高位置分辨厚GEM研制及应用

谢 宇 广

ygxie@ihep.ac.cn

中国科学院高能物理研究所

2014-07-19

4th CMPGD， 山东，威海， 2014

内　容

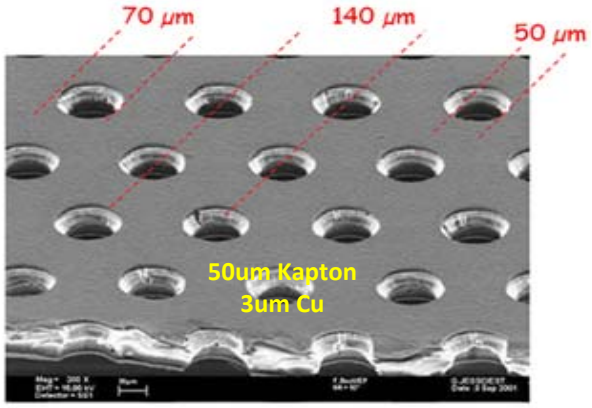
- 动机
- 技术
- 进展
- 应用
- 总结

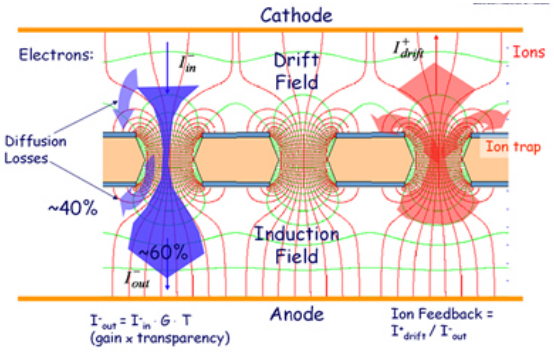
动　机

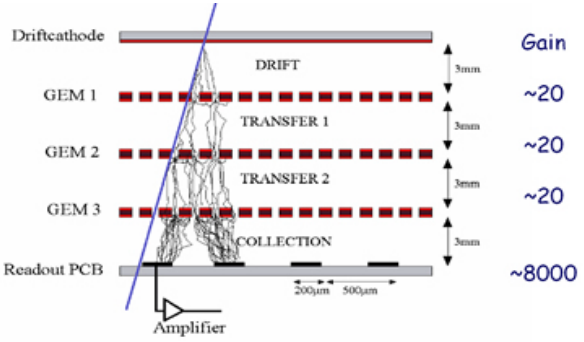
- GEM(**Gas Electron Multiplier**)
- 气体电子倍增器（1997 by F. Sauli）

⇨

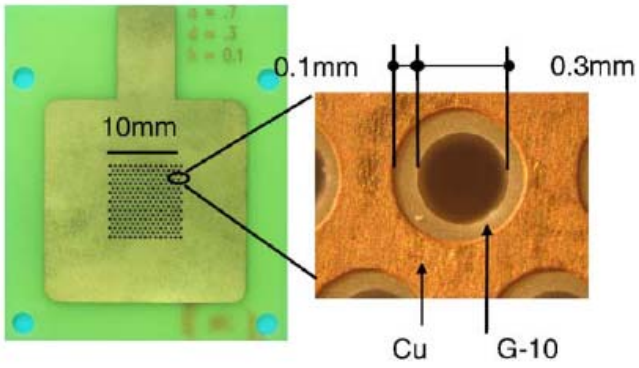
- THGEM(Thick **Gas Electron Multiplier**)
- 厚GEM （2004 by A. Breskin）

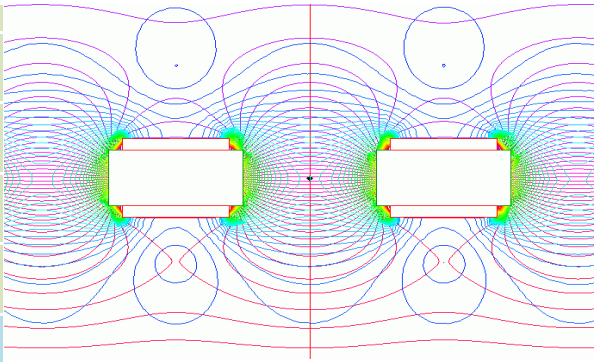


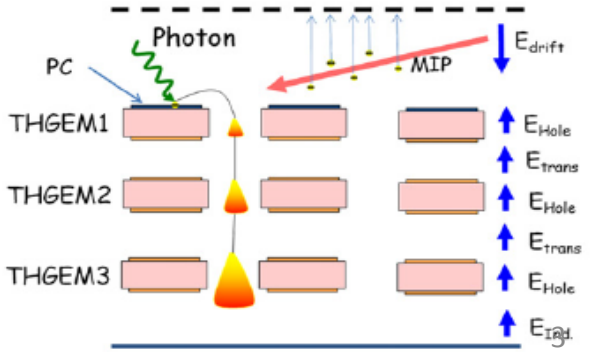




GEM	项目	THGEM
50	T/um	>=200
70	D/um	>=200
140	P/um	>=500
10	Rim/u	>=20
~10^3	GainS	>=10^4
~10^4	GainD	>=10^5
<20%	σE(FWHM)S	~20%
~25%	σE(FWHM)D	~30%
<200u	σx	<500u
High	Tech	Normal
High	Cost	Low
Fragile	Durability	Robust
Good	Stability	+++
Kapton	Substrates	FR-4, PTFE, Ceramic , Kapton







厚GEM探测器可能的应用

应用场合	具体内容	可能应用实验项目	规模
VUV/UV成像及探测	高能粒子鉴别、 契仑科夫成像（RICH）	ALICE升级， COMPASS升级	大
	暗物质液氙、液氩闪烁光探测	上海交大PandaX 清华暗物质实验等	一般
	GPM，单光子探测		一般
径迹室	外层径迹室，u探测器	LHC2	大
读出	TPC 读出单元		一般
	数字量能器采样读出单元	ILC，CEPC	大
宇宙线探测	大型宇宙线触发阵列	LHAASO	大
X射线、医疗中子成像	同步X射线散射		一般
	医疗PET成像	PET开发	一般
	散裂中子/核物理	CSNS等	一般

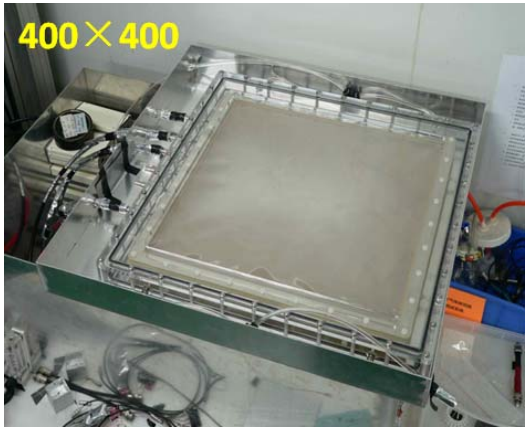
50×50　100×100

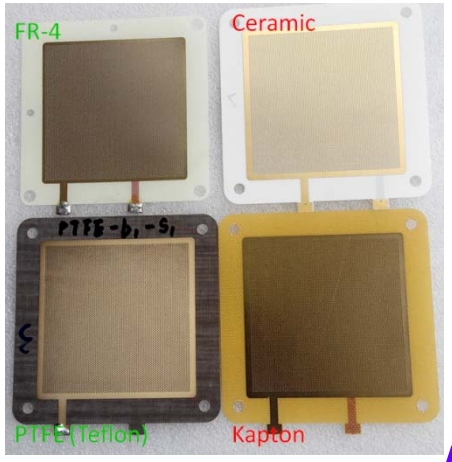
200×200　300×300

400×400

600×600

600×1200





大面积

THGEM
应用

新基材

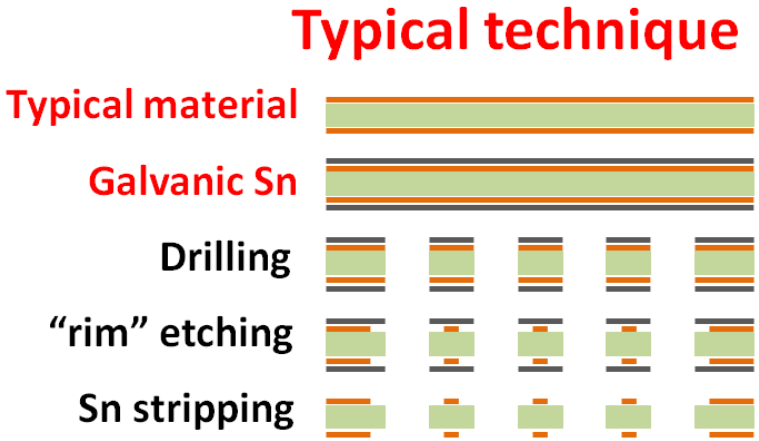
高分辨

低中子吸收
低放射本底

本征分辨<=200um

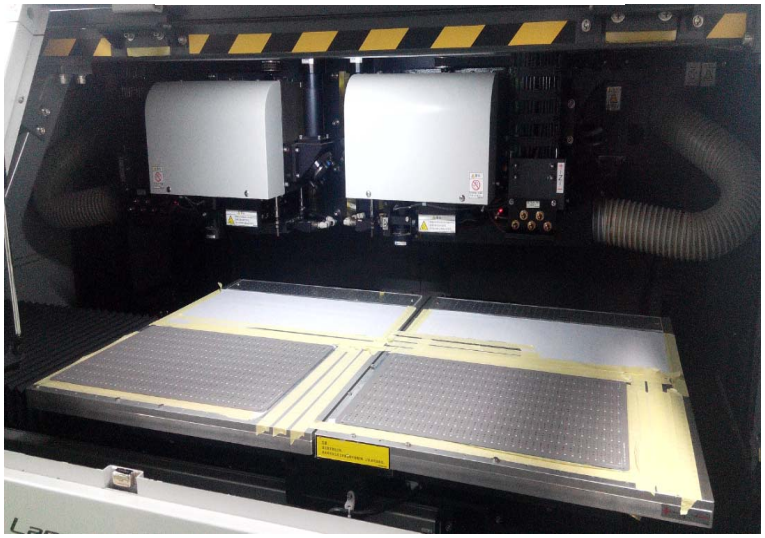
技　术

机械打孔



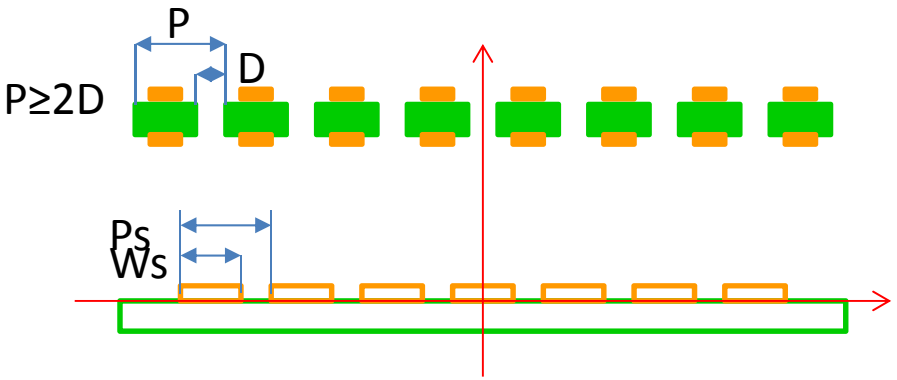
普通：孔径200um，孔间距500um
极限：孔径150um，孔间距400um

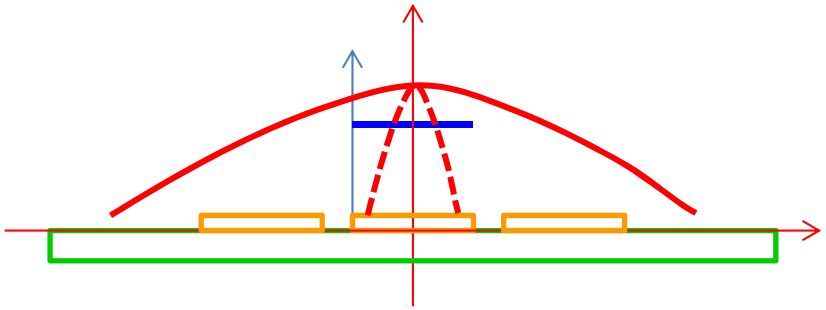
激光打孔

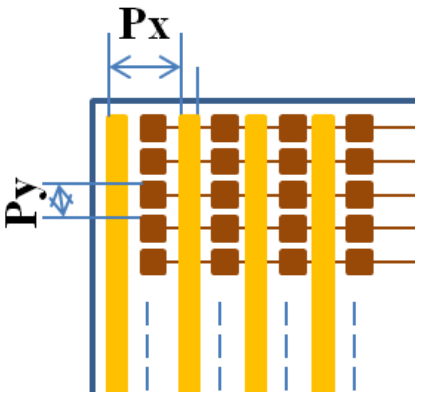


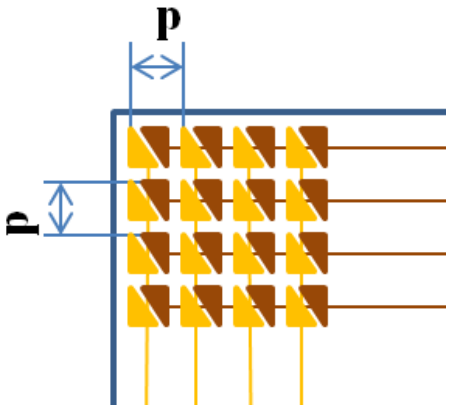
普通：孔径100um，孔间距300um
极限：孔径50um，　孔间距150um

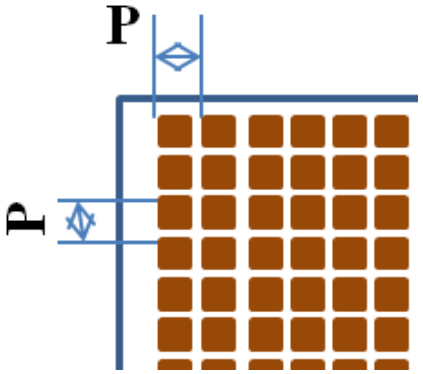
本征分辨与孔径、孔间距的关系



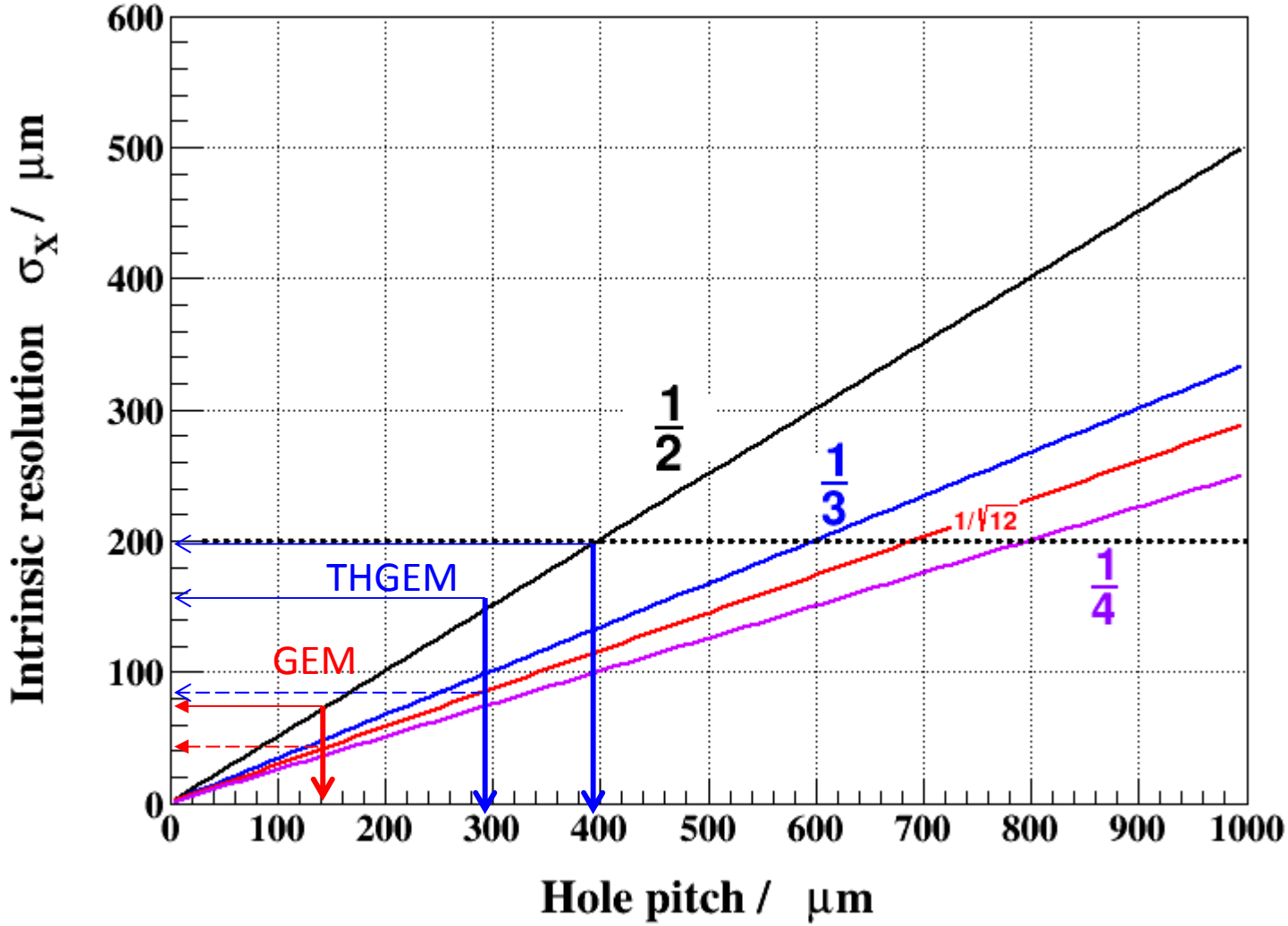






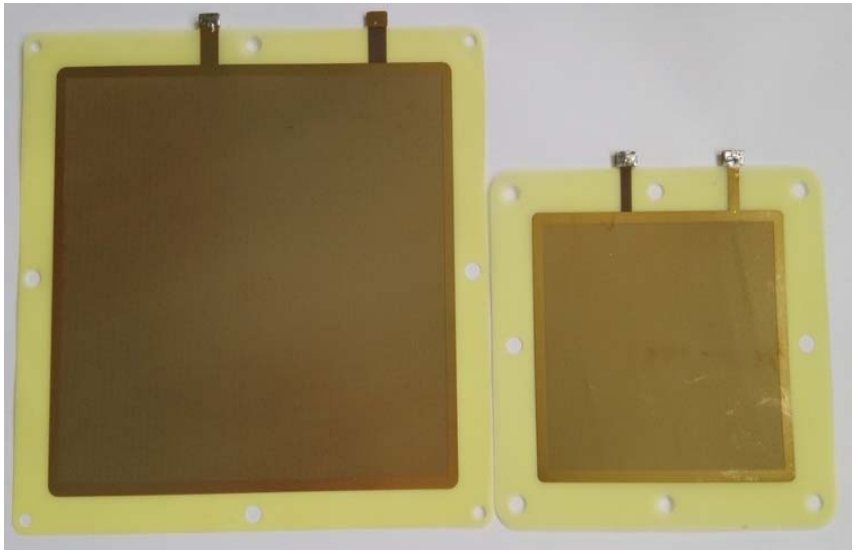


读出结构	读出方式	概率分布	本征分辨（σ）
Strip	Digital	Uniform	P/√12(1/3.464)
	Analog	Gaussian	<P/4?
Pad	Digital	Uniform	P/√6 (1/2.45)
	Analog	Gaussian	<P/3?

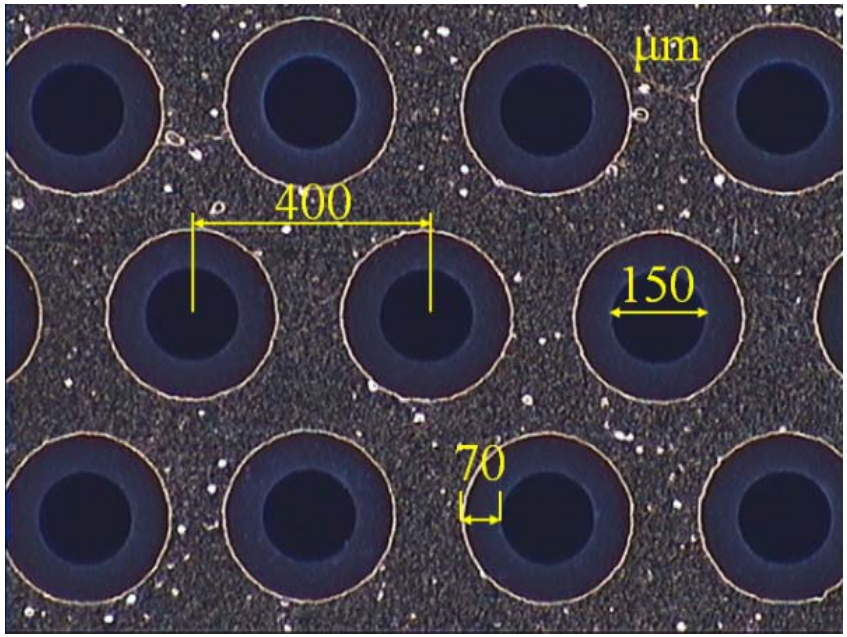

Intrinsic resolution σx / μm
Hole pitch / μm
0
100
200
300
400
500
600
700
800
900
1000
1/2
1/3
1/√12
1/4
THGEM
GEM

进　展

机械打孔

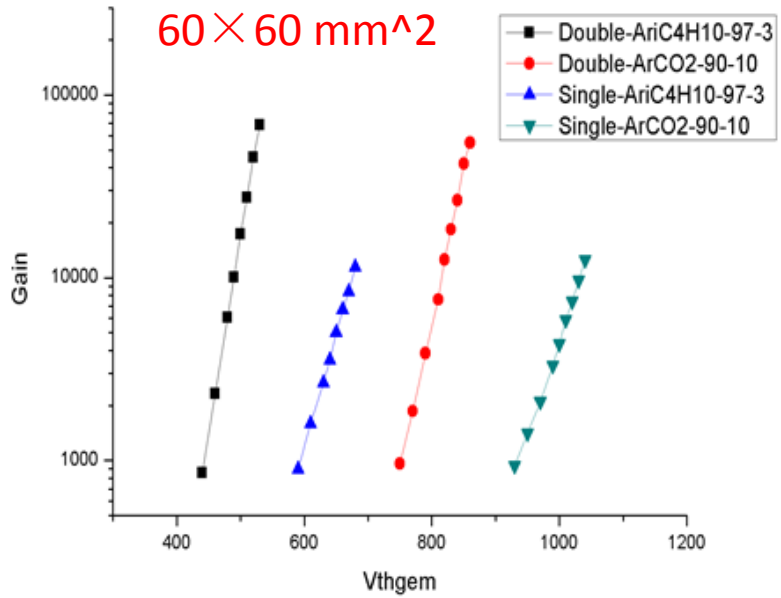


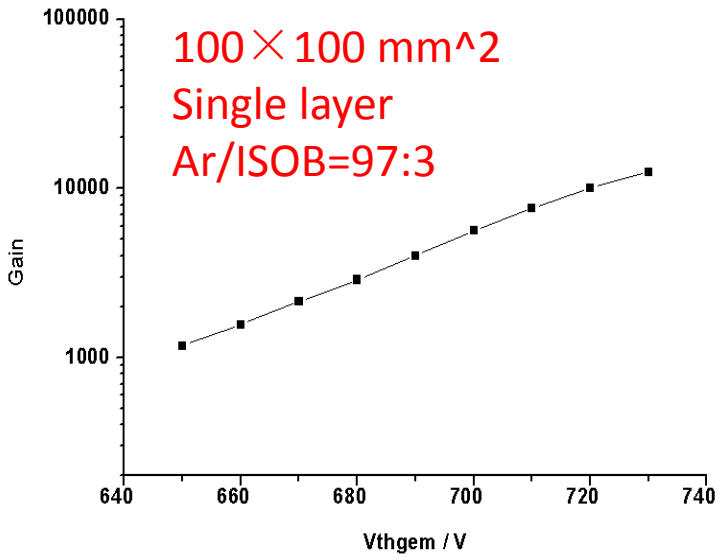
孔径: 150um
孔间距: 400um
厚度: 150um
Rim: 70um
灵敏面积：60×60 mm^2
100×100 mm^2



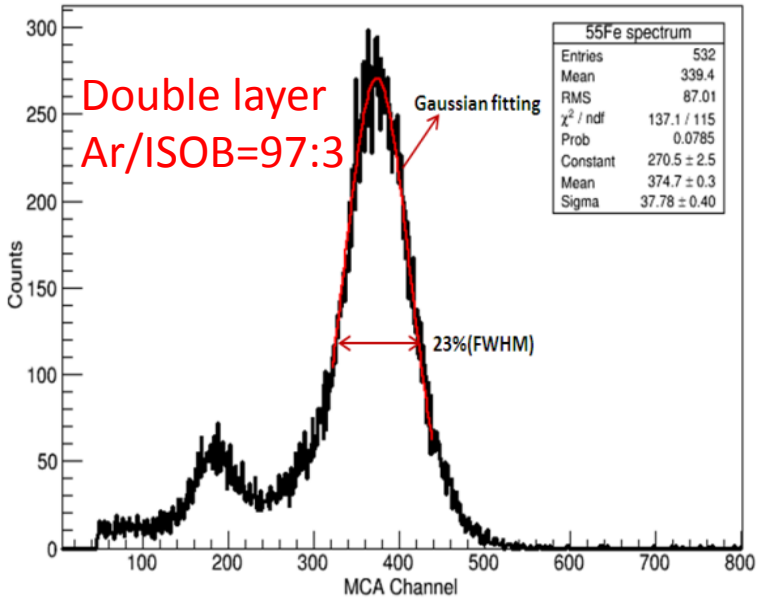
更换钻头数量较多；
加工费时

增益

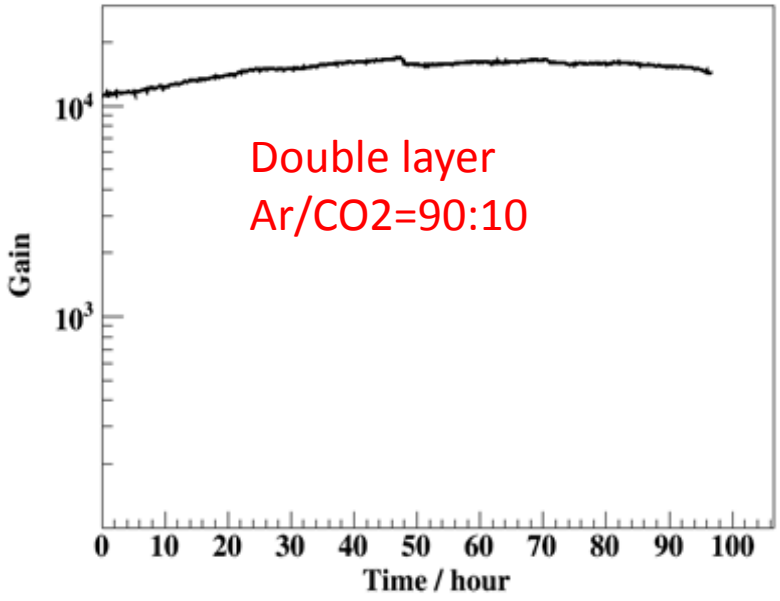

60×60 mm^2
Double-AriC4H10-97-3
Double-ArCO2-90-10
Single-AriC4H10-97-3
Single-ArCO2-90-10
Gain
Vthgem


100×100 mm^2
Single layer
Ar/ISOB=97:3
Gain
Vthgem / V

能量分辨

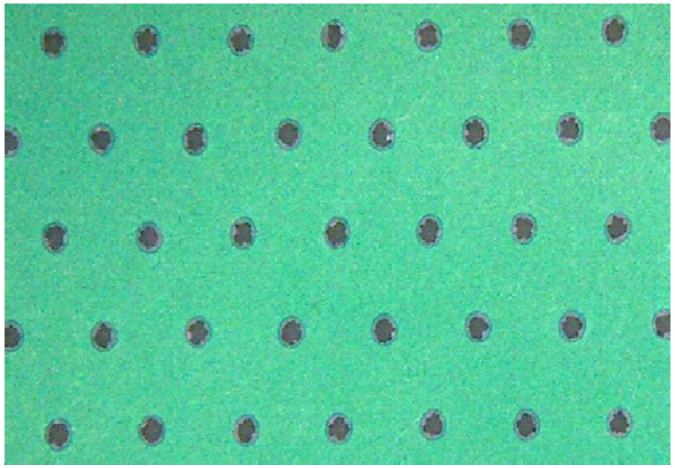

Double layer
Ar/ISOB=97:3
55Fe spectrum
Entries 532
Mean 339.4
RMS 87.01
χ² / ndf 137.1 / 115
Prob 0.0785
Constant 270.5 ± 2.5
Mean 374.7 ± 0.3
Sigma 37.78 ± 0.40
Gaussian fitting
23%(FWHM)
Counts
MCA Channel

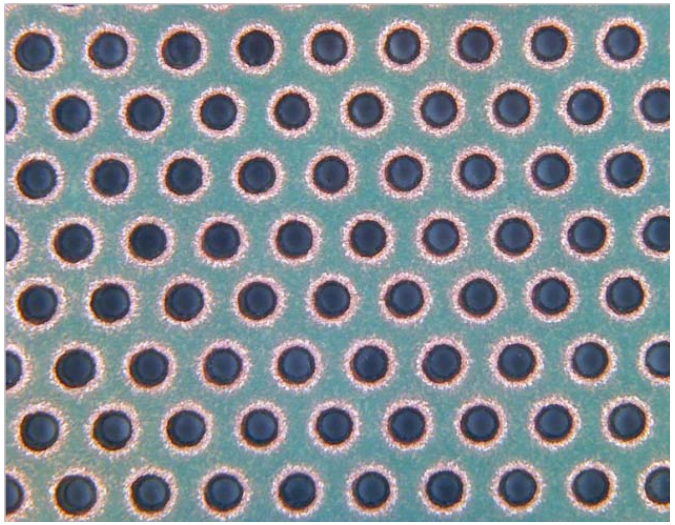
稳定性


Double layer
Ar/CO2=90:10
Gain
Time / hour

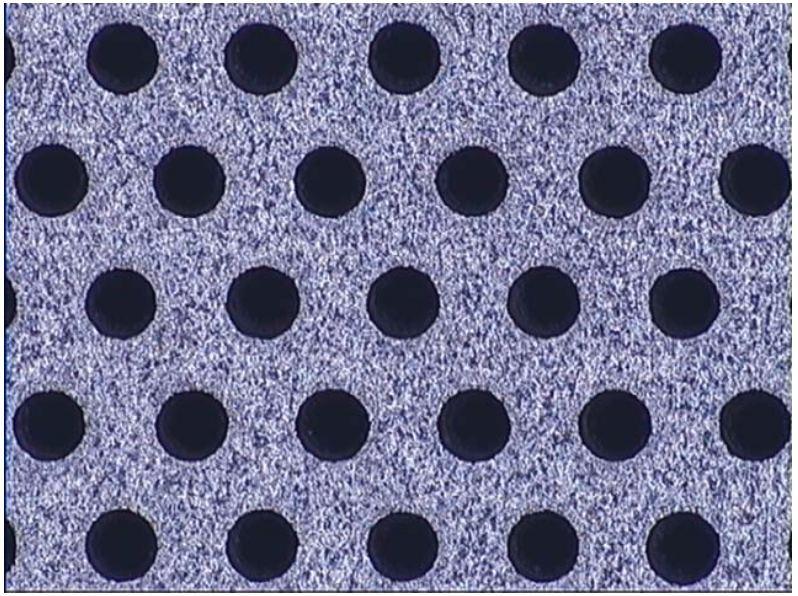
激光打孔

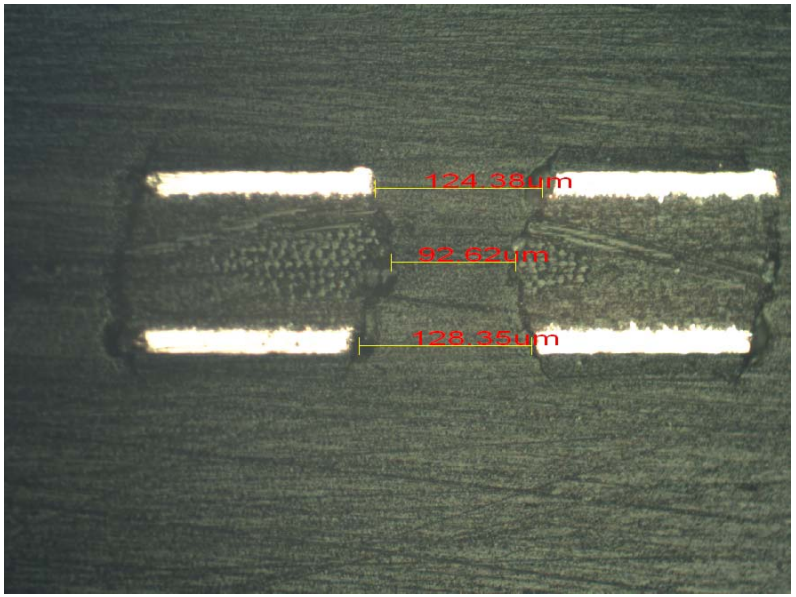
激光厚GEM快速加工制作工艺正在研究
工艺相对复杂，不同处理效果相差很大
孔型不是很完美，类似直孔小Rim。





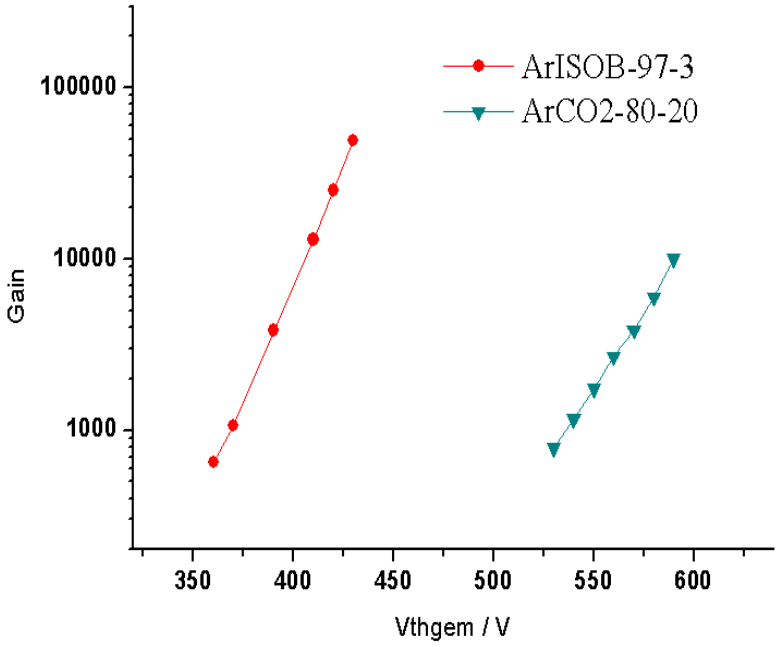
目前比较好的结果





Laser THGEM, double layer

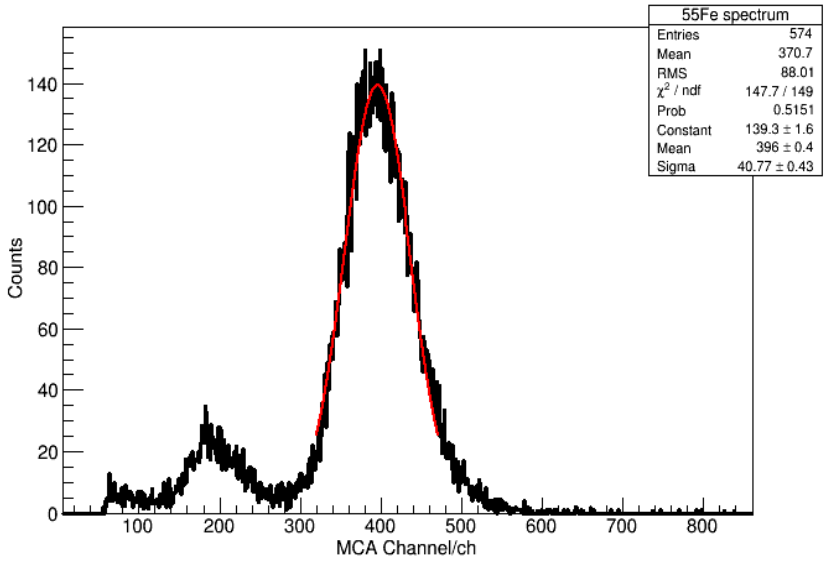
増益



>1×10^4@ArCO2=80:20

>5×10^4@ArISOB=97:3

能量分辨

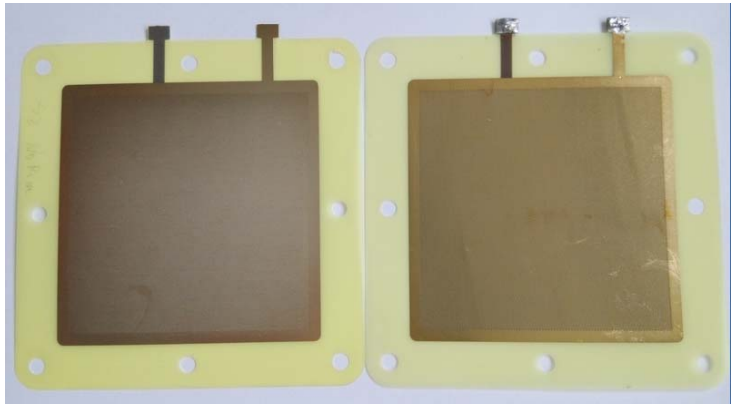


24%@gain=4×10^3

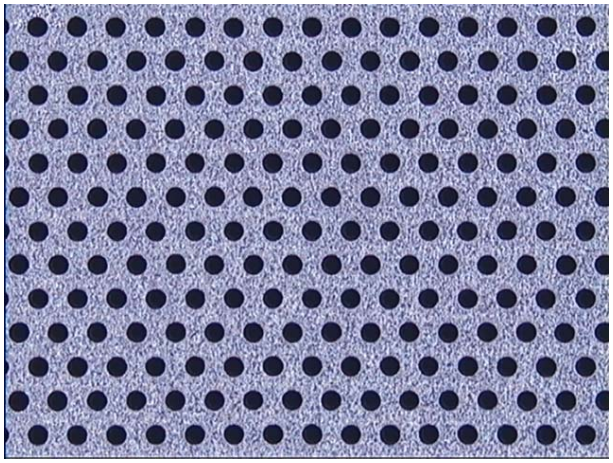
激光打孔

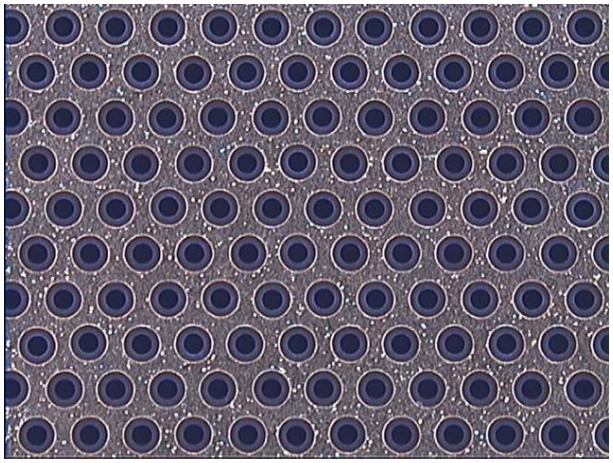
孔径100um
孔间距300um
厚度100um
Rim 20um
本征分辨87um

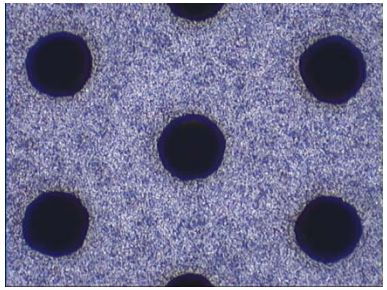
机械打孔

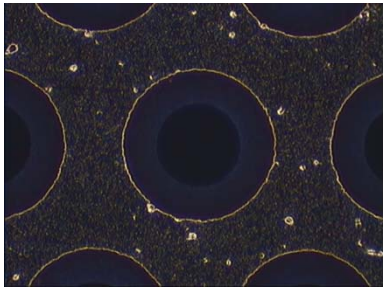


孔径150um
孔间距400um
厚度100um
Rim 70um
本征分辨116um









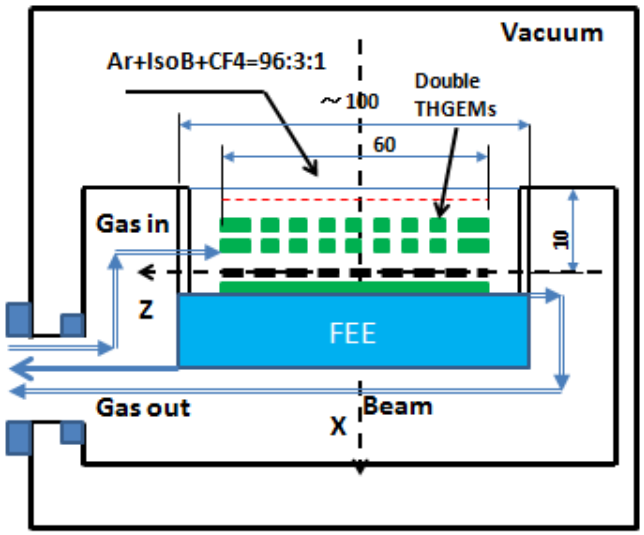
应　用

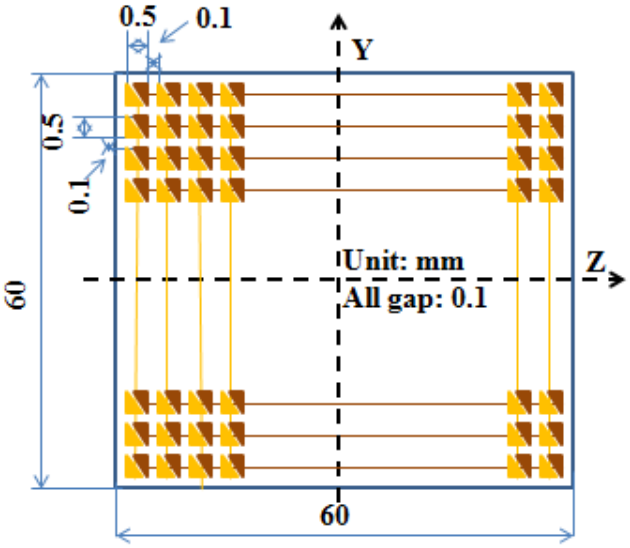
二维位置灵敏探测器

0.1～50 MeV 电子
位置分辨<200um
灵敏面积：60mm^2
拟采用激光THGEM

共200路X和Y条读出
基于国内16路ASIC

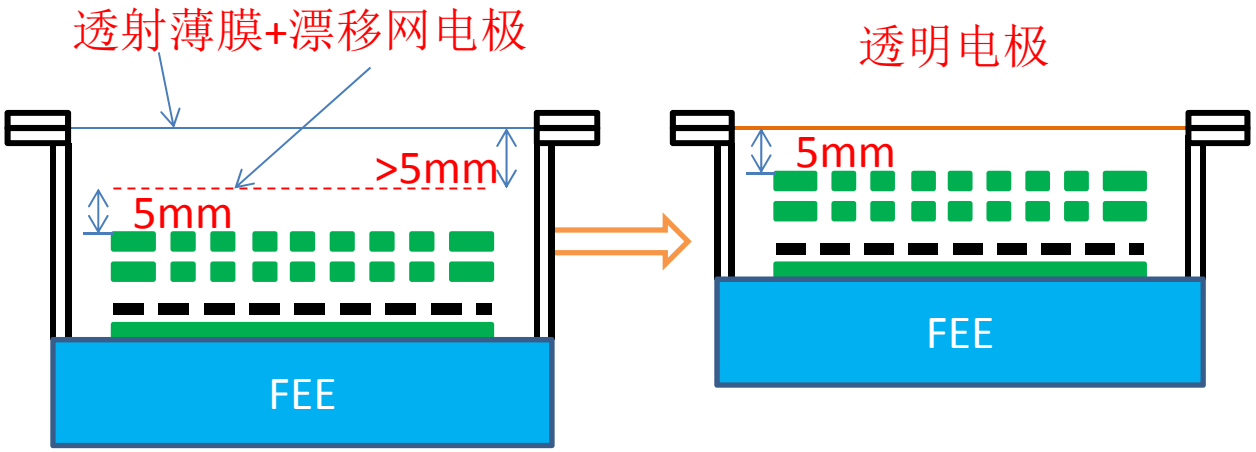
置于真空罐中
采用50～100um麦拉膜窗
流气式，0.1～1ATM（负压）



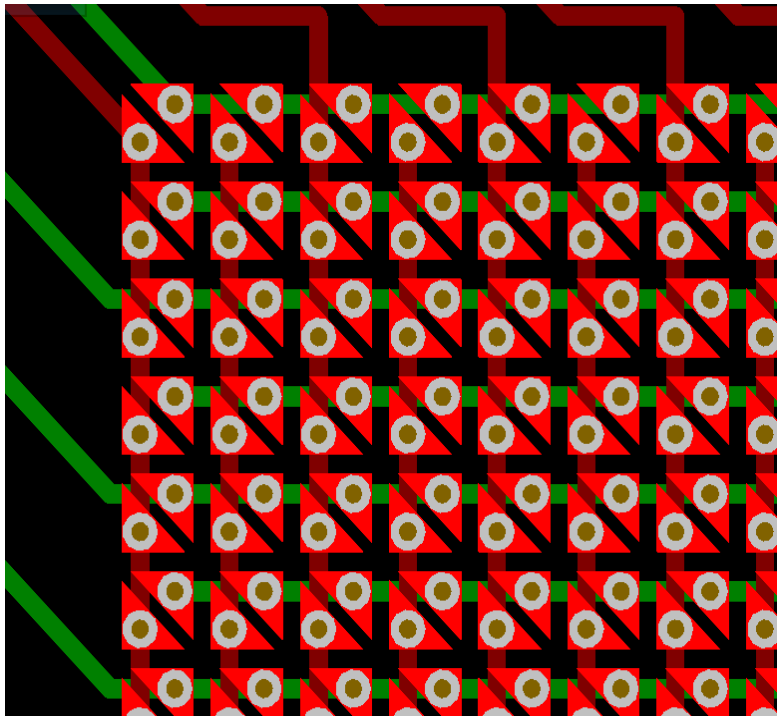


空气散射

漂移距离3～5mm，平衡效率与散射
如果有很薄的透明电极(<100um)，用其作透射窗可减小电子的散射



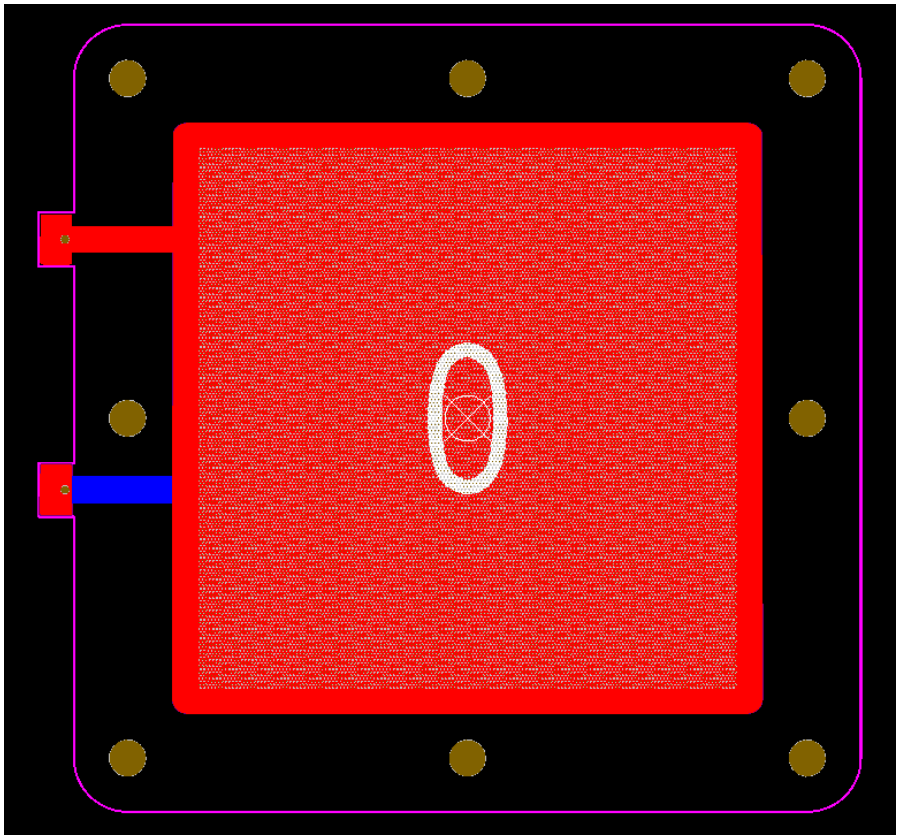
读出条



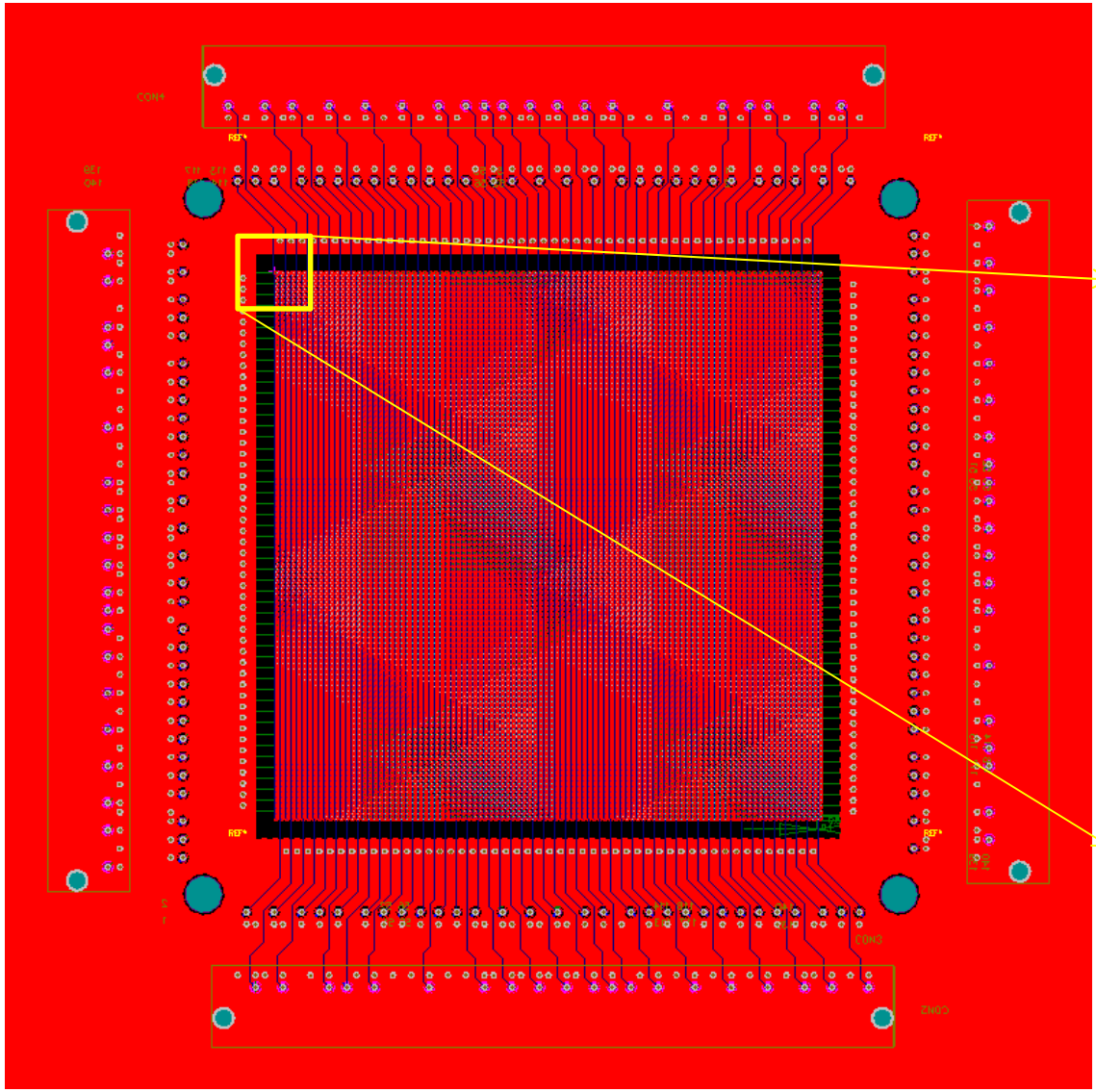
条读出，条宽：0.50*0.50mm，
间隙：0.1mm，周期pitch：0.6mm
全取Q，通过重心法空间分辨优于
Pitch/sqrt(12)<200um，

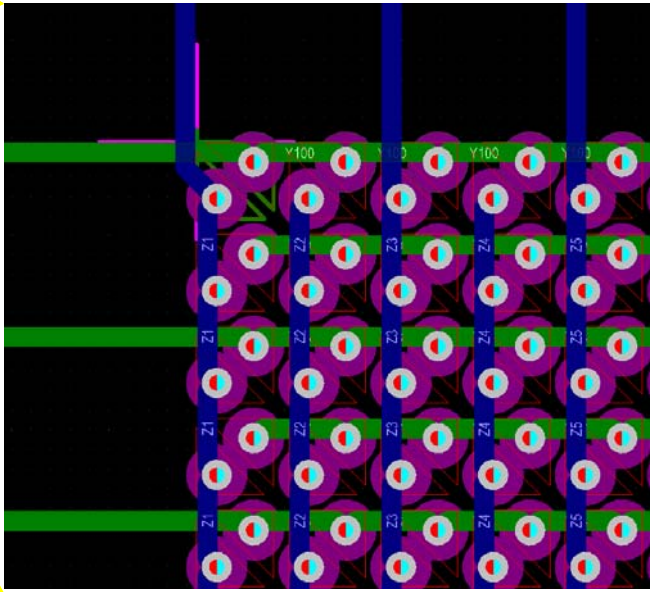
THGEM

双层，增益>1×10^4
拟采用激光**THGEM**

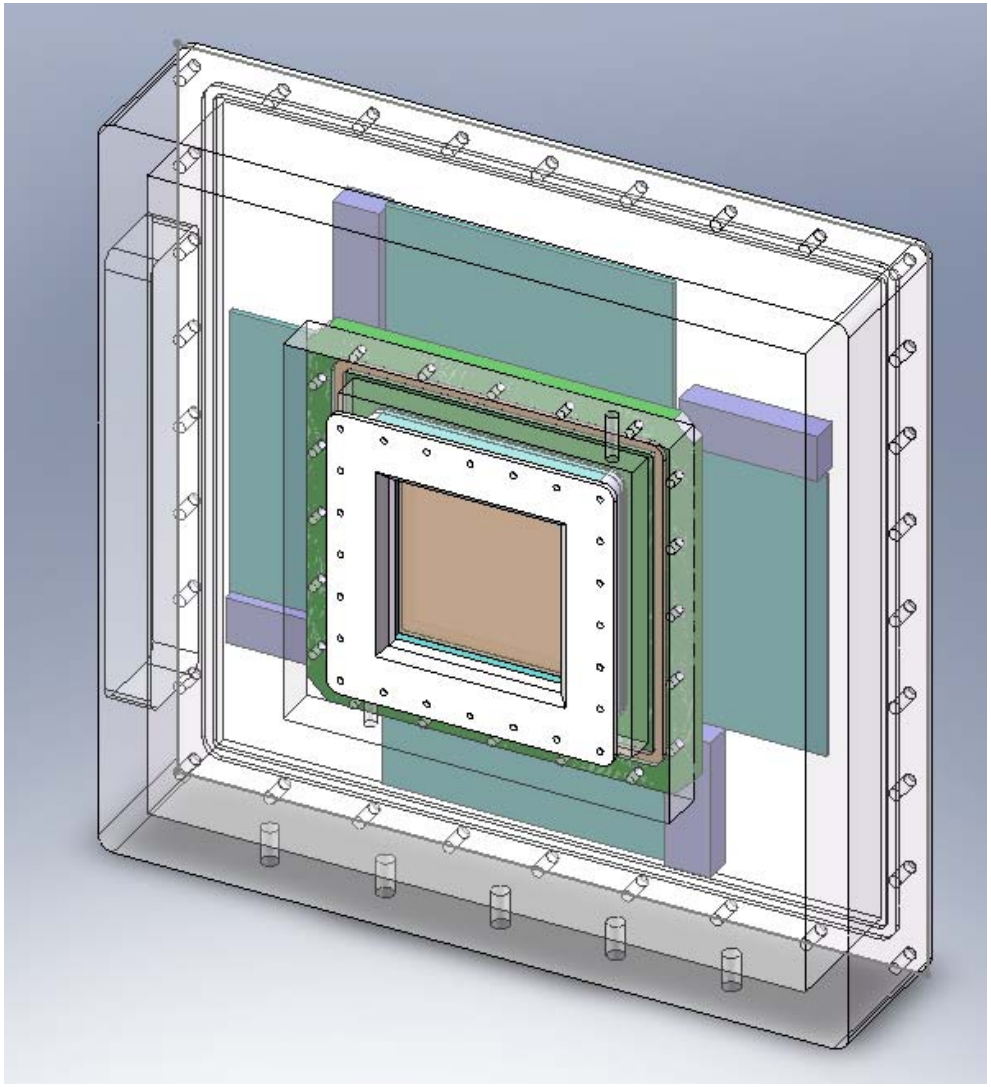


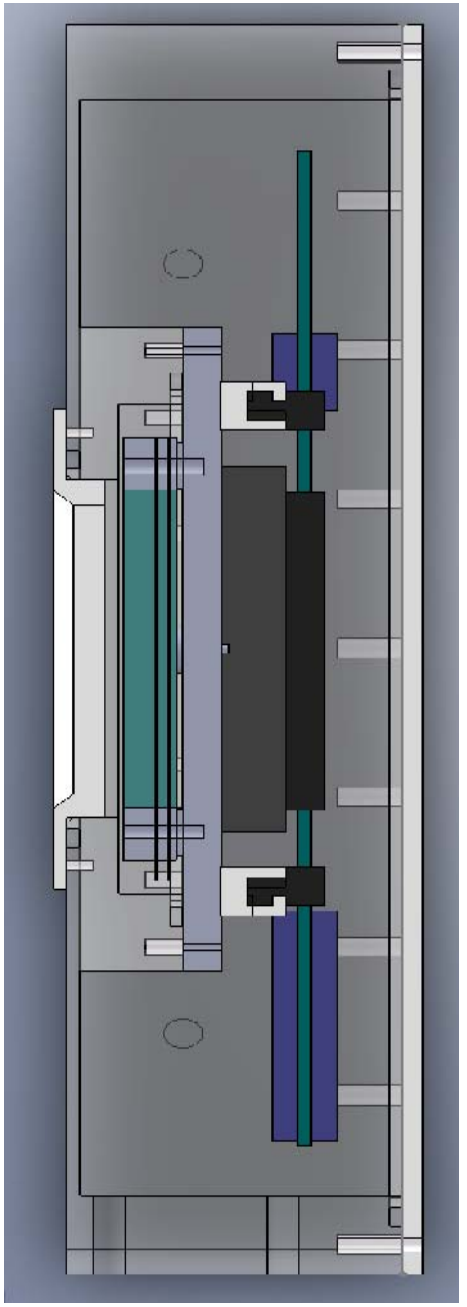
感应板





整体结构

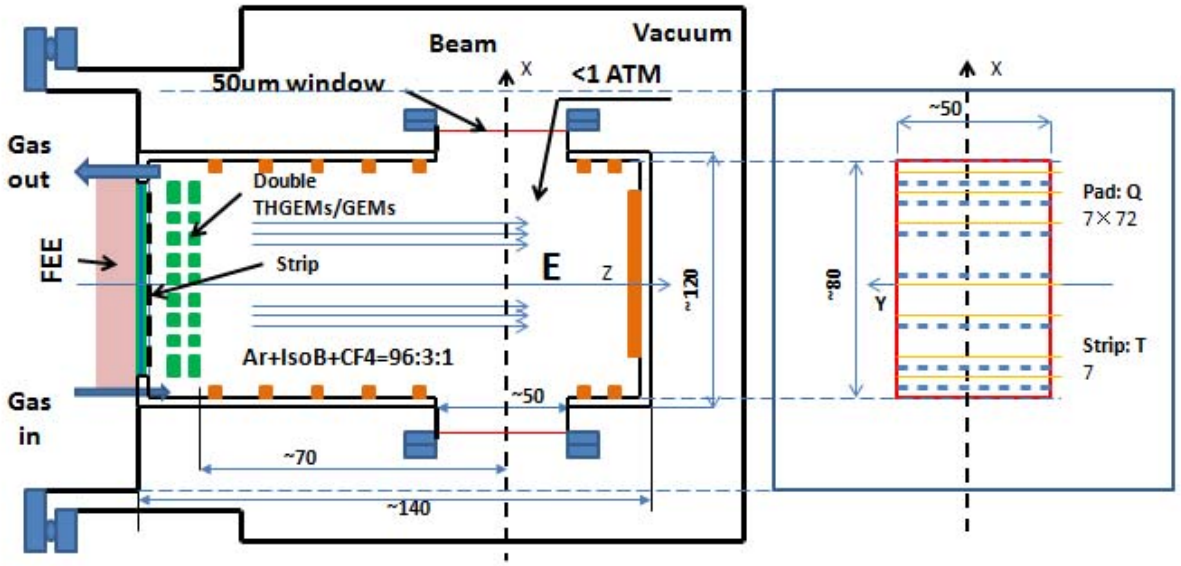




TPC径迹探测器

3～50 MeV 脉冲电子
位置分辨<200um
灵敏面积：50*80mm^2
共512路pad读出
基于国内16路ASIC

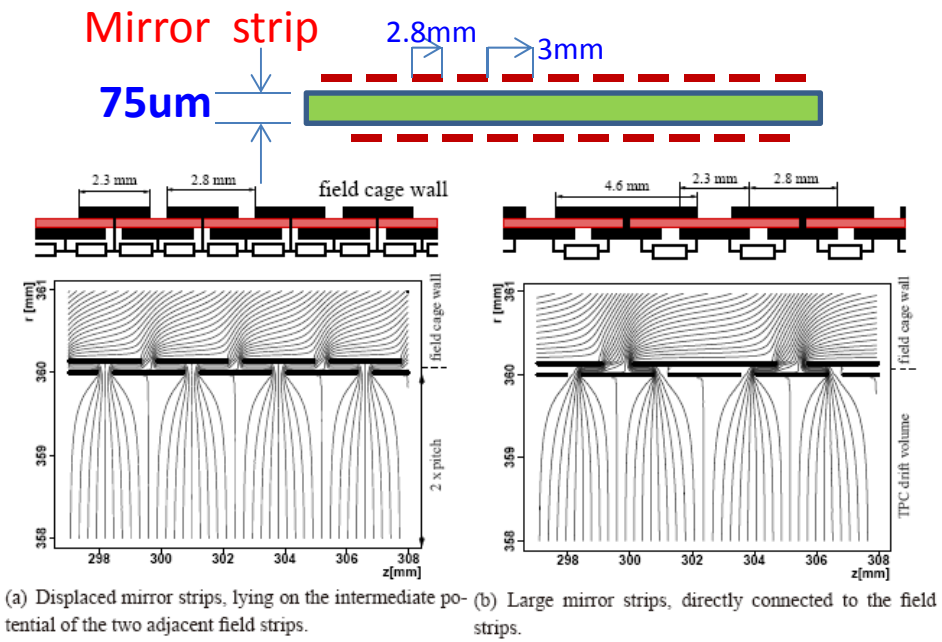
置于真空罐中，气压温度：
5×10^{-3}Pa， -15～+40℃
流气式，0.1～1ATM（负压）



已完成:
1. 关键参数优化
2. 漂移场设计
3. 透射窗设计
4. 厚GEM设计
5. 感应板设计

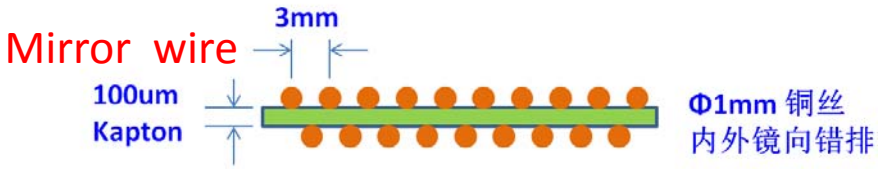
关键参数优化-
径迹长度: 76 mm
漂移距离: 70 mm
膜窗厚度: 50 um
工作气压：0.5 ATM

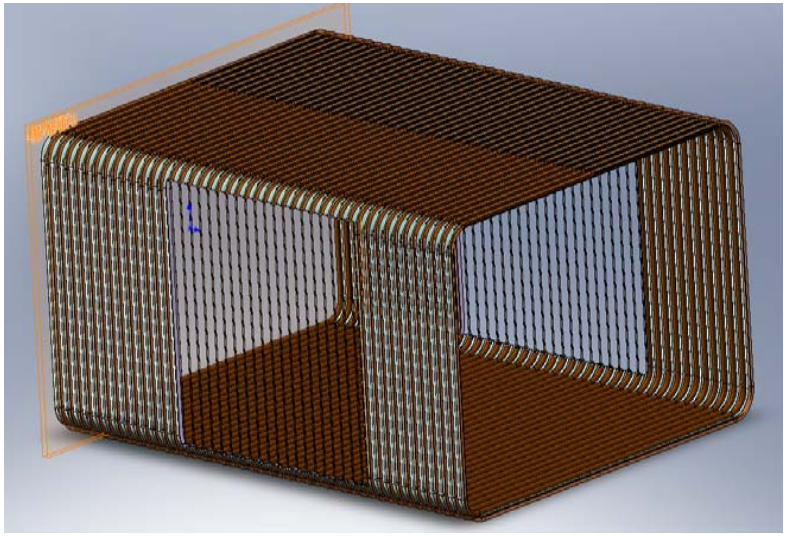
漂移场设计

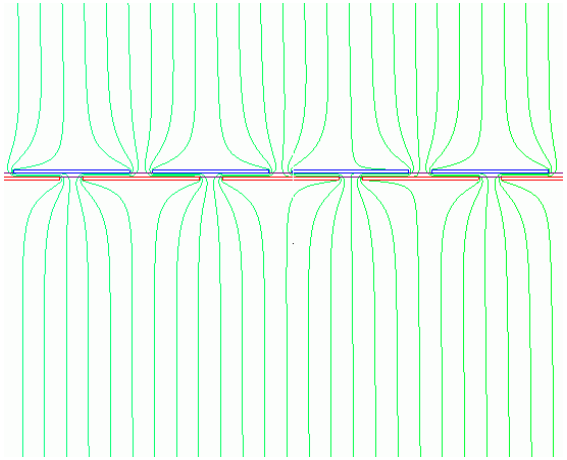


(a) Displaced mirror strips, lying on the intermediate potential of the two adjacent field strips.

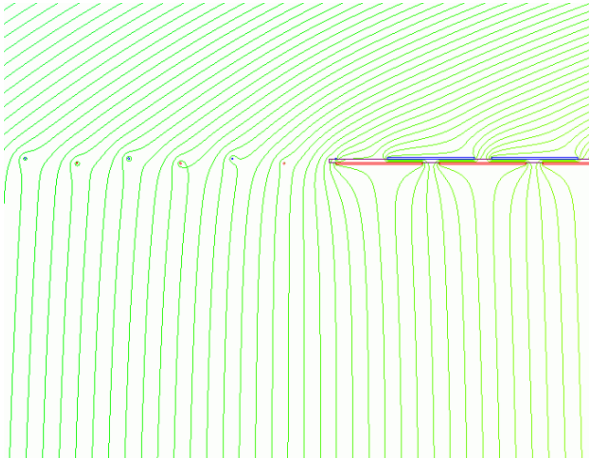
(b) Large mirror strips, directly connected to the field strips.



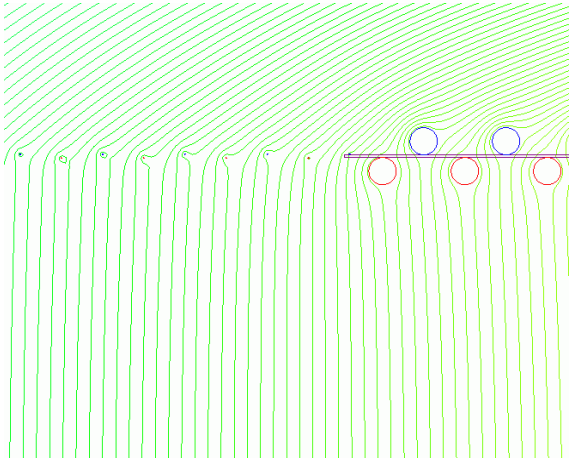




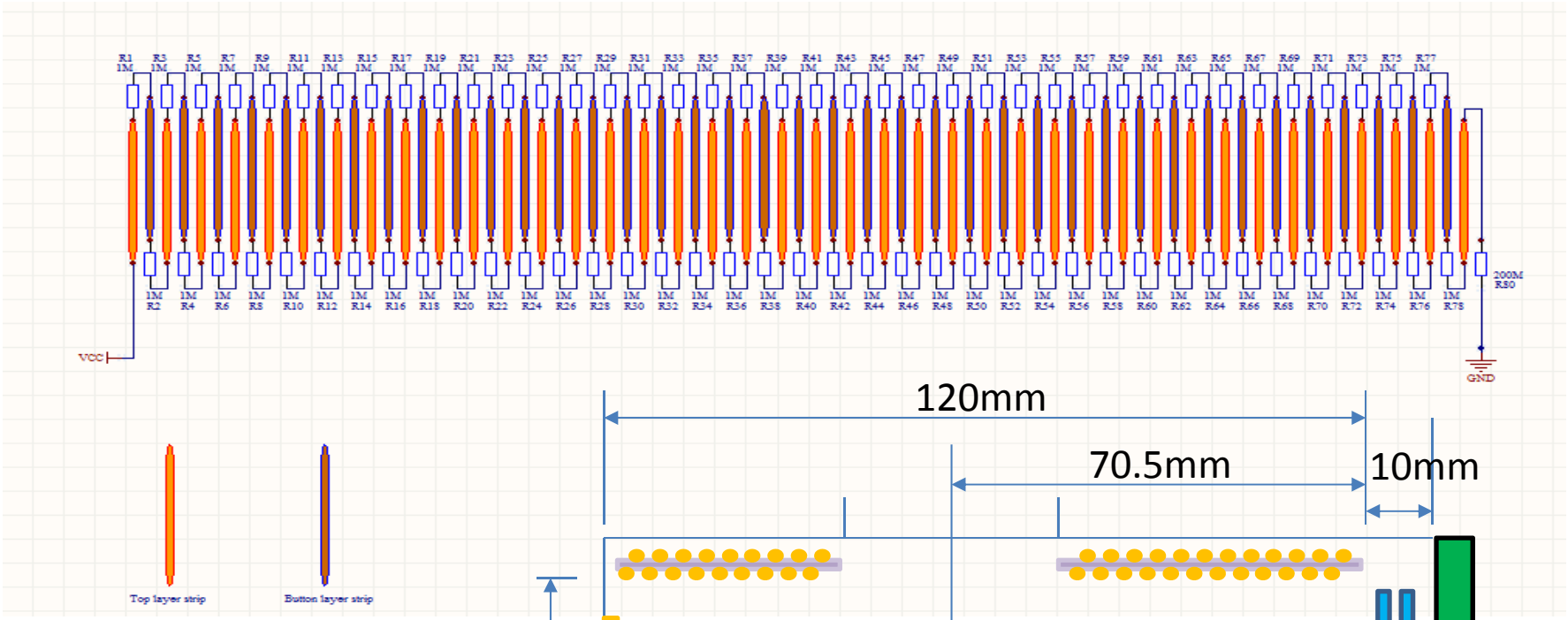
Mirror strip



Mirror strip + window



Mirror wire + window



Ns=80

NR: 1MΩ:79 个

200MΩ:1 个

I_leak<8000V/279MΩ

=28.7uA

Pmax<0.165W(1MΩ仅0.0008W)

电阻：国产0.02%

5ppm/℃

120mm

70.5mm

10mm

Ed=80~200V/cm

Vdmax<3600

300*12cm=3600

92cm

Vmax<7000V

Vamax<3200

500

1000

1000

800

39mm

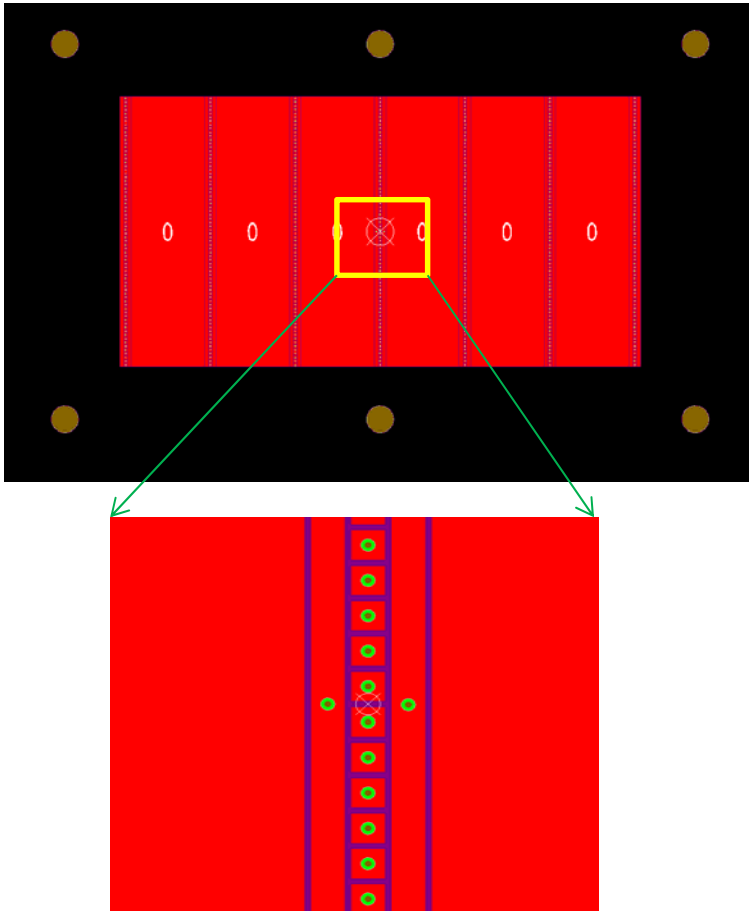
Gd/Gt/Gi

5/2/2

5/1/1/1

读出PAD

使用高密、低噪声的插槽，电子学板读出板分离，实现设计灵活性。180*180mm

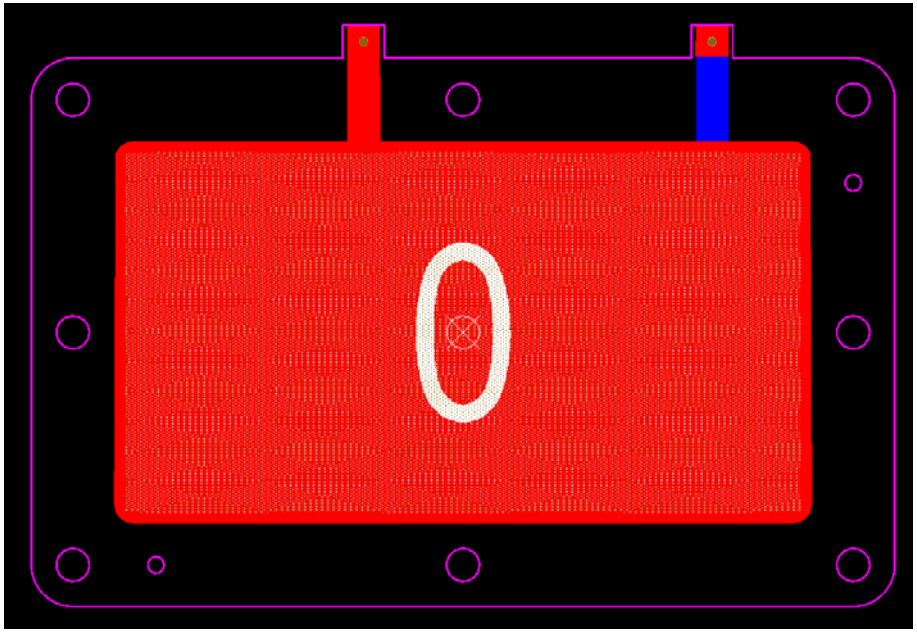


6层板，7个采样点（7列Pad），每列72道，共511道，pad尺寸0.46mm，周期0.56mm，用重心法空间分辨预计好于200um.

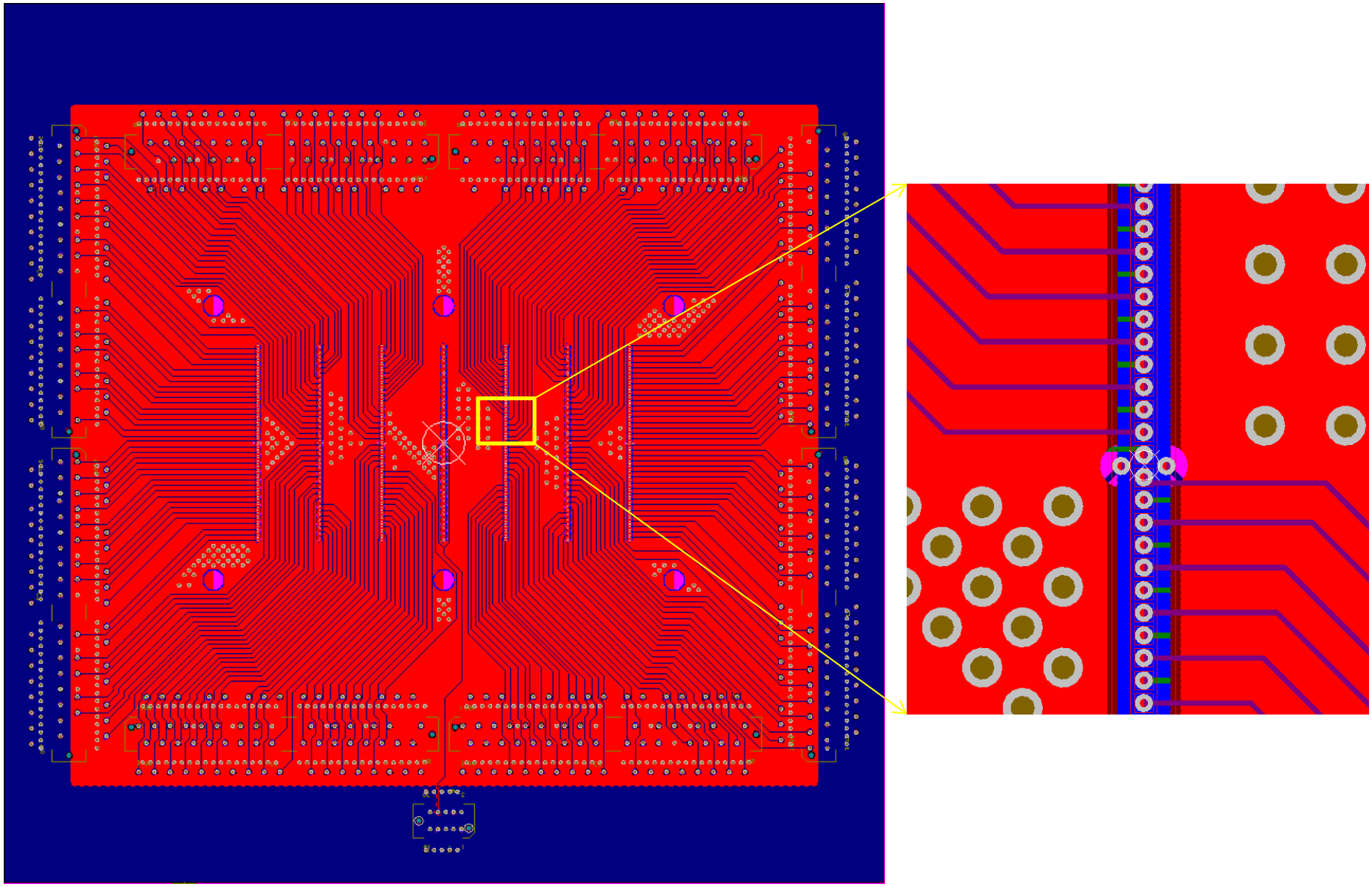
THGEM

双层，增益>1×10^4

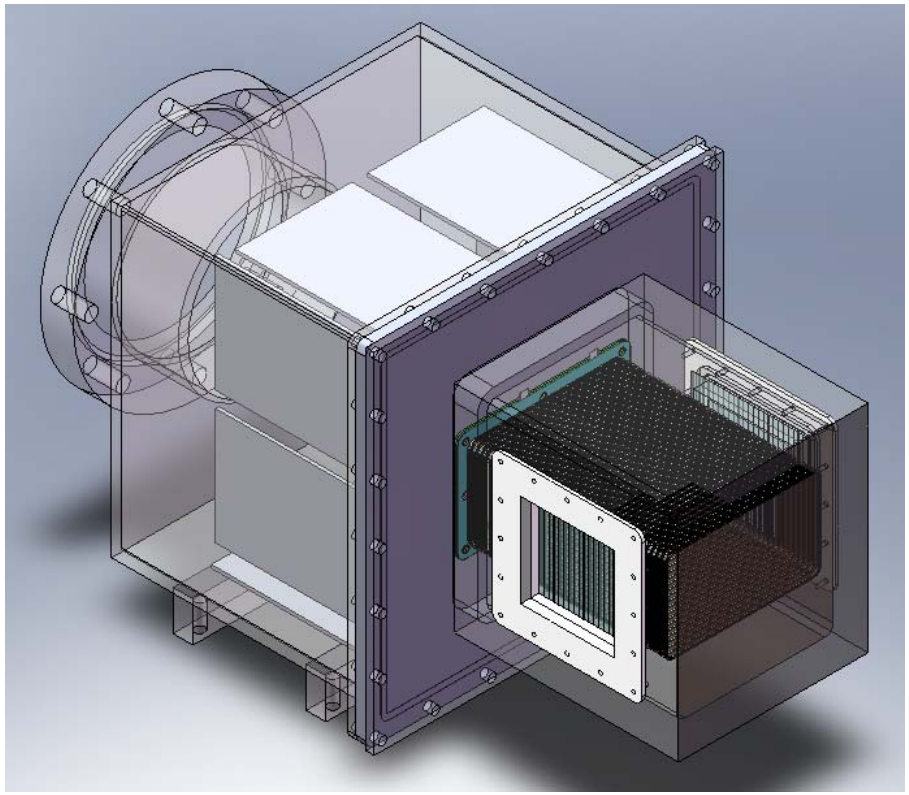
拟采用激光**THGEM**

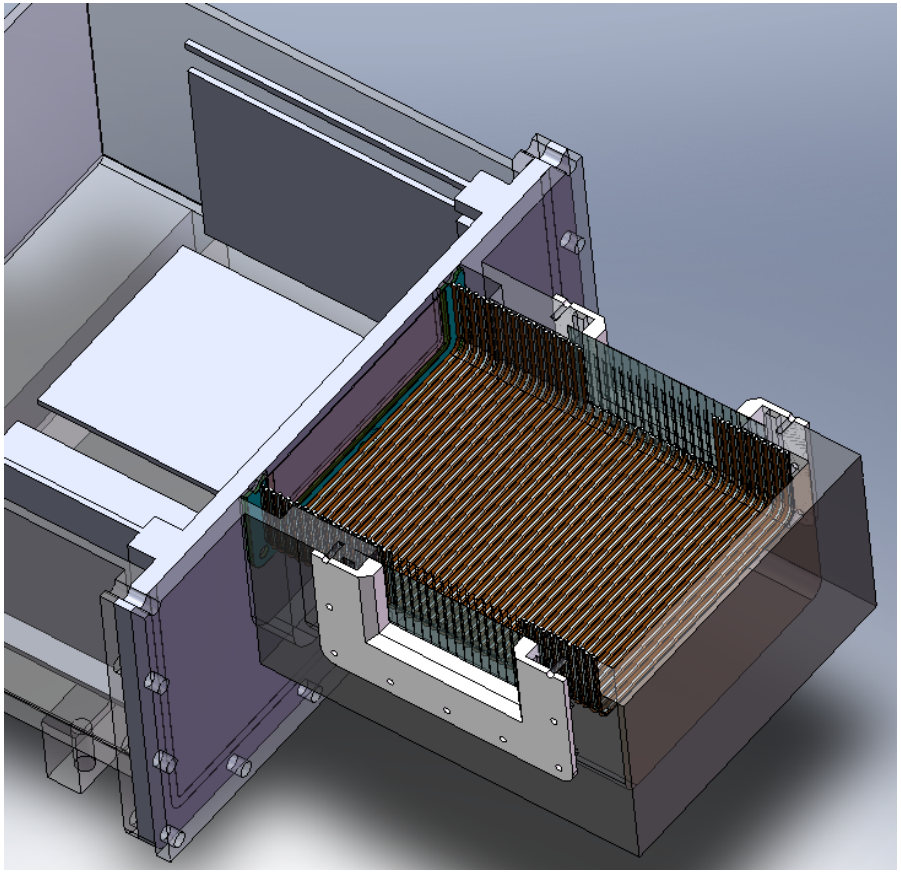


感应板



整体结构





总　结

1. 成功开发了本征位置分辨<200um的新型厚GEM。

2. 基于机械打孔和FR-4基材，达到孔径150um，孔间距400um，性能良好。

3. 基于激光打孔和FR-4基材，达到孔径100um，孔间距300um，性能良好。

4. 大面积高位置分辨的厚GEM正在研究，期望达到500×500mm^2以上。

5. 此类高分辨厚GEM正应用于工程项目，并期望有更多的实际应用。

谢谢！