DISCUSSION ON APPLICATION SCENARIOS OF ADVANCED SILICON DETECTORS AND ELECTRONICS

先进硅探测器和电子学的应用场景讨论

实验物理中心学术小组全体会议

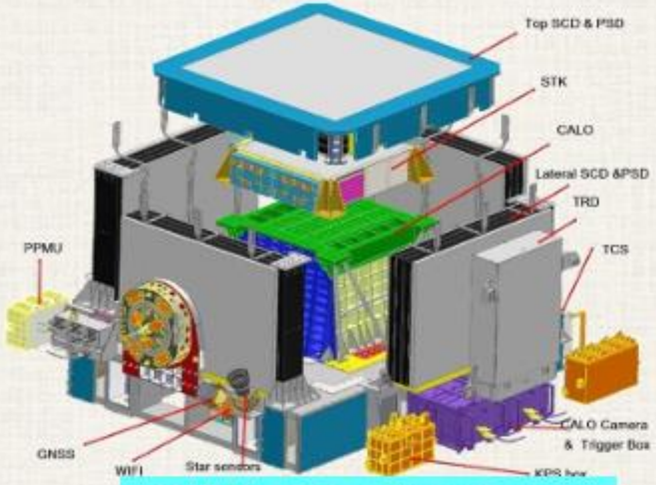
2026.5.13

SILICON DETECTOR APPLICATION SCENARIOS

- What we have in EPD, an incomplete list:
  - To detect charge particles and x-ray (a few keV) photons:
    - TaichuPix
    - BPIX
    - LGAD (mm-size pixel), AC-LGAD, LGAD-strip
    - COFFEE
    - SiC
  - To detect scintillating (UV to visible) photons:
    - SSD, SPD, SiPM

SILICON DETECTOR APPLICATION SCENARIOS

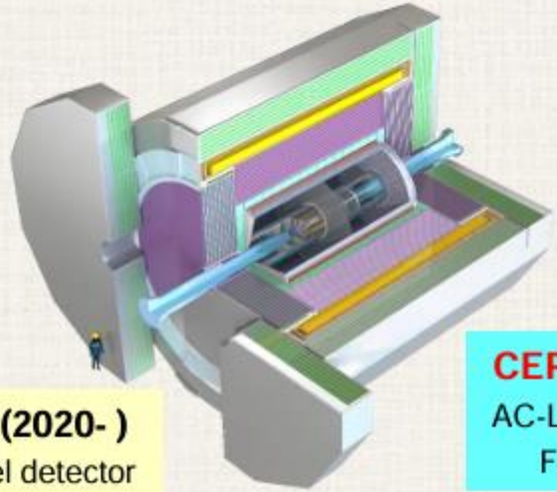
- The current (aimed) applications:
  - In particle-physics and astrophysics experiments,
  - In HEPS, national facilities,
  - In medical imaging and other commercial applications,
  - In instrumentations, especially those to replace the imported.



HERD SCD, STK (2025-)
Strip detector, FE ASIC readout

乔锐

CEPC VTX (2020-)
Monolithic pixel detector

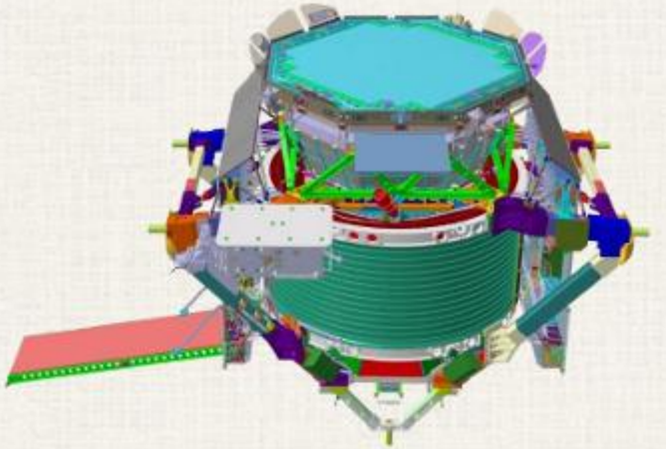


CEPC OTK (2024-)
AC-LGAD strip detector
FE ASIC readout

严琪、严雄波

CEPC ITK (2022-)
Monolithic pixel detector

李一鸣



AMS L0 (2021-2027)
Strip detector, FE ASIC readout

徐子骏

LHCb VELO (2005-2012)
Strip detector, BE ASIC readout

LHCb VP (2010-2012)
Hybrid pixel detector

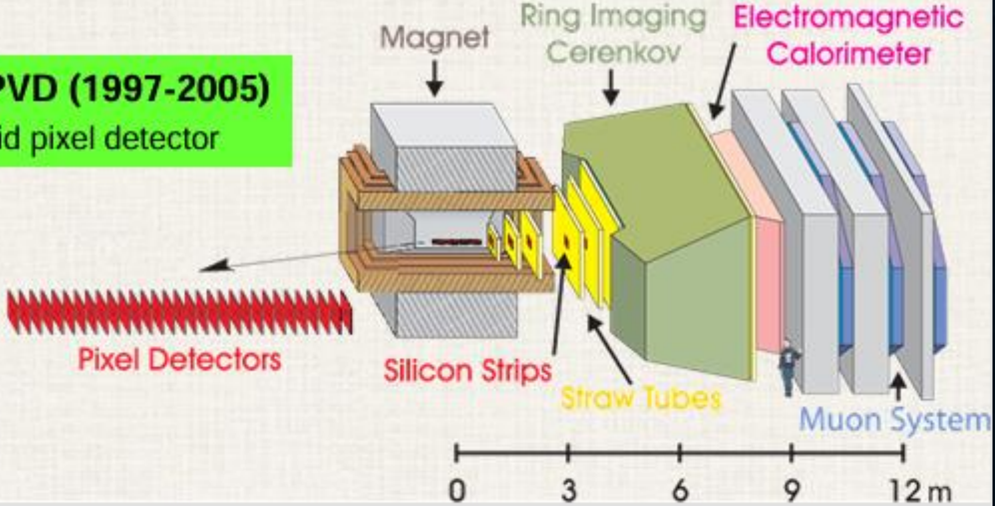
周扬、张慧

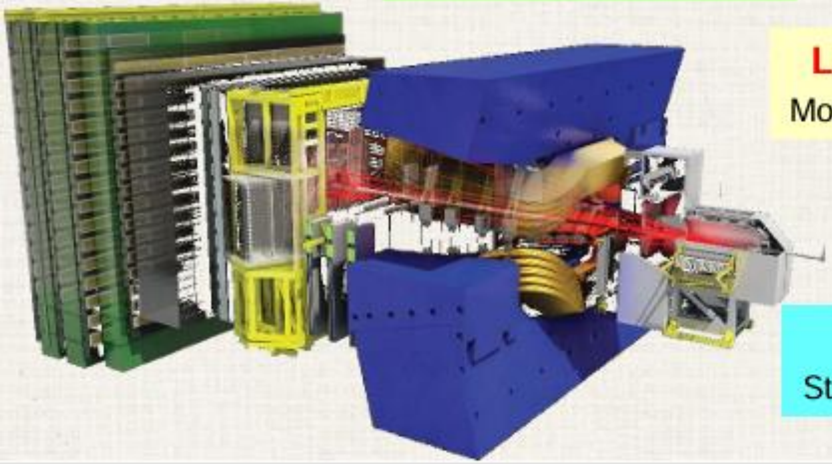
LHCb UP (2020-)
Monolithic pixel detector

袁煦昊

Slide from JC Wang

BTeV PVD (1997-2005)
Hybrid pixel detector





LHCb UT (2010-)
Strip detector, FE ASIC readout

Current R&D's in China for LHC Experiments

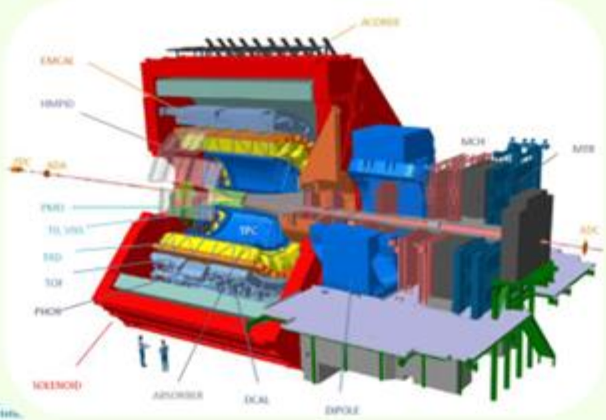
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041

Run 1 | LS 1 | Run 2 | LS 2 | Run 3 | LS3 | Run4 | LS4 | Run 5

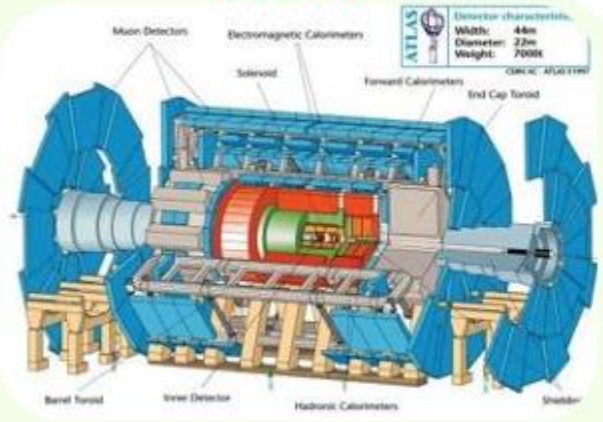
ATLAS	ITK, **HGTD**
CMS	HGCAL, MTD-ETL
ALICE	ITS3, FoCal

LHCb	**UP**
ALICE	VD, ML, TOF

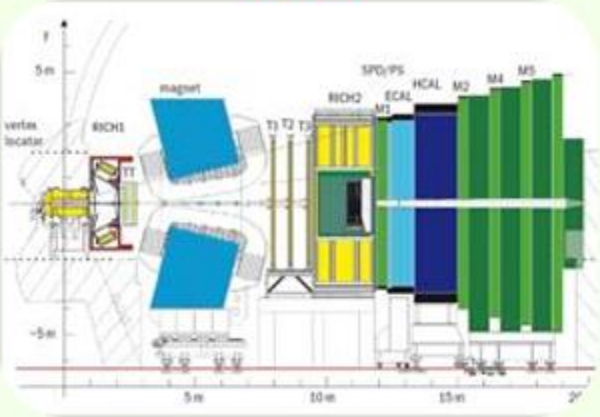
ALICE



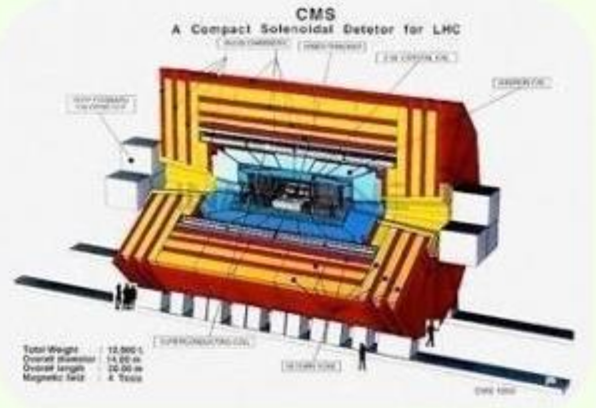
ATLAS



LHCb



CMS



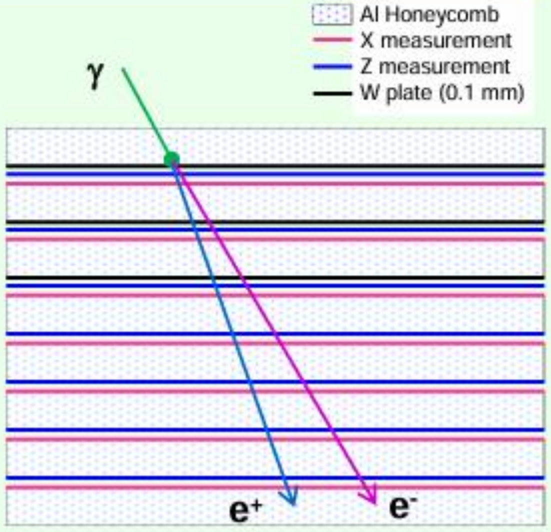
Slide from JC Wang

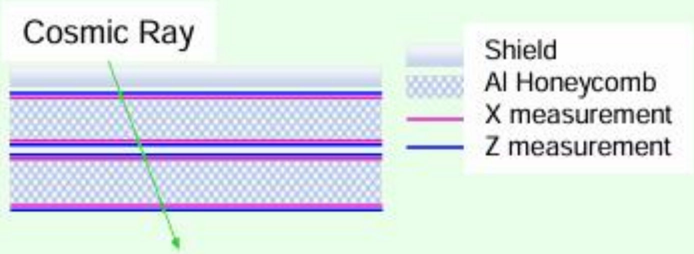
HERD Silicon Detectors: SCD and STK

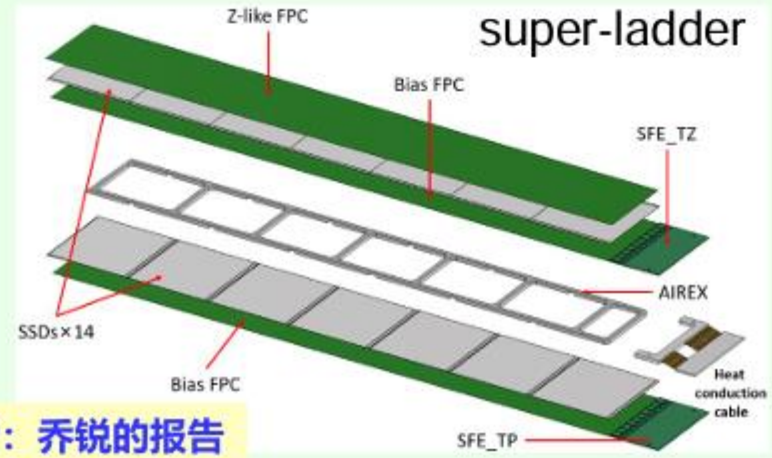
Slide from JC Wang

HERD SCD, STK (2025-)

- HERD (High Energy cosmic-Radiation Detection) is to be installed on the Space Station by ~2028. The detector system has SCD, STK, +3 others
- SCD: **5-side, 8-layer** charge measurement Z=1~28, total area 38.8 m^2
- STK: **14-layer** detecting trajectories of $\gamma \rightarrow e^+e^-$ conversion in 3 W plates, angular resolution ≤ 0.1° @ 10 GeV, total active area 8.3 m^2
- HPK SSDs: 150 μm pitch, 320 μm thick, DC with bias resistor
- Front end readout chips: IDE1140, VATA450.3

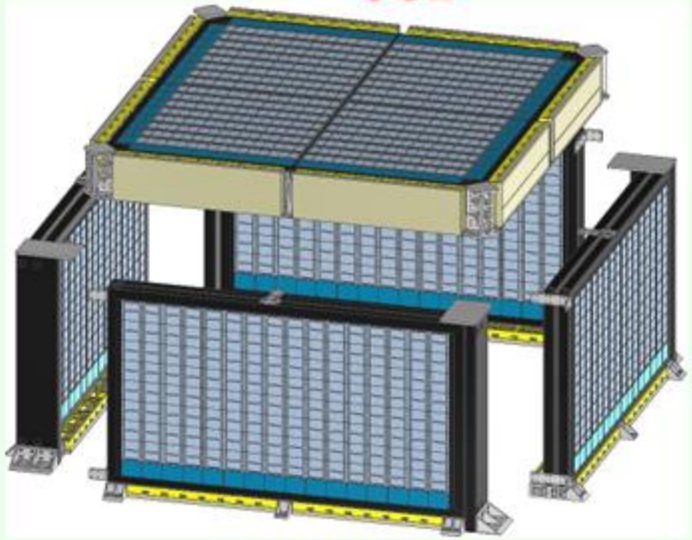




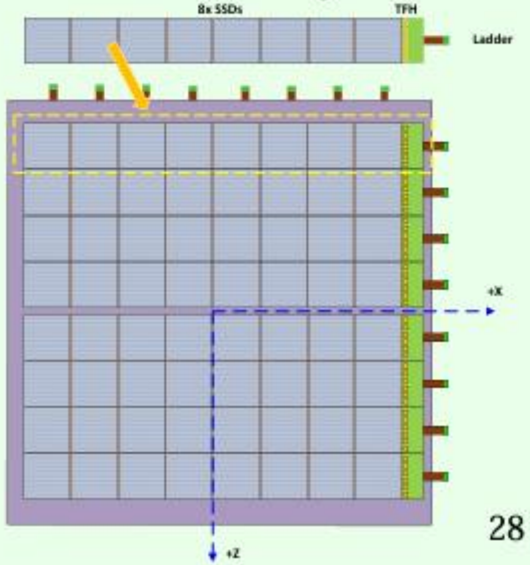


参考：乔锐的报告

SCD



STK

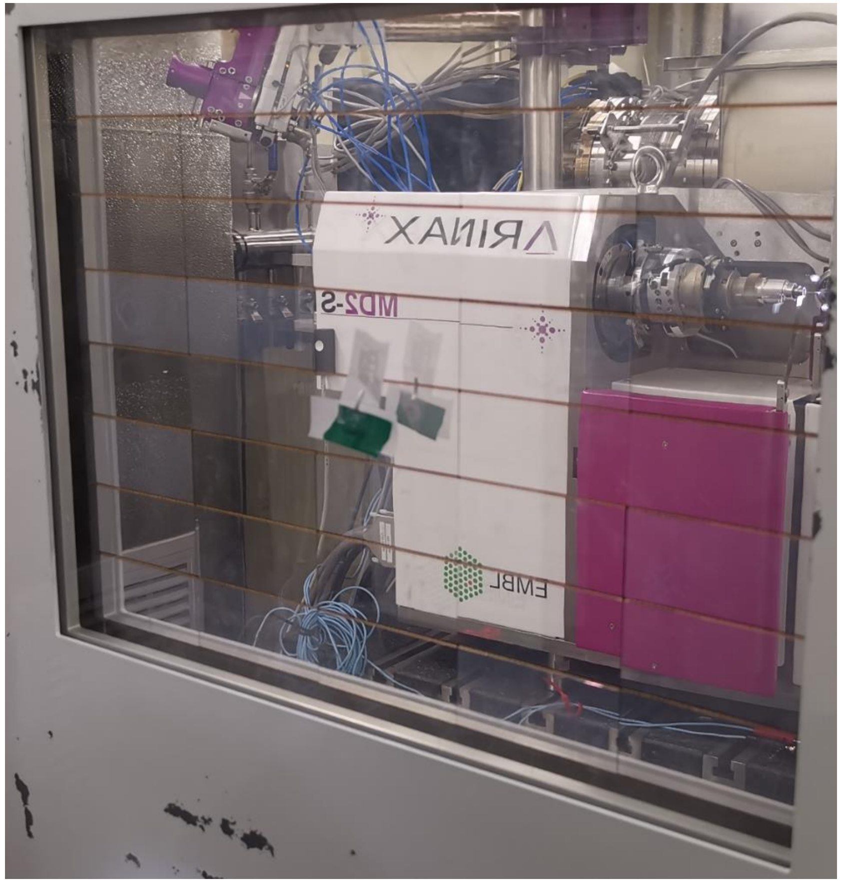


Participating institutes:

IHEP, PMO, Perugia

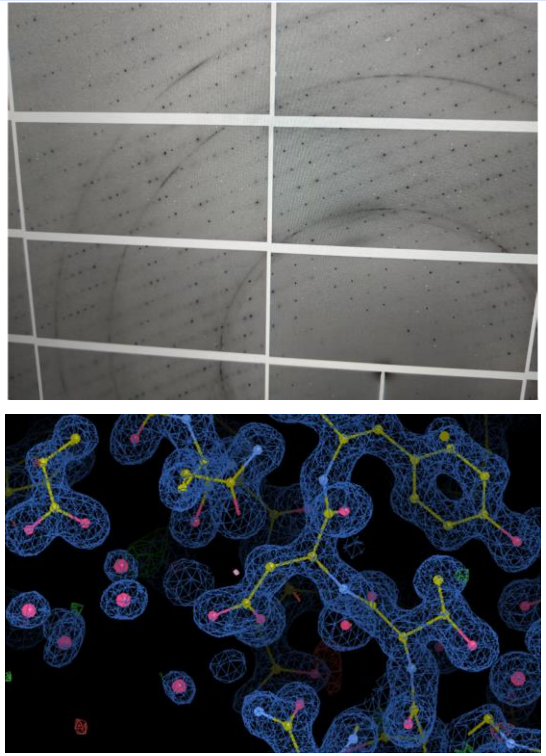
高能光源硅像素探测器——现状

Slide from Wei Wei



探测器面板

HEPS-BA生物大分子线站



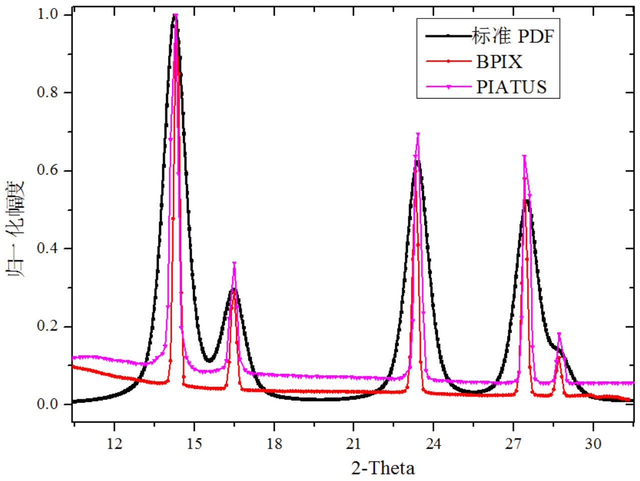
溶菌酶蛋白衍射图样及结构解析

- 面向高能同步辐射光源研制X射线硅像素探测器
- 一期线站交付6M像素探测器一台，2M/1M像素探测器数台，目前已稳定开展用户实验
- 批量生产单、双模块整机（150/300K像素），已提供多个合作单位试用

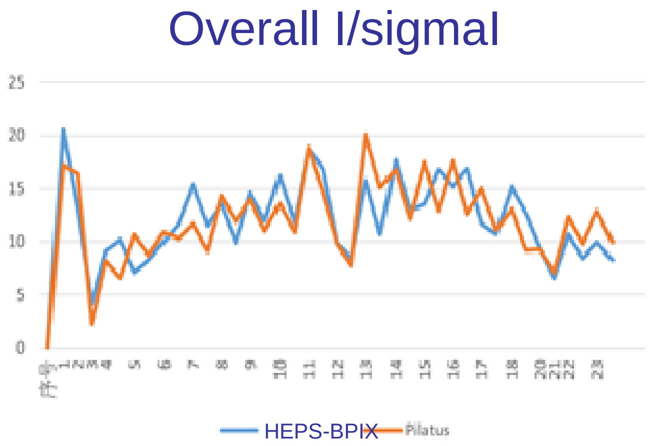
高能光源硅像素探测器——性能

Slide from Wei Wei

Specs	BPIX-40-6M
Pixel size	140µmX140µm
Sensor	Silicon 450um
Pixels/module	256X576
Number of module	5X8
Total pixels	5.898M
Threshold	2
Gain	2 bits tunable
Counting rate	> 1Mcps /pixel
Frame rate	100Hz (1kHz)
Counting Depth	14 bit
Image Depth	16bit/32bit
Module Gap	2.7mm by WB
Bad pixels	<0.5‰



角分辨：标准样品vs
BPIX vs PILATUS



标准样品数据解析R因子
BPIX vs PILATUS

- 全面对标同步辐射主流探测器PILATUS，实现国产替代
- 性能：像素140µm vs 172µm；探测器规模6M/2M/1M对标；刷新率1kHz vs 100Hz（超过）
- 稳定性：标准样品解析R因子（品质因数）在相同水平，还可进一步提升
- 生产：关键器件、工艺全部国产化

高能光源硅像素探测器——研发

Slide from Wei Wei

- 生产
  - BPIX芯片已量产三个批次（12片+50片+50片），功能、良率均非常稳定，定型
  - 模块、整机工艺基本定型，后续批次将进一步加强QA/QC管理，提高模块良率和模块生产一致性
- 研发
  - 光源二期正在进行线站规划（70条线站），BPIX将作为标准设备，批量生产大量采购
  - 根据线站需求，已讨论确定四种新型像素探测器的后续研发，均已开展芯片设计
- 衍生应用及合作
  - 一些原本采用PILATUS探测器的国内高端设备/应用单位已与我们开展接洽、部分已开展合作
  - 聚变诊断：已同ITER签订横向合同，一期提供BPIX模块开展qualification评估，有望进一步赢得二期合同（针对ITER能量的探测器改进及定制）
  - 半导体设备：部分采用XRD原理进行测厚的设备厂商已与我方接洽，已提供单模块样机试用评估，部分已尝试申请联合课题开展合作
  - 电镜：有单位接洽，暂无实质动作

SILICON DETECTOR APPLICATION SCENARIOS

- Future applications
  - Continuation in particle-physics and astrophysics experiments,
  - Continue in HEPS, national facilities,
  - Should we explore applications in other fields? If yes, what would be the priority?

ELECTRONICS APPLICATION SCENARIOS

- What we have in EPD, an incomplete list:
  - Readout electronics in silicon sensors
  - LGAD-strip readout ASIC
  - SiPM readout ASICs
  - FPMT readout ASIC: FPMROC1 and FPMROC16
  - TDC aiming to reach 5 ps resolution/precision
  - High speed data link for detector front-end electronics:
    - Data aggregator, SerDes, LDD, TIA (for optical module), at 11 Gbps
    - R&D for 20 Gbps with PAM4
  - ADC at various precisions and sampling rates
  - Radiation tolerate ASICs for configuration/control/monitoring: I2C, SPI

ELECTRONICS APPLICATION SCENARIOS

- Technologies we use, again an incomplete list:
  - Sensor dictated: Tower Semiconductor, others?
  - SMIC CMOS 180, 130 and 55 nm, with recent concentration on 55 nm
- Technologies CERN uses:
  - Sensor dictated: many.
  - TSMC CMOS 130, 65 and 28 nm

ELECTRONICS APPLICATION SCENARIOS

- The current (aimed) applications
  - In particle-physics and astrophysics experiments
  - In HEPS (mostly silicon sensor readout related)
  - In medical imaging: TOF-PET

ELECTRONICS APPLICATION SCENARIOS

- Future applications
  - Continue all the R&Ds for the physics experiments and facilities
  - Continue the efforts in applied fields, such as the TOF-PET
  - China ASIC development Platform for physics Experiments (CAPE)
    - To address the problem ASIC R&D faces: slow, high risk and high cost
    - To promote collaborations among research institutes and universities in China.
  - Should we explore applications in other fields? If yes, what would be the priority?

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