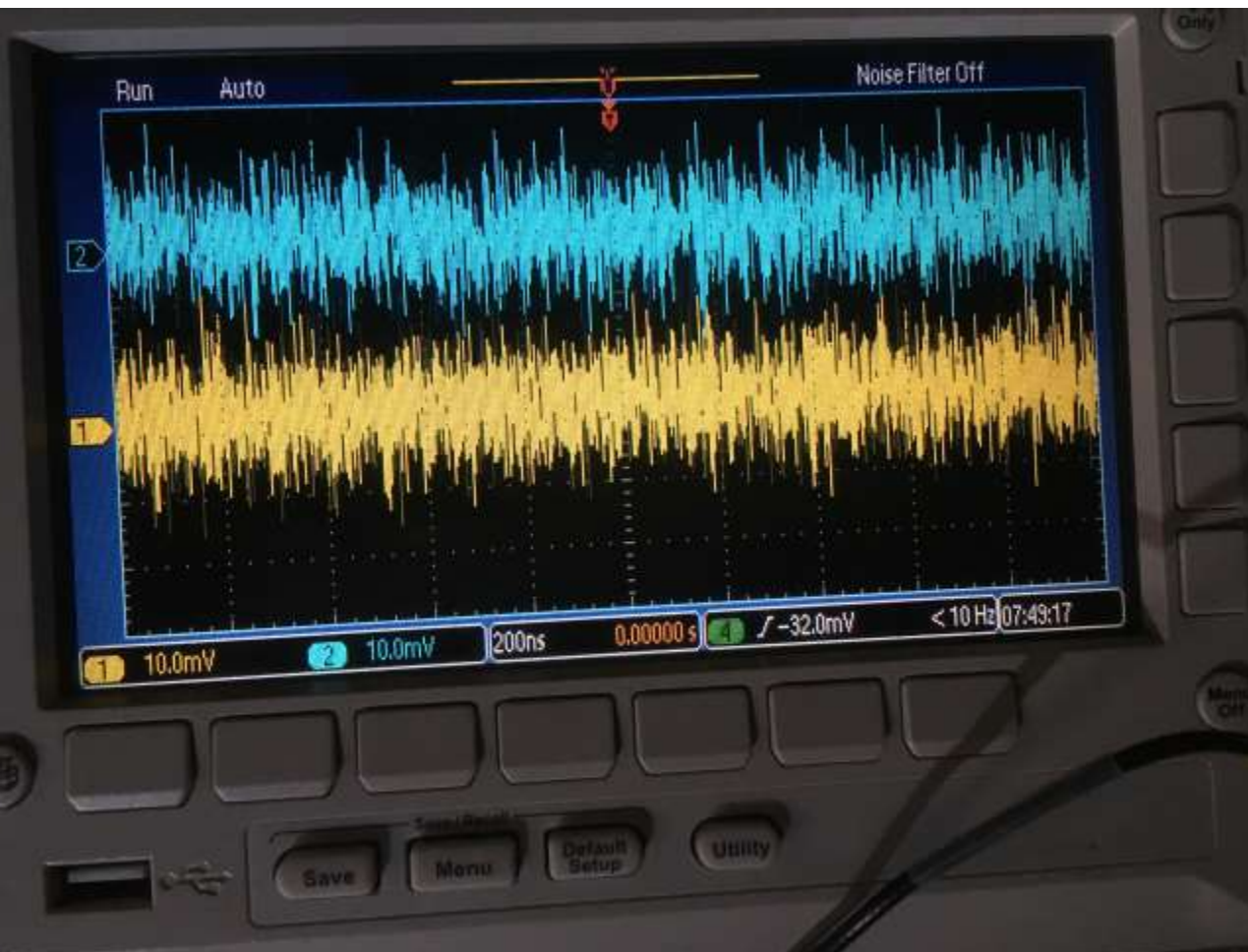
- Remove glue => glue again => OK

SHiP type with BGOegg strip

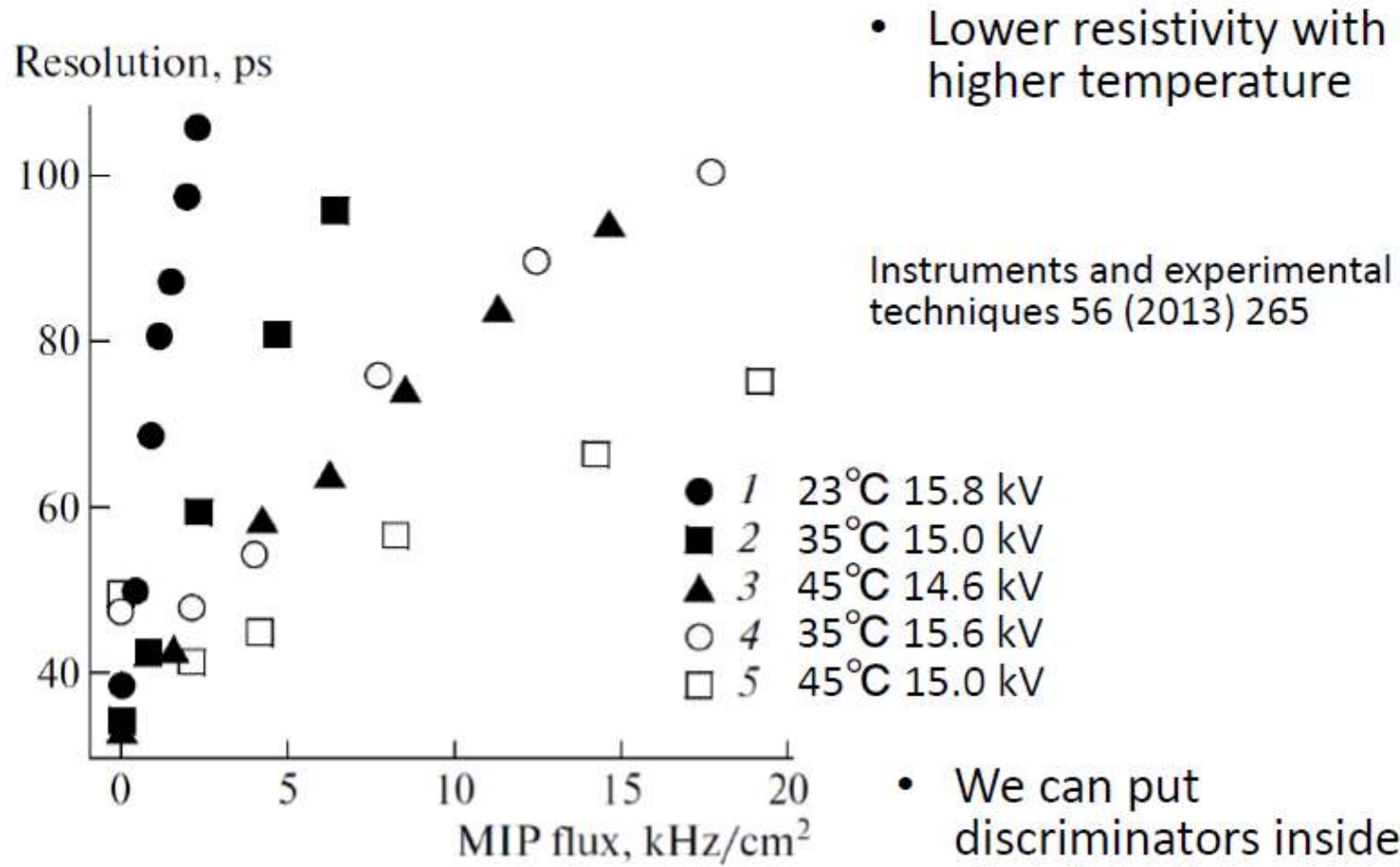








Temperature dependence



Proposal報告

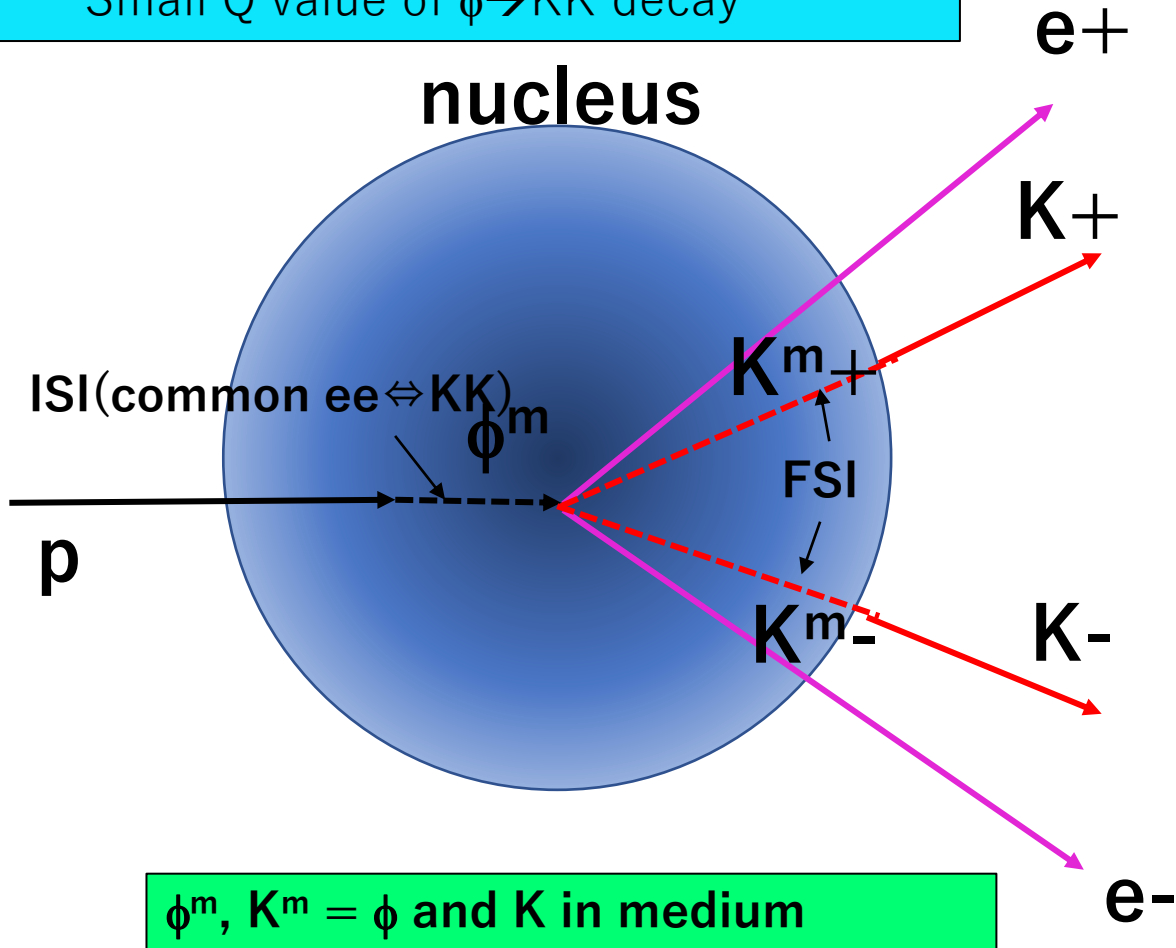
- 今回は残念ながらStage-Iはもらえない見込み。正式なPAC commentはまだ。
- 宿題
 - KN interactionの考察が不十分。特にKK invariant mass spectrumに high mass tailが現れるかというところ
 - Philipp Gublerが次回PACまでにいくつかの仮定に基づいたsimulationを行ってくれる
 - Nu Xuが $e+e^-$ と $K+K^-$ を同時に測る検討をするようにというcomment
 - 実際上はスペースが無いのでHBD, LGとAC, MRPCの両立は不可能という反論はしてある

$\phi \rightarrow K^+K^-$ measurement in p+A at E16

Advantage of $\phi \rightarrow KK$ over $\phi \rightarrow ee$

1. Much higher statistics
2. Another tool : Partial decay width (or Branching ratio)

Small Q value of $\phi \rightarrow KK$ decay



$\phi^m, K^m = \phi$ and K in medium

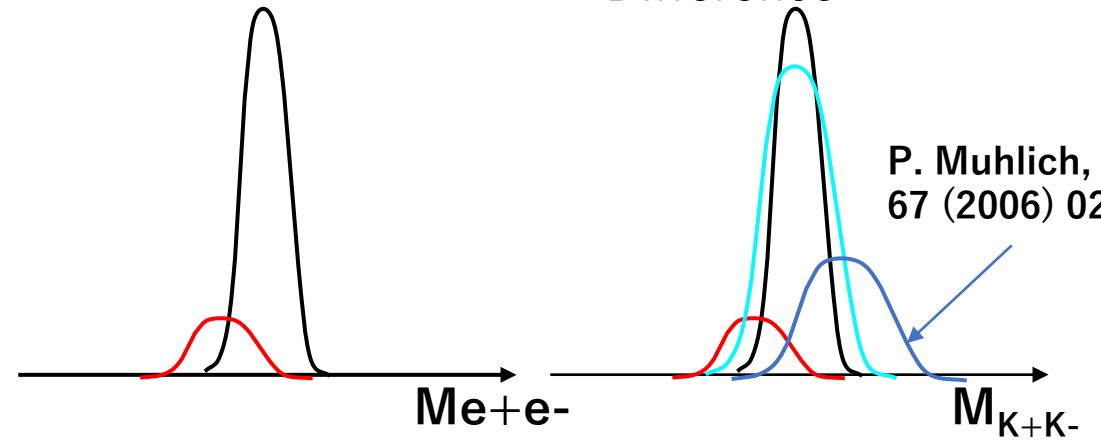
$\phi \rightarrow ee$

$$|S| + \phi^m$$

$\phi \rightarrow KK$

$$|S| + \phi^m + K^m + FSI$$

Invariant mass spectrum



Target mass dependence of BR (yields)

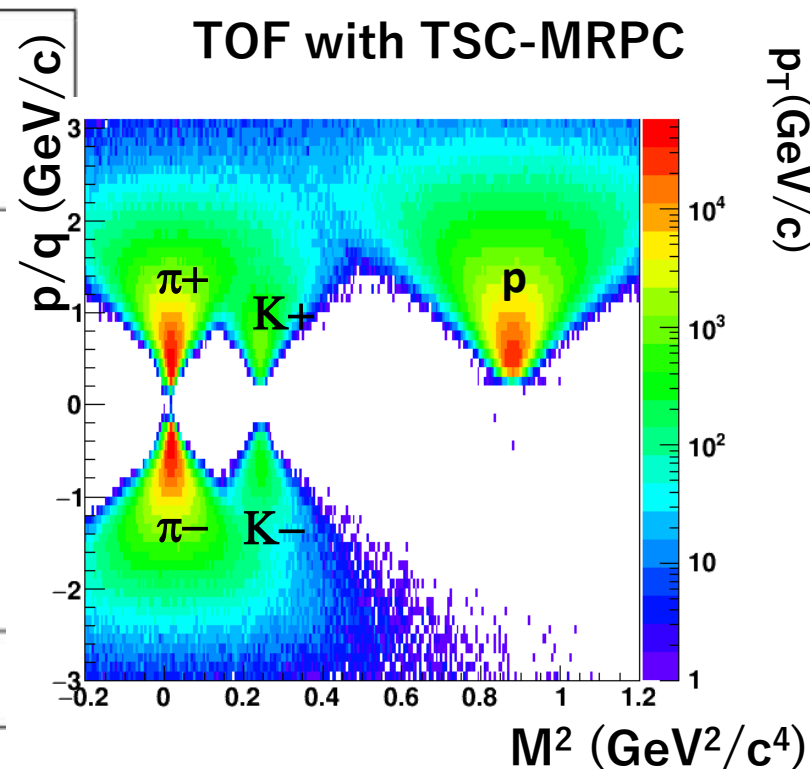
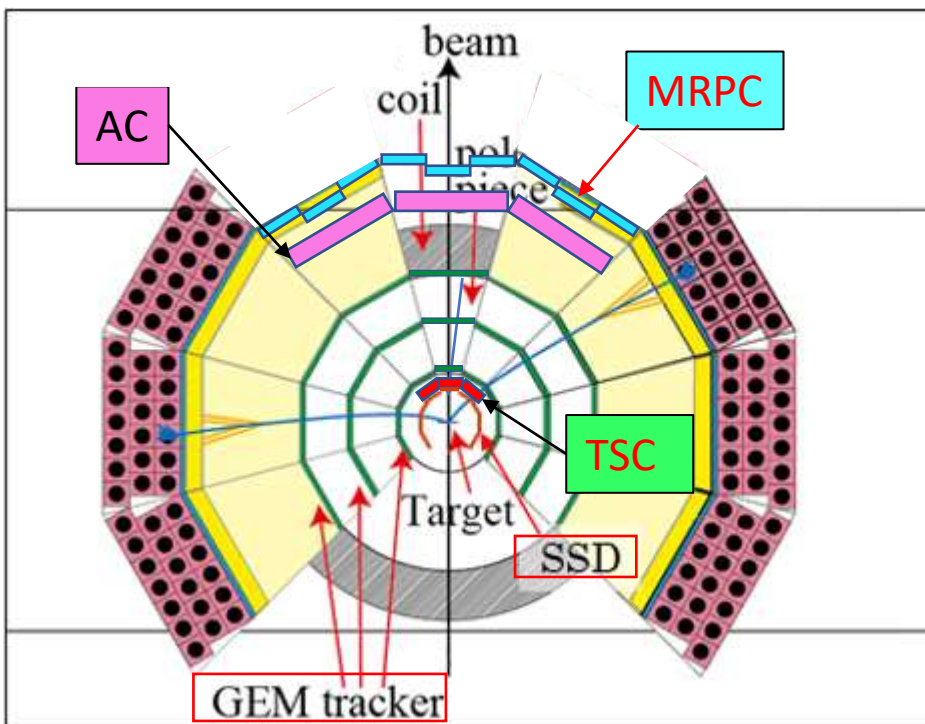
α : Index of target mass (A) scaling changes with ϕ and K modification

$$\sigma(A) = \sigma_0 A^\alpha$$

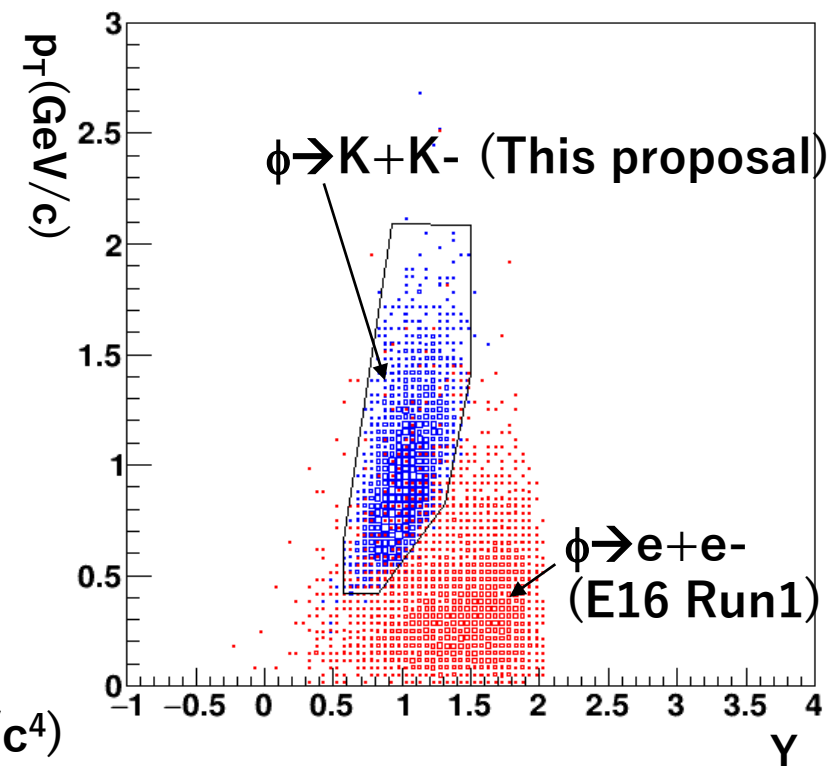
$\alpha(KK) < \alpha(ee) \rightarrow$ phase space suppression (ϕ mass drop)
 $\alpha(KK) > \alpha(ee) \rightarrow$ phase space increase (K mass drop)

Proposed detector configuration

Top and bottom layers

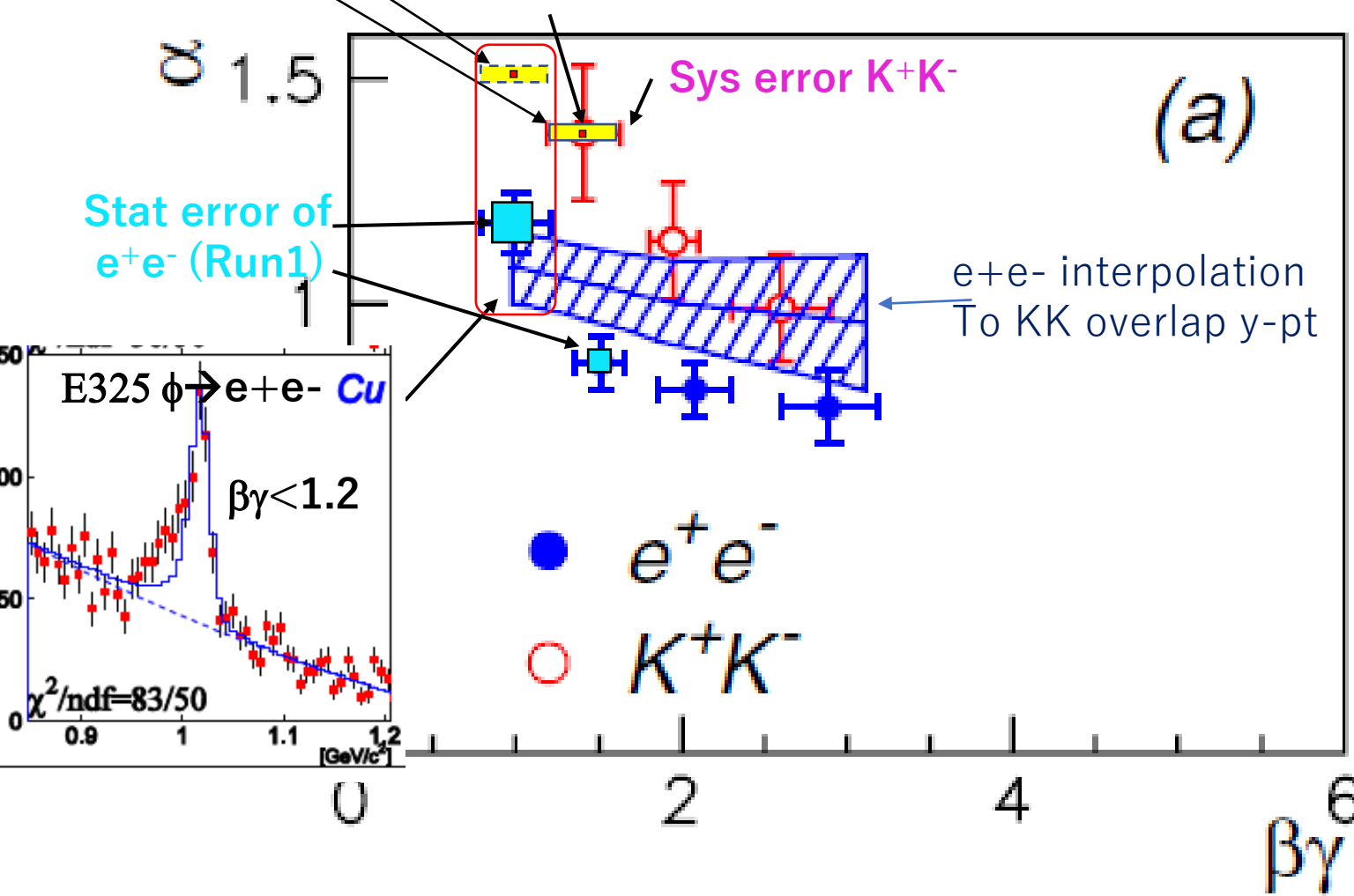


p+Cu (No AC veto)



Expected statistical and systematic errors

New K^+K^- data points E325 Result, PRL 98, 152302 (2007)



Beam time request

- 30 days
- 30GeV proton at 1×10^9 /spill

\rightarrow A few 100k $\phi \rightarrow K^+K^-$ events (2-order higher stat. than E325)

We will clarify

- α (common $\beta\gamma$ dep. $KK \Leftrightarrow ee$)
 - ϕ production in p+A
 - ϕ modification
- $\alpha(KK) - \alpha(ee)$
 - KN interaction
 - K modification

TSC,AC,MRPC rate estimation

- Based on E16 rate measurements

TSC	Beam rate (/spill)	Target	R (cm)	Rate (kHz/cm ²) θ=30° top layer	Rate (kHz/slat) θ=30° top layer
		1x10 ¹⁰	C/Cu	20	6.7

AC	Beam rate (/spill)	Target	R (cm)	Rate (kHz/cm ²) θ=30° top layer	Rate (kHz/PMT) θ=30° top layer
		1x10 ¹⁰	C/Cu	90	0.48

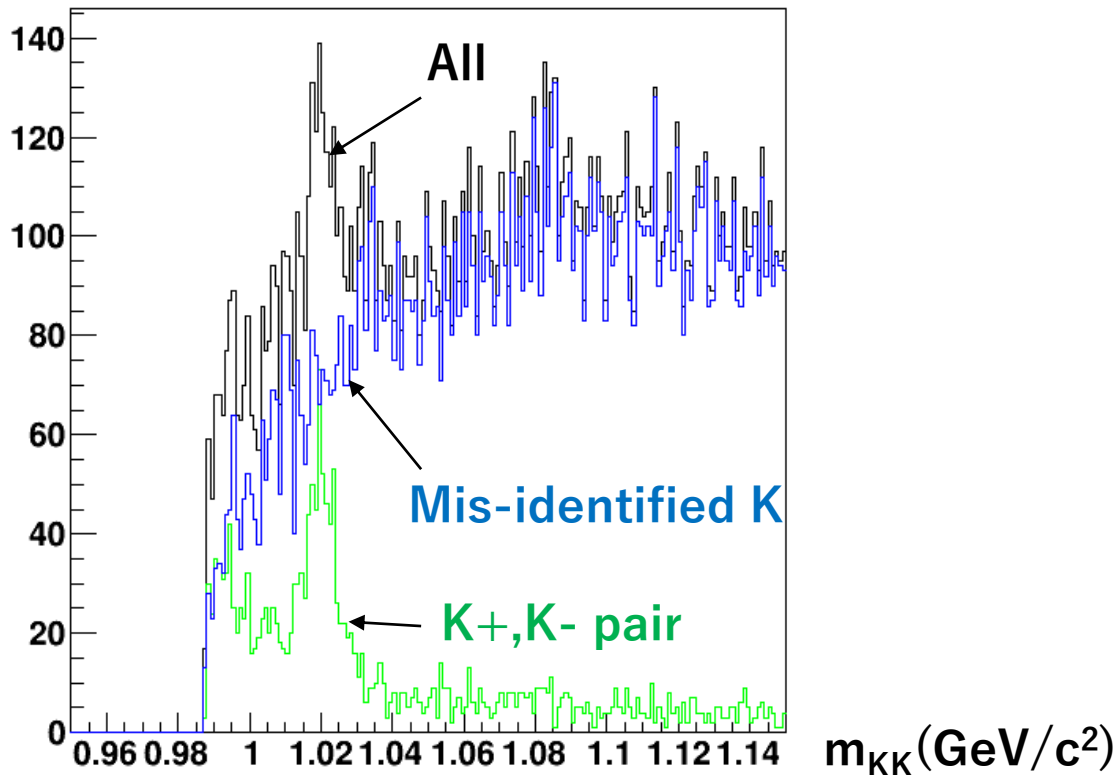
MRPC	Beam rate (/spill)	Target	R (cm)	Rate (kHz/cm ²) θ=30° top layer	Rate (kHz/strip) θ=30° top layer
		1x10 ⁹	C/Cu	130	0.274

S/B of $\phi \rightarrow KK$

- S/B ~ 1.3 (integral over 1.013-1.028 GeV/c^2)
 ~ 3.0 (at the ϕ peak)

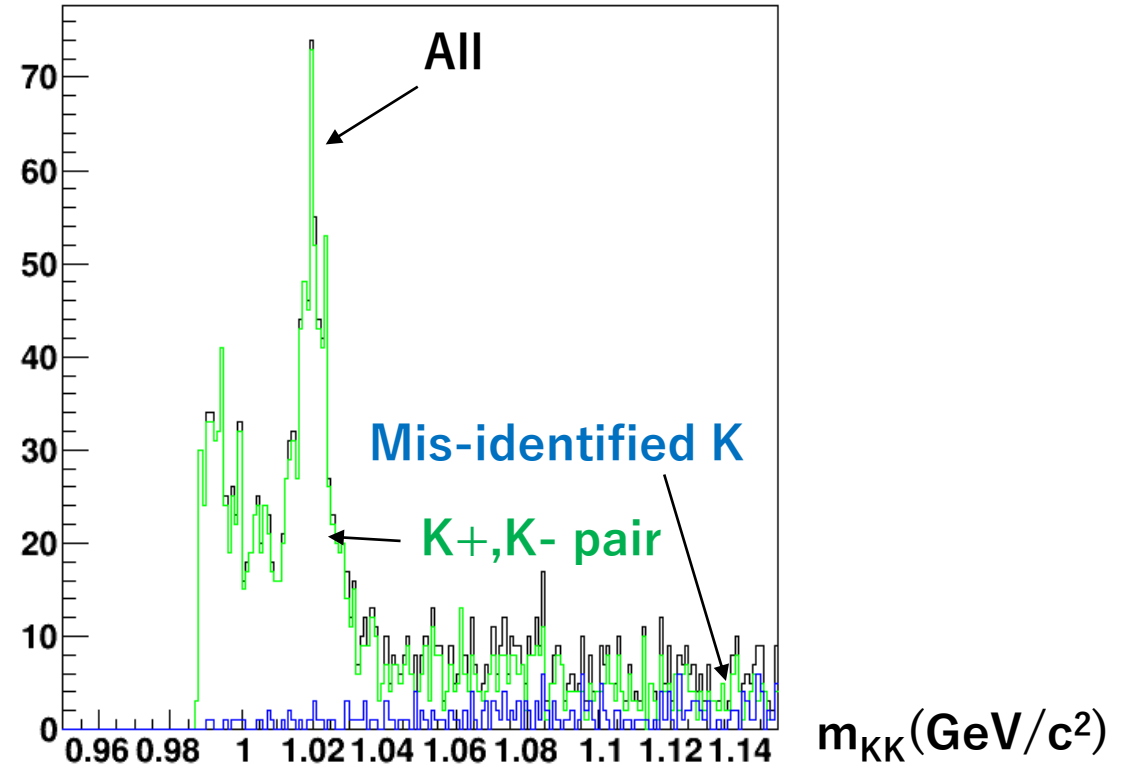
w/KK trigger, no additional PID cut

hrminvack2_phi_bkgall_ex7_5

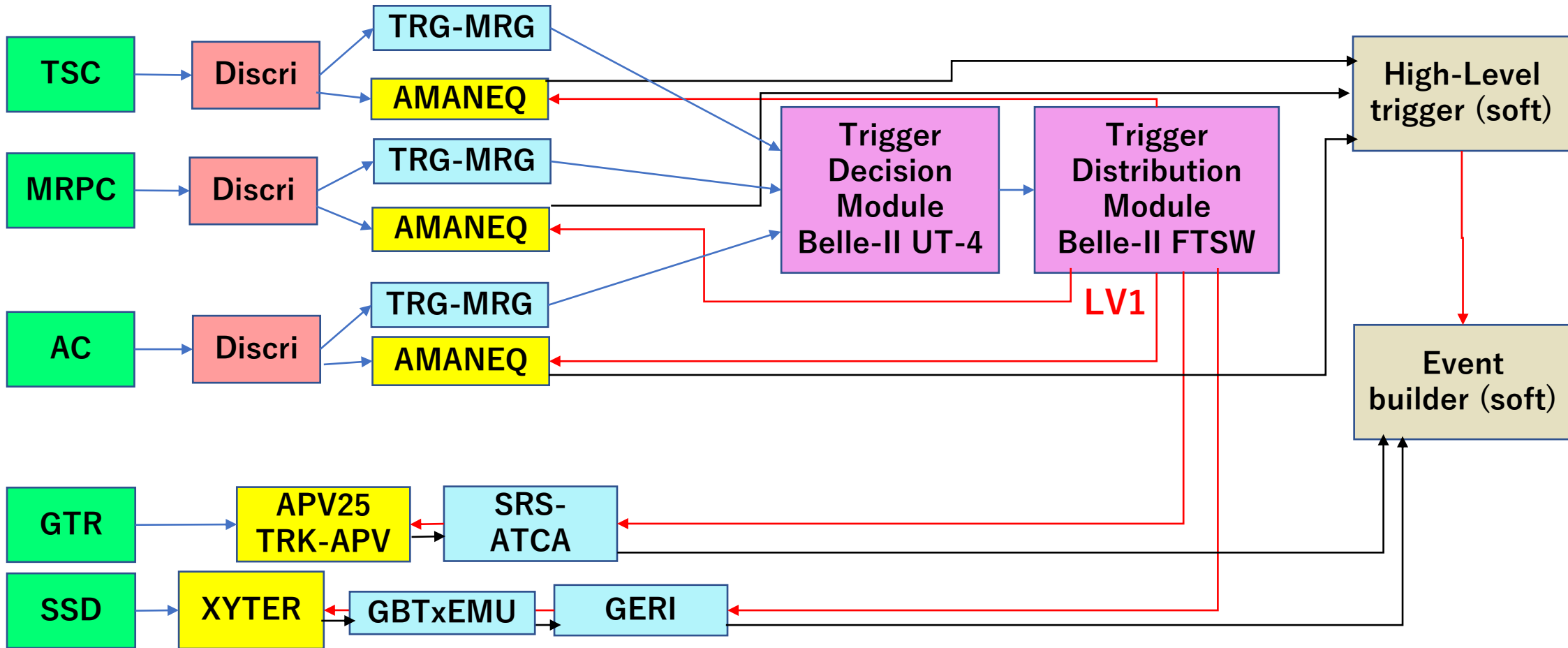


w/KK trigger, w/ additional PID cut

hrminvack2_phi_bkgall_ex7_5



Trigger Scheme 1 (LV-1 and HL(soft) trigger)



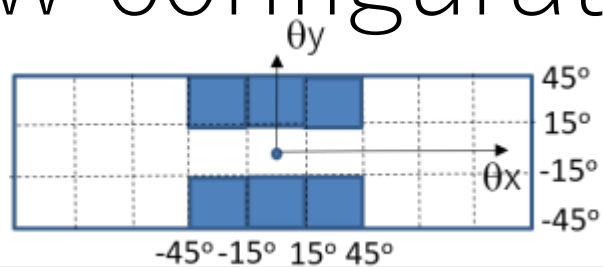
LV1 (unlike-sign trigger): defined with TSC hit, MRPC hit and AC hit

HLT(KK trigger) : Software trigger with TSC and MRPC TDC

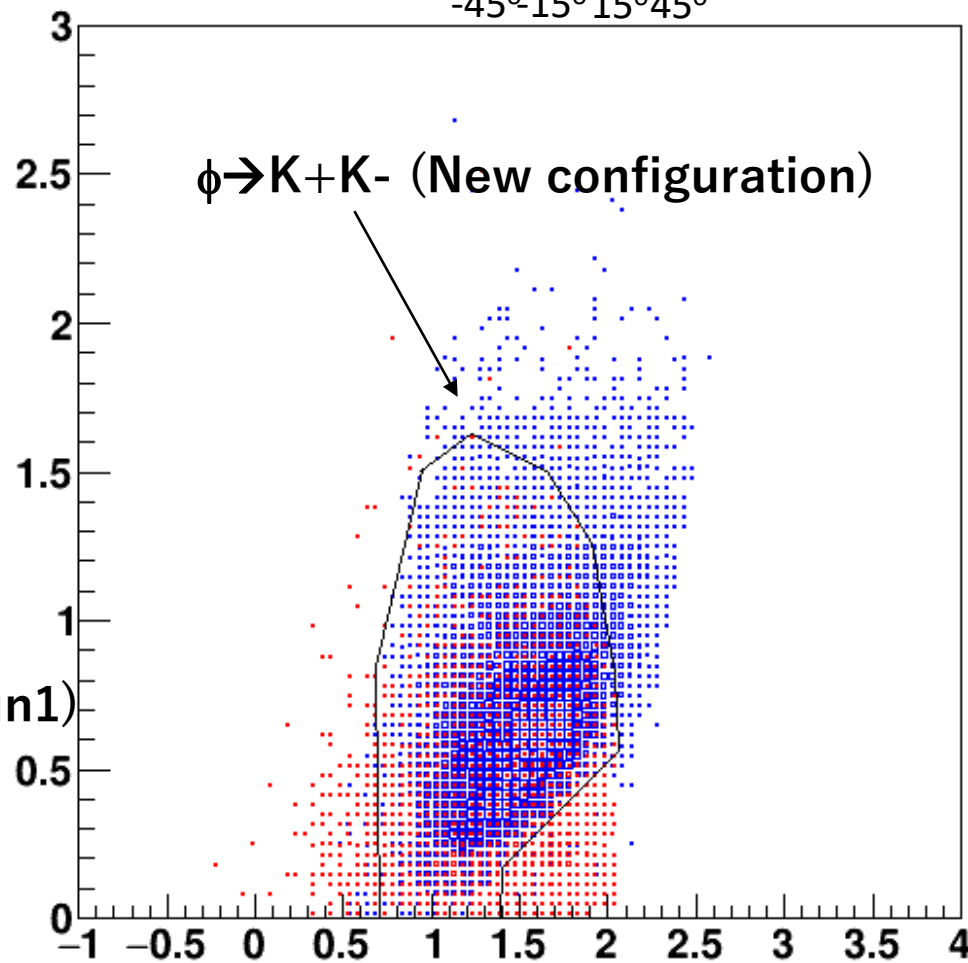
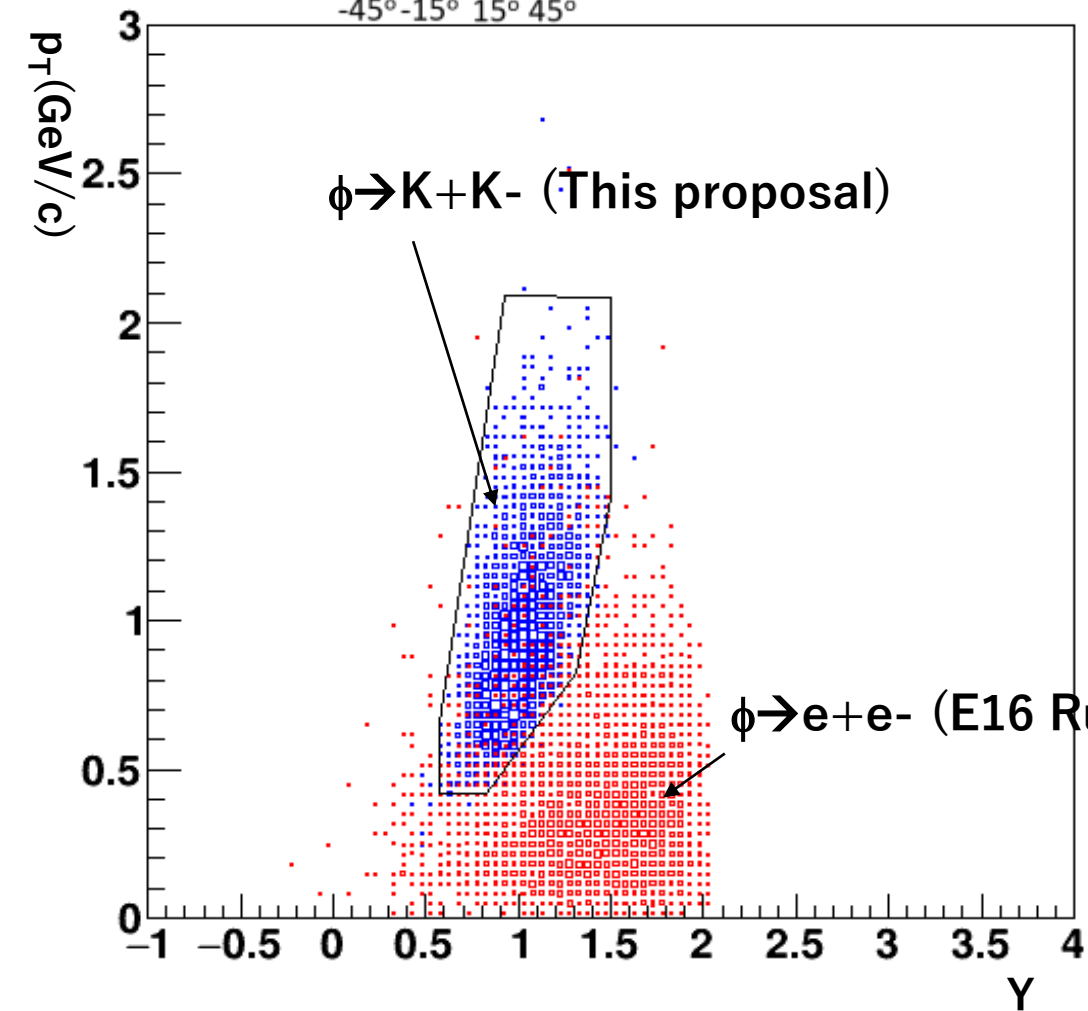
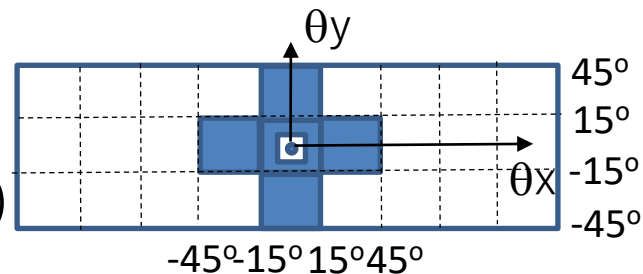
Or LV2 (KK trigger) :After LV1, TDC data are sent to UT4, and UT3 generates LV2 → Used for LV1 of SRS-ATCA and XYTER

LV1 rate: ~ 40kHz

New configuration



p+Cu (No AC veto)



Much better overlap

Issues

- Conflict with ee in middle layer
- New high-rate detectors necessary in the most forward module

Statistics ($\phi \rightarrow K+K^-$)

- C (0.1% int.) + Cu (0.1% int.) combined target

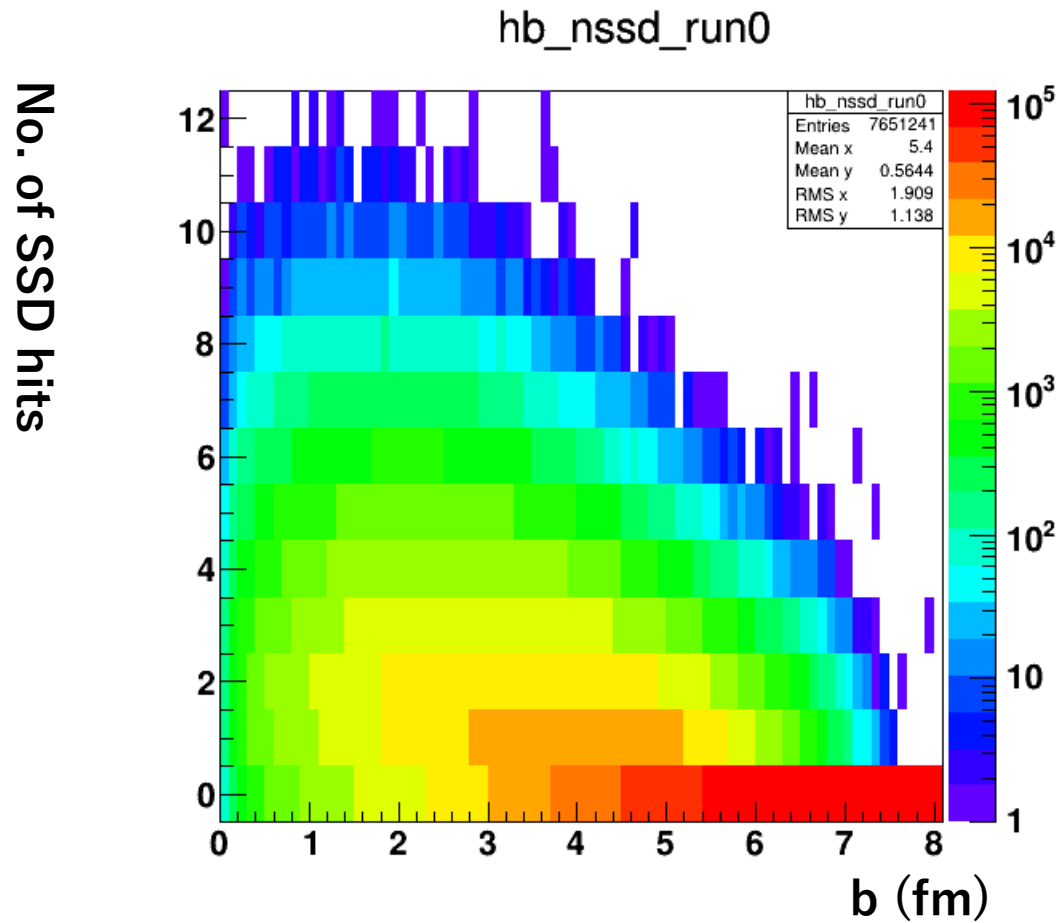
$\phi \rightarrow K+K^-$	Conf A		Conf B+F	
	C	Cu	C	Cu
Total	159k	262k	707k	892k
$\beta\gamma < 1.25$	72k	113k	323k	385k
$1.25 < \beta\gamma < 1.75$	84k	146k	376k	497k
Overlap y-pt ($\beta\gamma < 1.25$)	64k	100k	314k	370k
Overlap y-pt ($1.25 < \beta\gamma < 1.75$)	83k	143k	376k	497k

$\phi \rightarrow e+e^-$	Conf A		Conf B+F	
Overlap y-pt ($\beta\gamma < 1.25$)	98	147	1040	1320
Overlap y-pt ($1.25 < \beta\gamma < 1.75$)	128	184	2320	3020

Costs

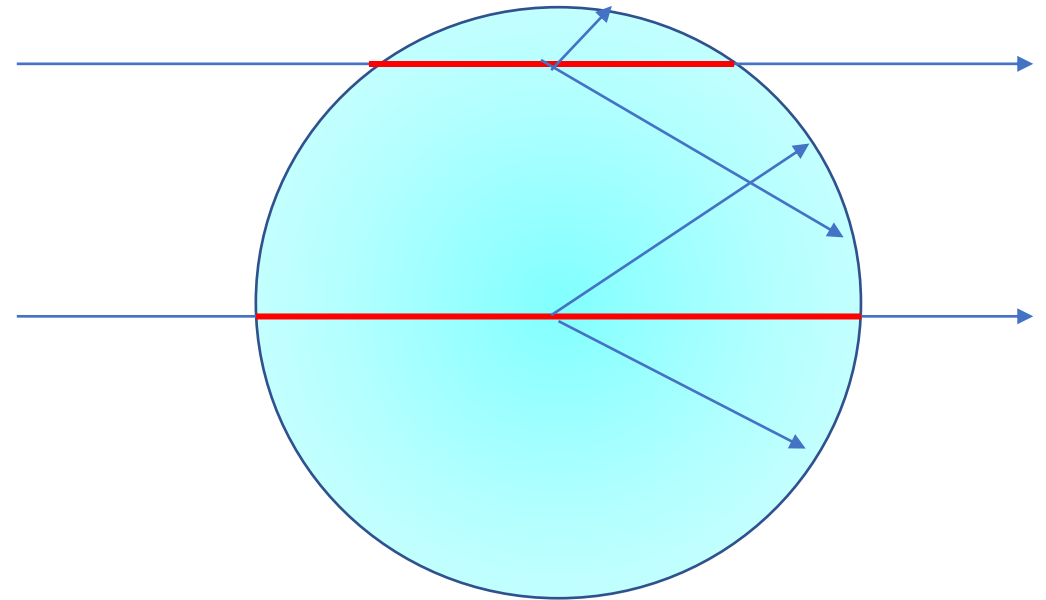
Detectors	6 modules(kyen)
MRPC	51090
TSC	21390
AC	55620
GTR	84330
DAQ	23890
Others	6300
Total(Include GTR)	242627
Total(exclude GTR)	158297

Impact parameter and multiplicity (JAM p+Cu)



No. of GTR1 hits

Smaller b
 → Longer path length
 For ϕ and daughters
 Can we use it?

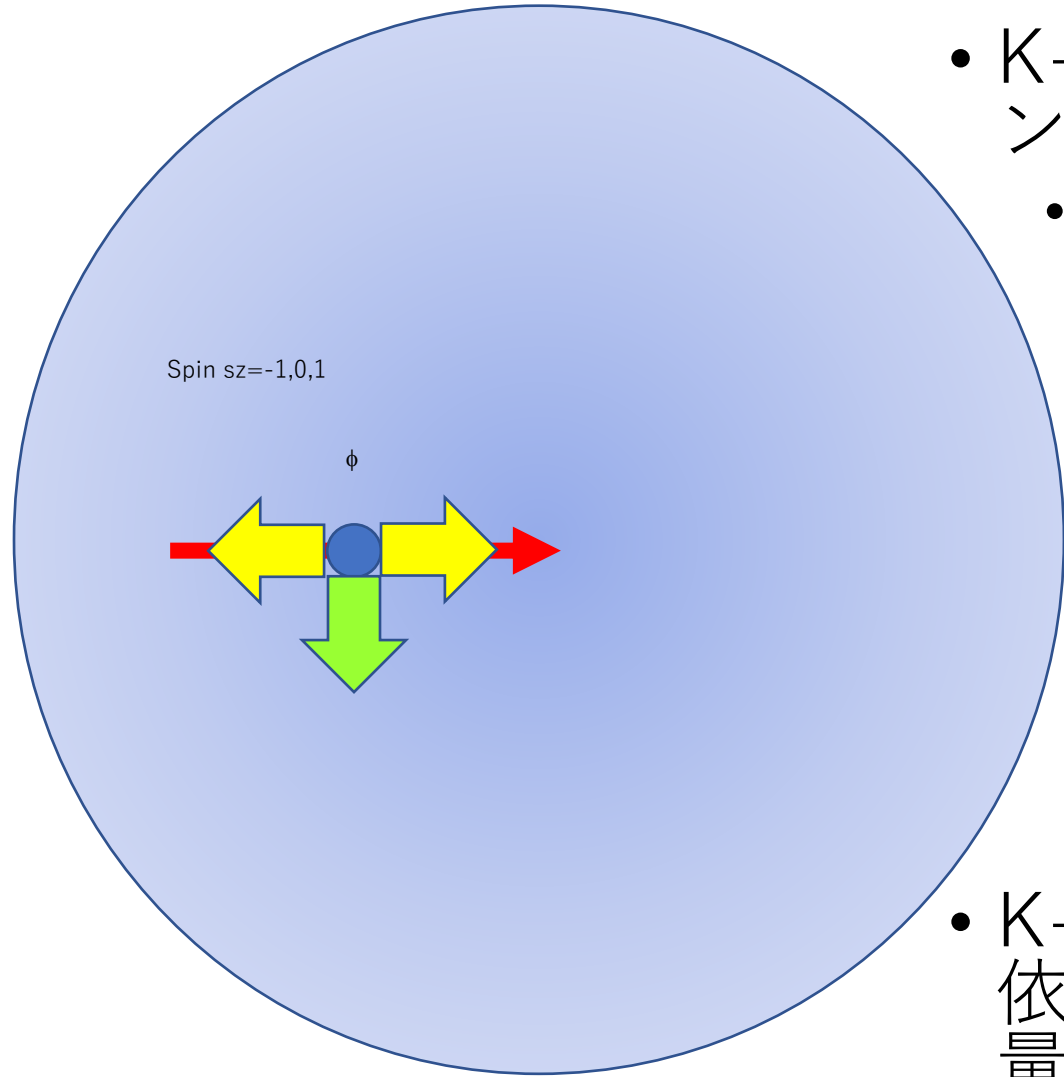


- Select high-multiplicity events → small impact parameter events → ϕ sees higher density in average?

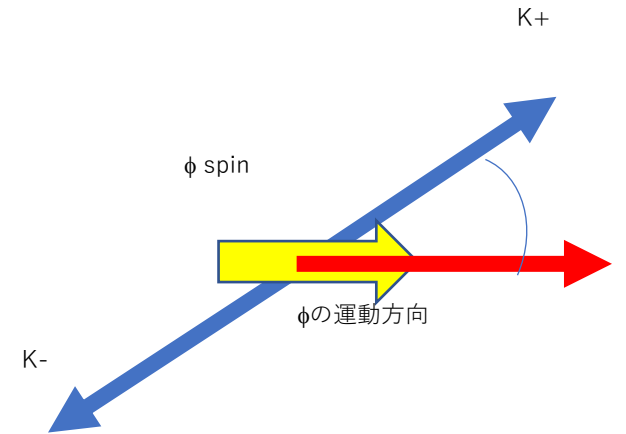
Φの「縦質量」と「横質量」

Φスピンが進行方向の場合と垂直方向の場合で媒質との抵抗が異なる
 →Φの質量分布が異なる
 (水泳中に進行方向に手を伸ばす場合と横に手を伸ばした場合)

未観測の物理量
 高統計のΦ→KKデータで解析可能か？



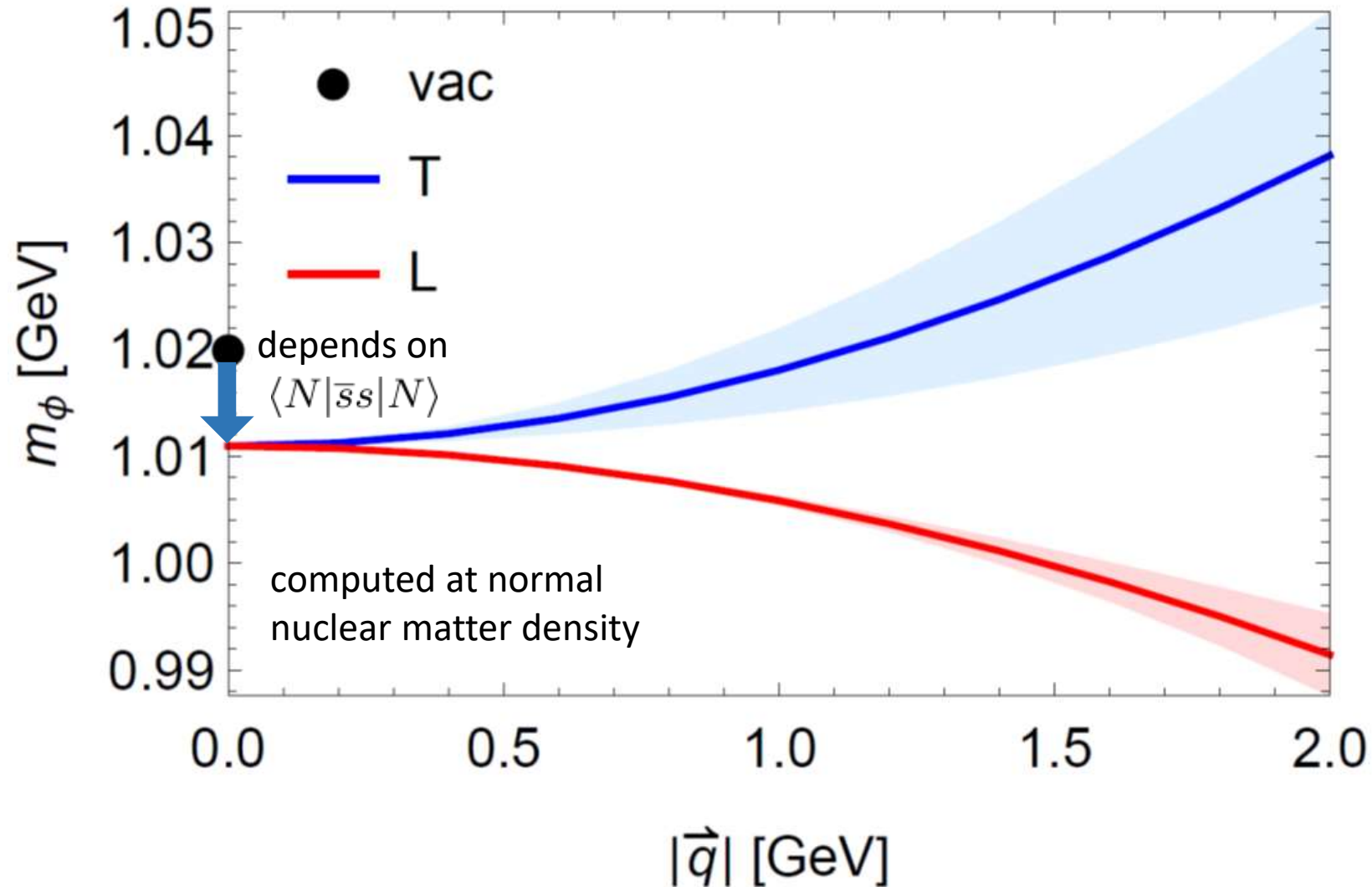
- K^+, K^- の放出: ϕ のスピン方向と相関がある
 - 縦偏極の場合:
 - 放出確率 $\propto \sin^2\theta$ (θ : ϕ 静止系における ϕ と K の角度)



- K^+K^- 不変質量分布の θ 依存性: 縦質量と横質量を区別できる

In a dense medium, longitudinal and transverse modes of vector particles can have independently modified dispersion relations due to broken Lorentz invariance.

Results for the ϕ meson mass with non-zero momentum

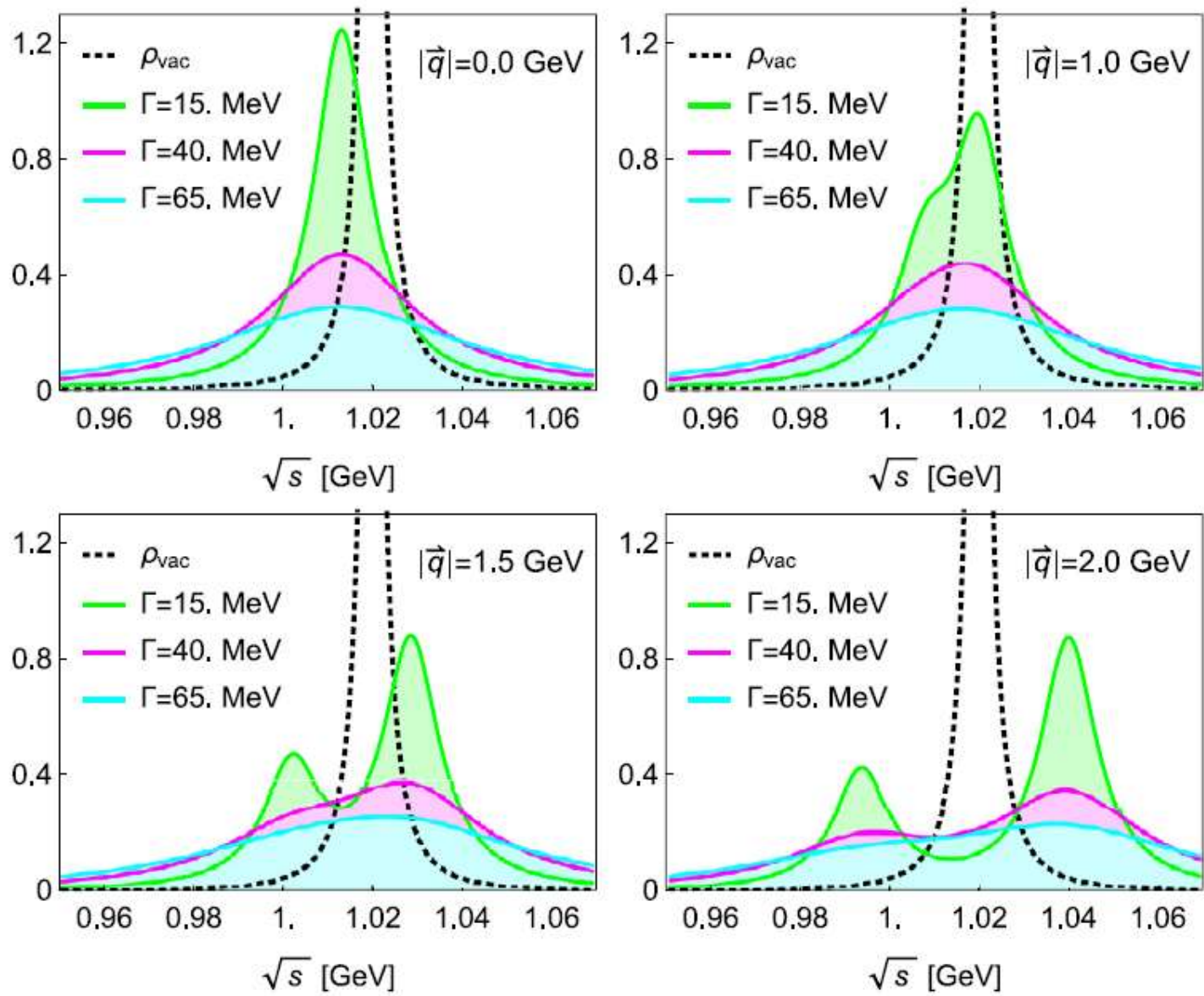


caused by

$$\langle N | ST \bar{s} \gamma^\alpha i D^\beta s | N \rangle + \langle N | ST G_\mu^{a\alpha} G^{a\mu\beta} | N \rangle$$

caused by

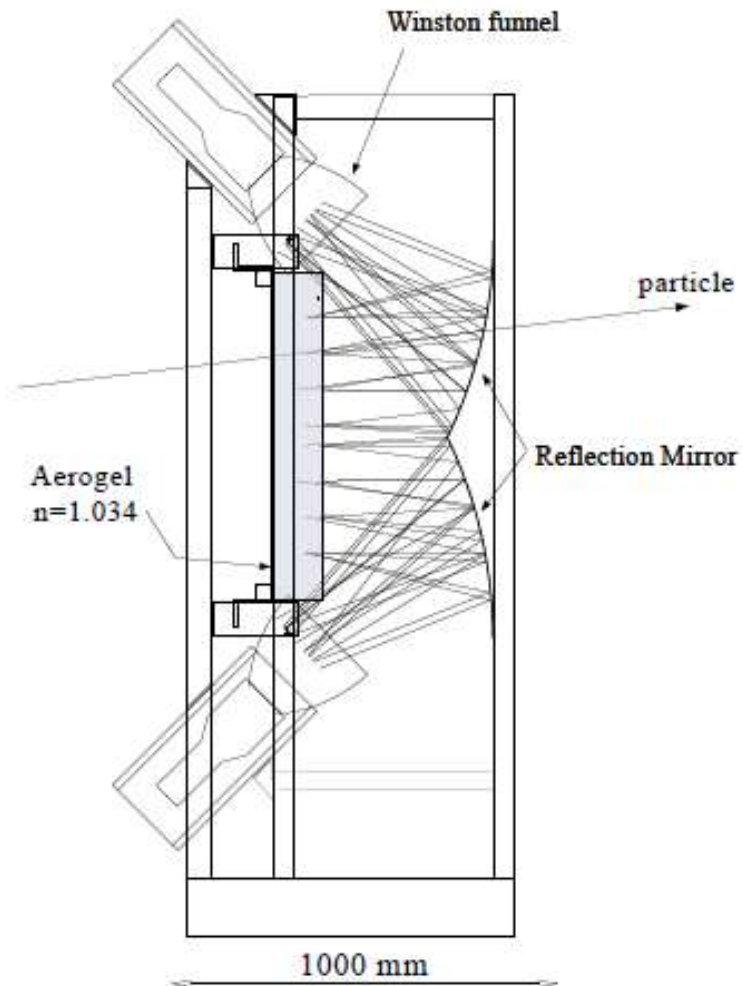
$$\langle N | ST G_\mu^{a\alpha} G^{a\mu\beta} | N \rangle$$



H.J. Kim and P. Gubler,
 Phys. Lett. B **805**, 135412 (2020).

Fig. 4. The polarization-averaged ϕ meson peak with $\Gamma=15, 40,$ and 65 MeV at normal nuclear matter density. The vacuum peak is shown as a black dotted line for comparison.

E325 AC



- Aerogel
 - $n=1.034$
 - $2640 \times 706 \times 125$ (mm³)
 - No. of photoelectron ~ 5.3
 - 5" PMT Hamamatsu H6527
 - Gain 1.4×10^7
- 1/3 scale for $\phi \rightarrow KK$ at E16?

Run1(2022/12)の試験に向けて

- MRPC
 - Ship-type 3台の製作（ガラス昇温）
 - 今年度1台？
- AC試作機開発
 - 設計（GEANT 4）（今年度）
 - 成木さんを通じて千葉大とコンタクト
- TSC試作機製作(25 slat, 10cmx10cm)（今年度）
- エレキ
- トリガー
- 架台

科研費申請が必要