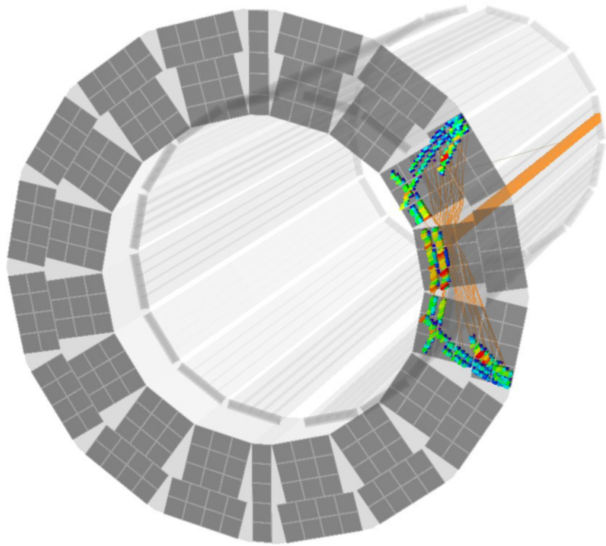
STATUS OF THE PANDA BARREL DIRC

• Barrel DIRC overview

• Baseline design and challenges

• Progress since last report

• TDR status and schedule



Current baseline design in PandaRoot

For additional details: see my PANDA CM talks June 2013, March 2014.

PANDA Cherenkov Group:

GSI Darmstadt, JINR Dubna, FAU Erlangen-Nürnberg, JLU Gießen, U. Glasgow, HIM Mainz, JGU Mainz, SMI OeAW Vienna.

Jochen Schwiening

PANDA CollabMeet
Vienna, December 2015

- Hadronic particle identification detector for PANDA, provides clean pion/kaon (and proton) separation up to about 3.5 GeV/c in the target spectrometer.

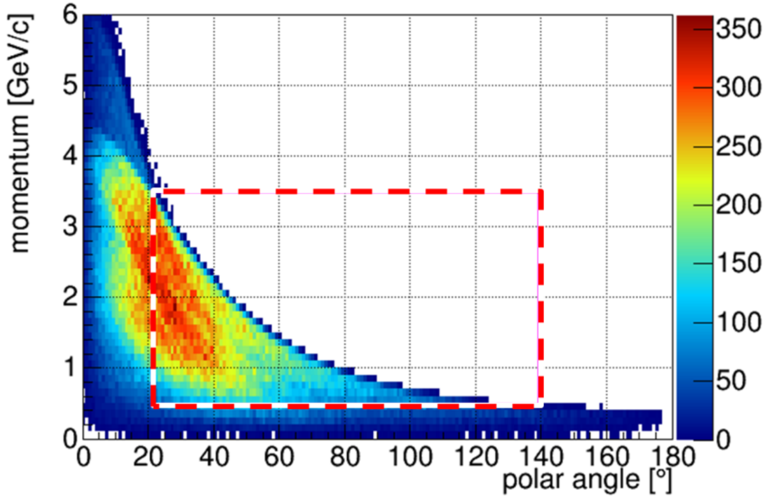
- PID with very high efficiency and purity one of the key requirements for many aspects of the PANDA physics program.

- Barrel DIRC a proven concept (BABAR, Belle II).

- DIRC geometry uniquely thin and compact, reducing size of PANDA solenoid and calorimeter.

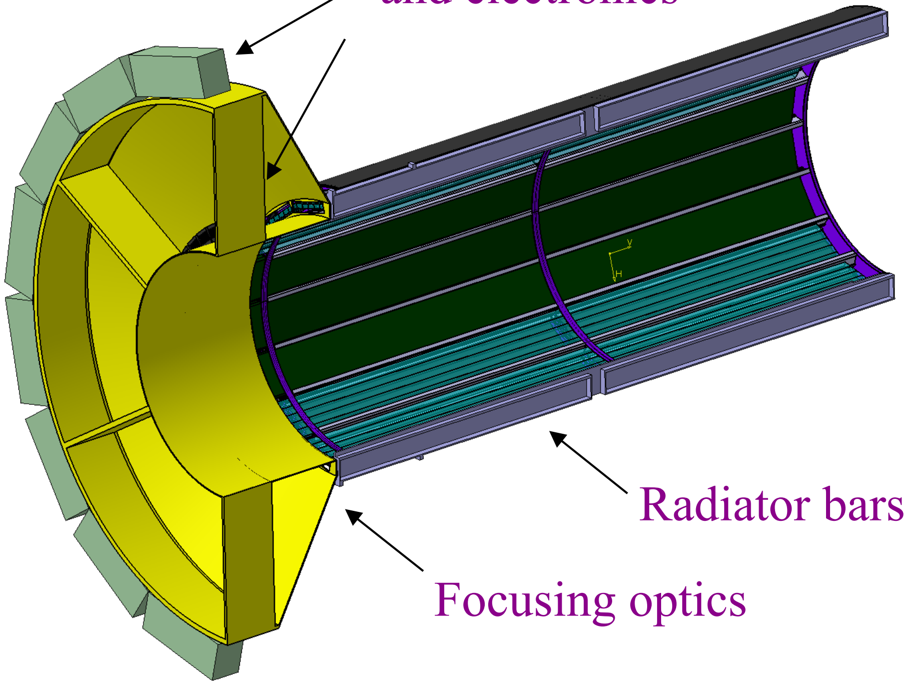
- German in-kind contribution to PANDA.
  (Construction cost covered 100% by GSI PMA.)

- R&D and construction collaboration currently between
  GSI, U Erlangen (since 2006), and U Mainz/HIM (since 2010)
  (with previous R&D contributions from JINR Dubna and SMI OeAW Vienna).



Kaon phase space for reactions with p-bar momenta 6 GeV/c ... 15 GeV/c

- Highly polished rectangular bars made from synthetic fused silica ("quartz") to produce Cherenkov light and guide photons to detectors.
- Focusing optics images Cherenkov photons ("Cherenkov ring") on sensor array
- Compact multi-anode photon detectors for efficient, fast detection of single photons.
- Fast readout electronics to measure photon signal charge and arrival time with ~100 ps resolution at 20 MHz average reaction rate in trigger-less environment.

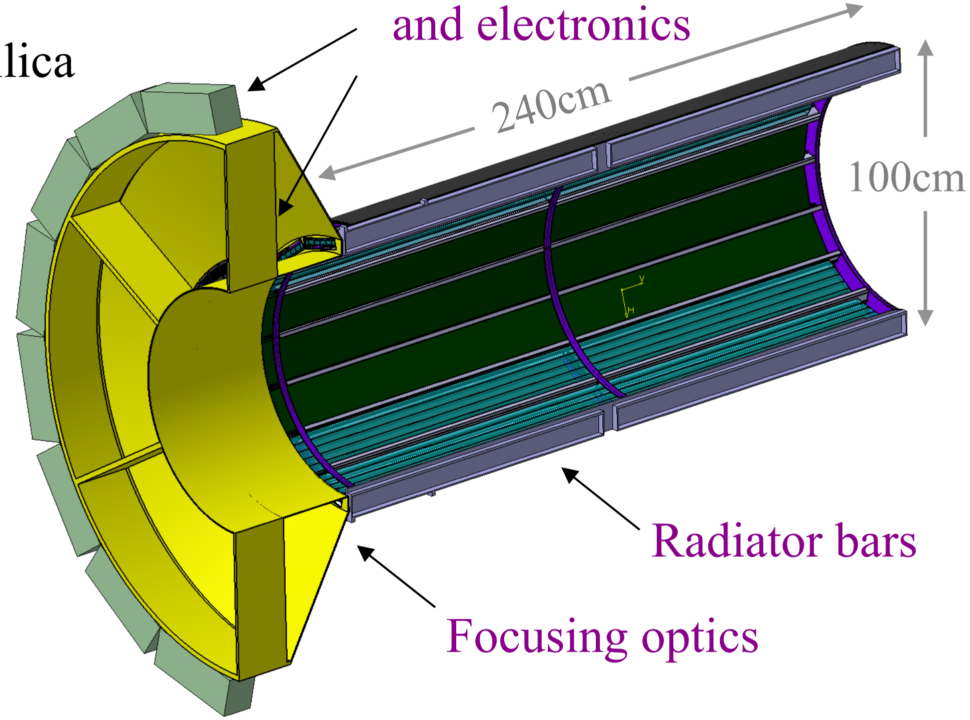


Goal: conservative design, similar to proven BABAR DIRC, confidence in PID performance.

Status: system nearing end of R&D phase aimed at cost reduction (bars, sensors) and solving technical challenges (MCP-PMT lifetime, readout electronics).

Based on BABAR DIRC with key improvements

- Barrel radius ~48cm; expansion volume depth: 30cm.
- 80 radiator bars (16 sectors), synthetic fused silica
  17mm (T) × 32mm (W) × 2400mm (L).
- Focusing optics: lens system.
- Compact photon detector:
  30cm oil-filled expansion volume
  ~18,000 channels of MCP-PMTs.
- Fast photon detection:
  FPGA-based electronics, fast TDC plus ToT.
- Expected performance:
  Single photon Cherenkov angle resolution: ~10mrad.
  Number of photoelectrons for β≈1 track: at least 15.



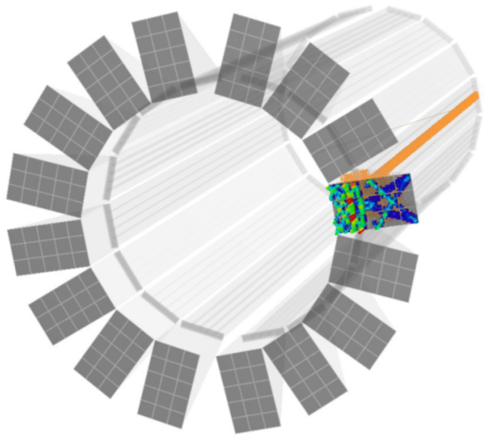
Validated with prototype in CERN test beam in 2012

Conservative design – but cost of component fabrication very high (~50% over budget).

COST *VS.* PERFORMANCE OPTIMIZATION

Radiator fabrication cost driven by number of surface/pieces

→ reduce number of bars in design



- use wider bars – 4 bars or even 3 per sector instead of 5 bars

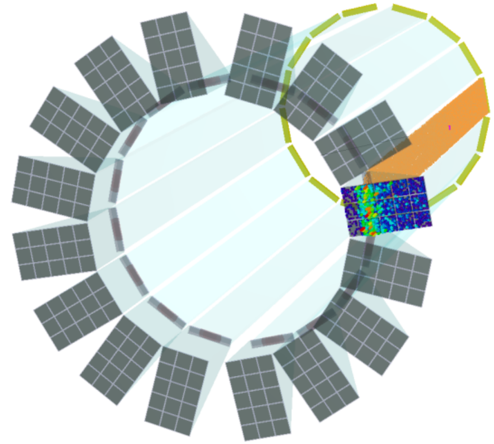
  simulation shows that resolution is still OK if spherical lens is used

  → potential cost savings ~500k€ (4 bars) to ~1000k€ (3 bars)

- or use one wide fused silica plate (16cm) per sector

  instead of 5 narrow (3.2cm) bars (inspired by Belle II TOP DIRC)

  → potential cost savings ~1600k€



Use one solid fused silica prism per sector instead of oil tank?

Better optical and operational properties, fewer MCP-PMTs, DAQ channels

→ potential cost savings ~ 60k€

We also investigated use legacy components (BABAR DIRC bar boxes)

Submitted application to SLAC in December 2013, DOE decision (July 2014) did not go our way.

Bar boxes awarded to GlueX DIRC upgrade (4 boxes) and LHCb TORCH R&D (1 box).

BABAR

COST UPDATE 2013/14

PMA: 3509k€ (escalated) transferred from BMBF to GSI in 2012

potential lower-cost alternative: wide plates and prisms			
	unit cost (k€)	units	total (k€)
Radiator support	15	2	30
Bar boxes	3	18	54
Radiators			
Plates	35	32	1120
Radiator spares			
Plates	35	3	105
Expansion volume			
Fused silica prisms	20	18	360
EV support	150	1	150
MCP-PMTs	6	220	1320
DAQ	0.01	7000	70
HV/LV	10	18	180
Calibration system	50	1	50
Mechanical utilities	20	1	20
Integration/installation	30	1	30
total			**3489**

please note: approximate numbers, for PANDA internal use only

Result of optimization study:

found potential cost reduction

from 5.2M€ to 3.5M€.

But: new plate/prism design

has to be validated to show

that PID performance is OK.

→ New prototype in test beam

at GSI in May/Aug 2014

If plate/prism design is validated in test beam: PMA funding covers construction cost.

(possible cost overrun to be covered by GSI base funding)

Extended DIRC R&D effort resulted in technical solutions for difficult challenges.

(MCP-PMT lifetime, readout electronics performance, bar/plate vendor qualification, etc)

Barrel DIRC system design has been optimized for cost vs. performance.

Identified significant potential cost reduction with little or no loss of PID performance.

~~*(Potential reuse of BABAR DIRC bars is possible but not likely.)*~~

Need to validate prism/plate design improvements with particle beams (summer 2014).

If test beams are successful TDR draft can be ready by end of 2014.

Update Dec 2015

Summer 2014 beam test at GSI was not very successful.

Main issue: poor beam conditions – divergence, spot size unsuitable for RICH PID.

Useful for tests of readout electronics, improved design (collaboration with CBM RICH).

Applied for beam time at CERN in 2015, delayed validation and TDR draft by one year.

First draft of Barrel DIRC TDR distributed within Cherenkov group.

2015 CERN Beam Test

CERN test beam 2015 (May 4-26, June 22-July 8)

Fused silica prism as expansion volume.

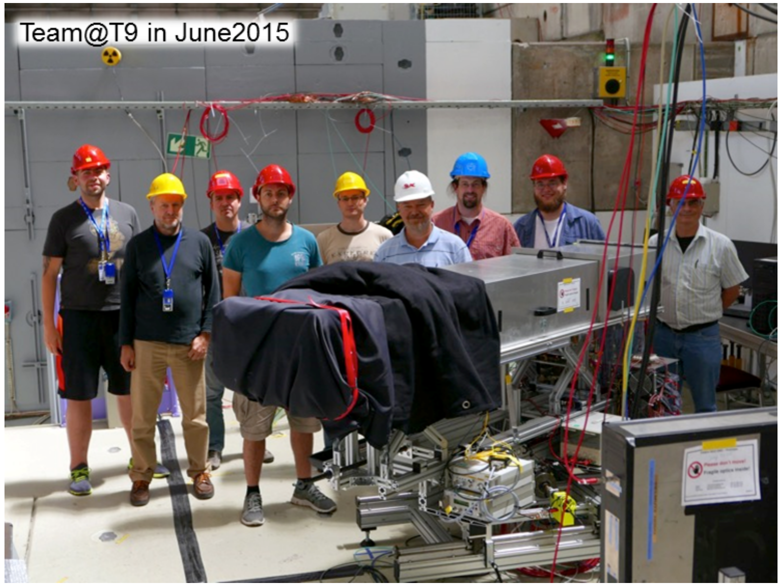
Narrow bar and wide plate as radiator.

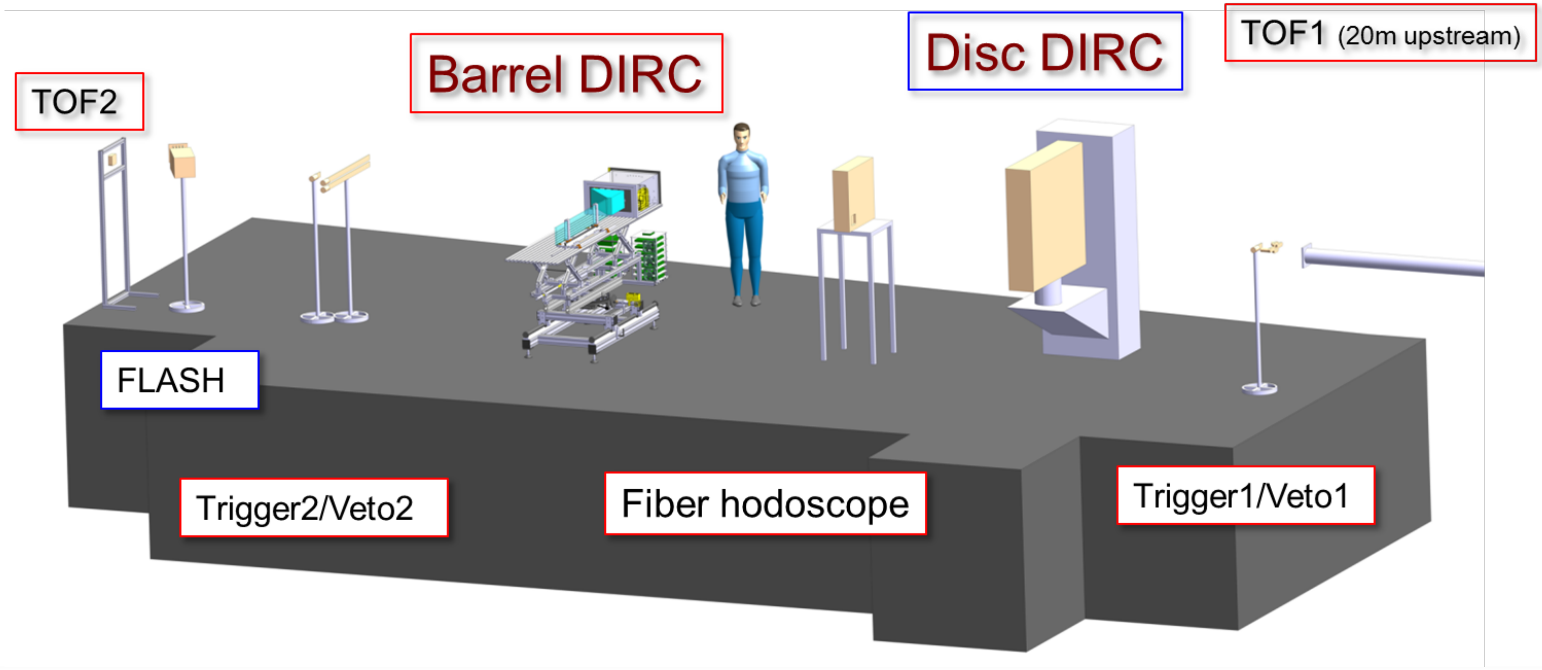
Many different imaging/lens configurations.

Momentum and angle scans.

TOF system to cleanly tag π/p up to 7+ GeV/c.

Data analysis ongoing.





CERN test beam 2015 (May 4-26, June 22-July 8)

Fused silica prism as expansion volume.

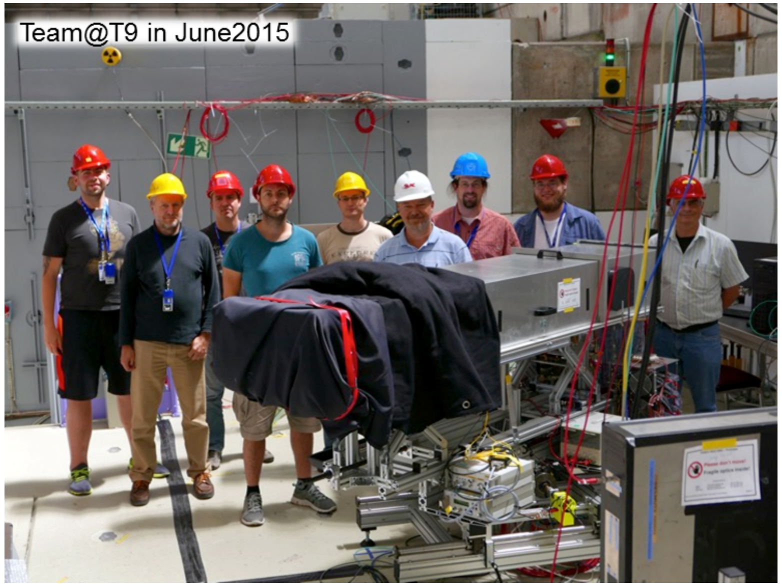
Narrow bar and wide plate as radiator.

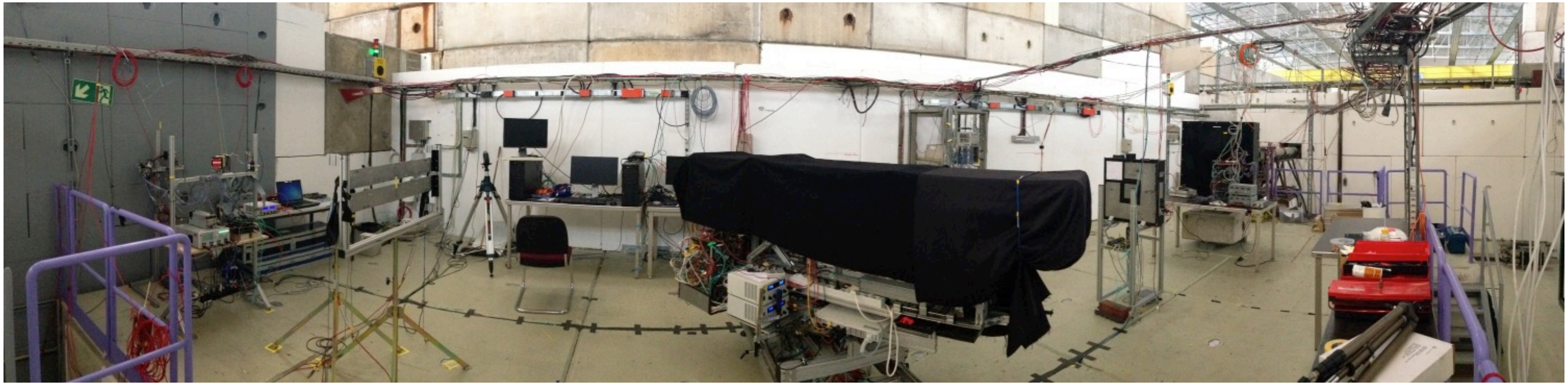
Many different imaging/lens configurations.

Momentum and angle scans.

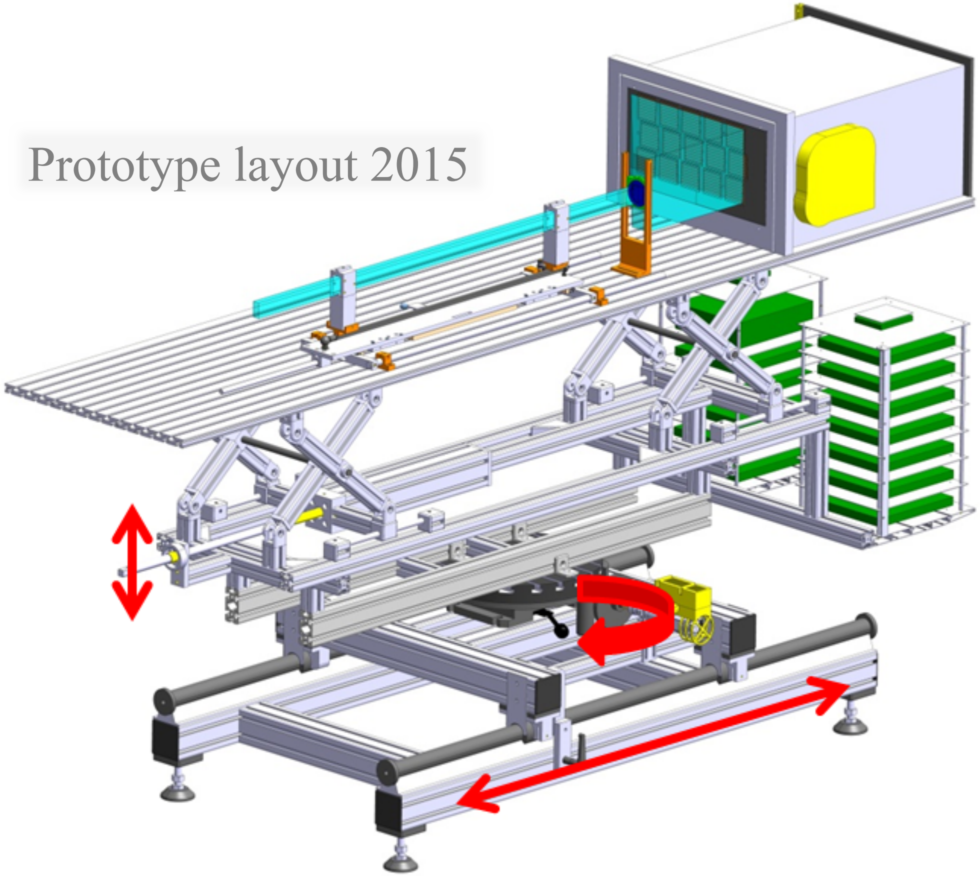
TOF system to cleanly tag π/p up to 7+ GeV/c.

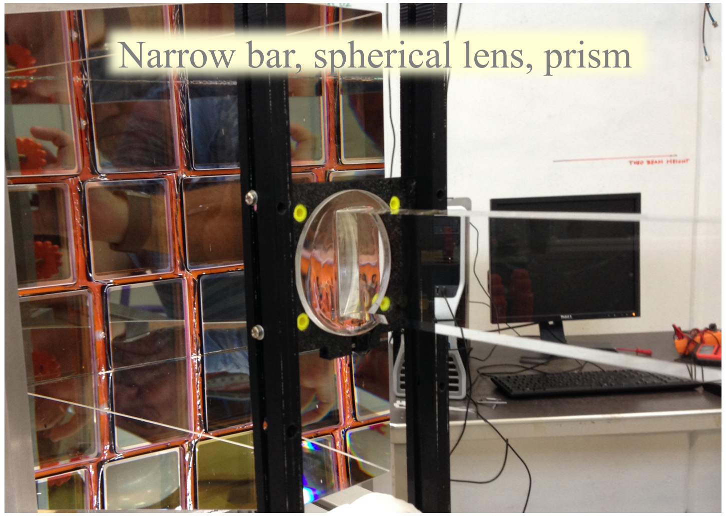
Data analysis ongoing.

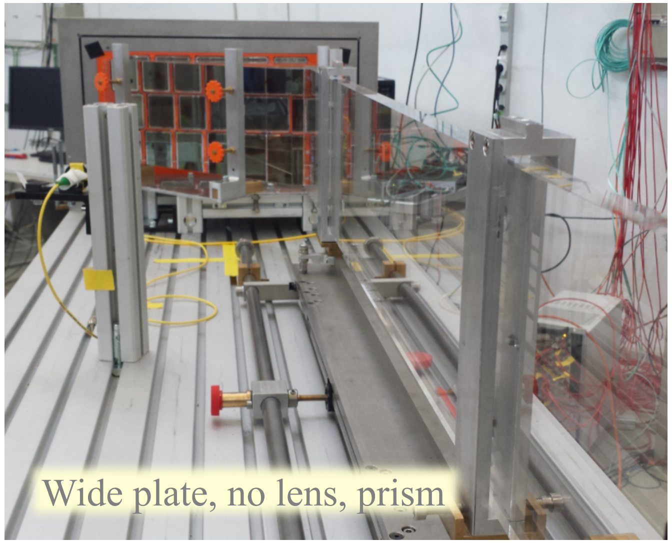


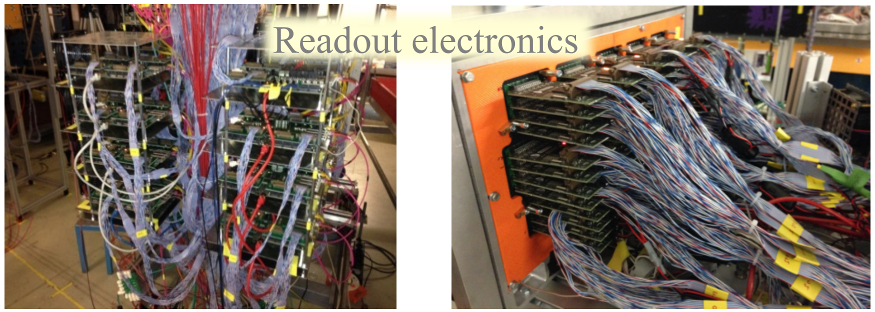


2015 CERN BEAM TEST

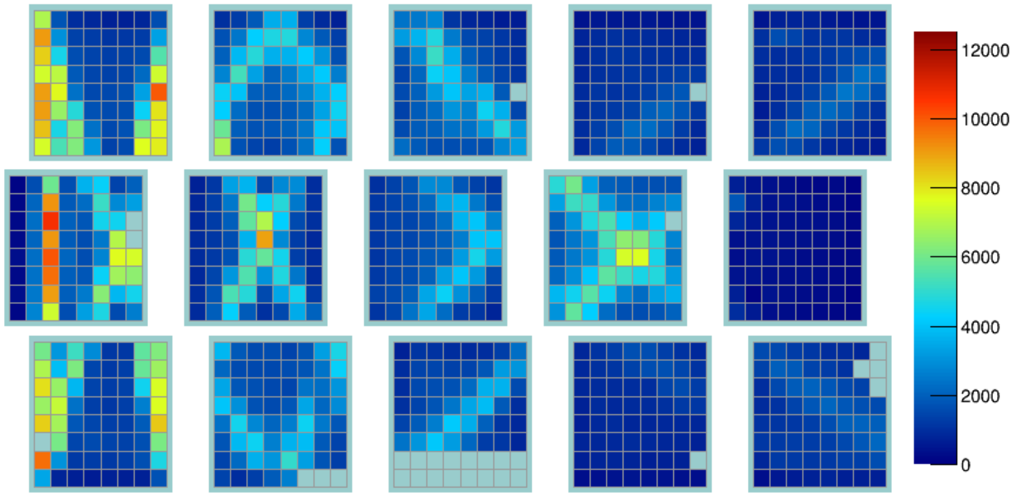






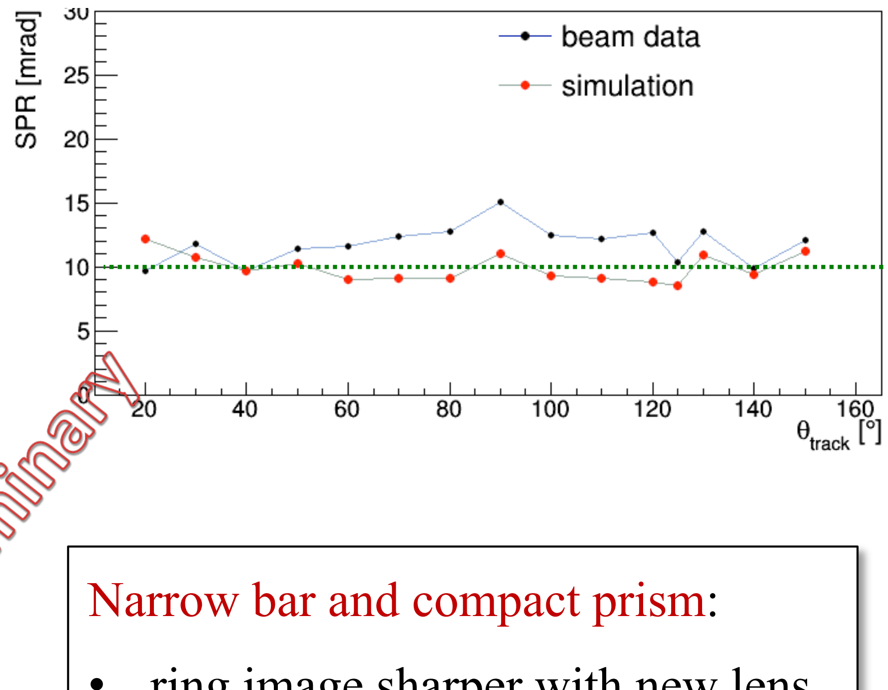


2015 CERN BEAM TEST – BAR DATA

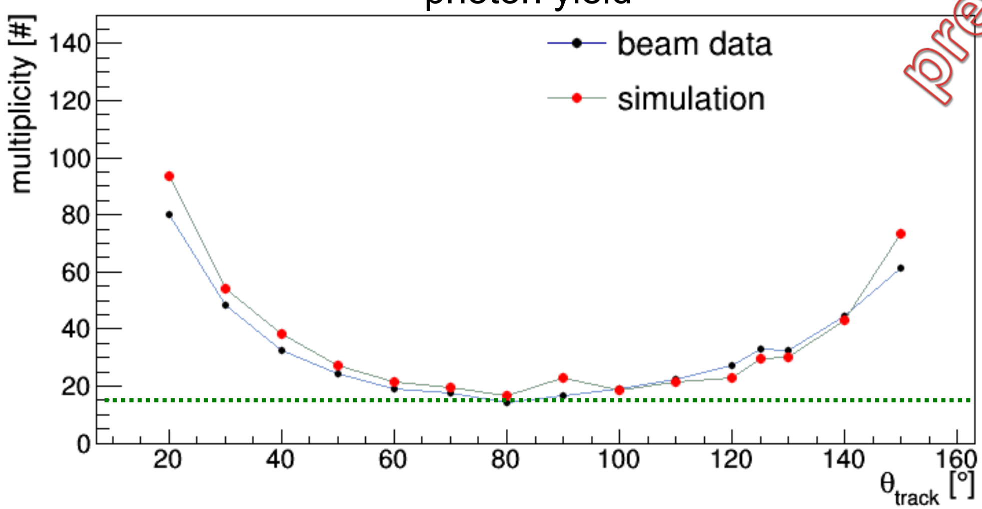


Narrow bar, spherical lens, prism, 50º polar angle, 7 GeV/c momentum

Cherenkov angle resolution per photon



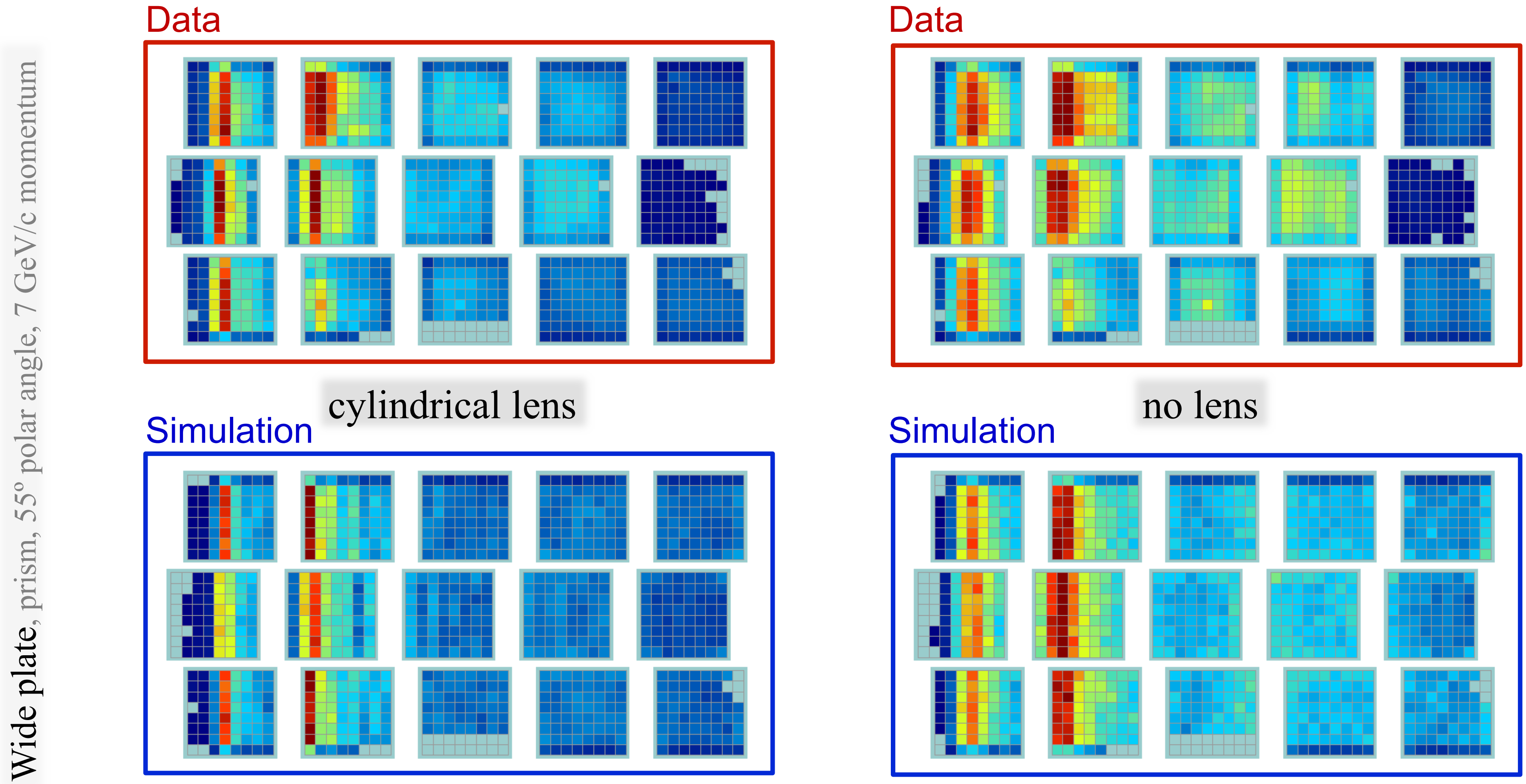
photon yield



Narrow bar and compact prism:

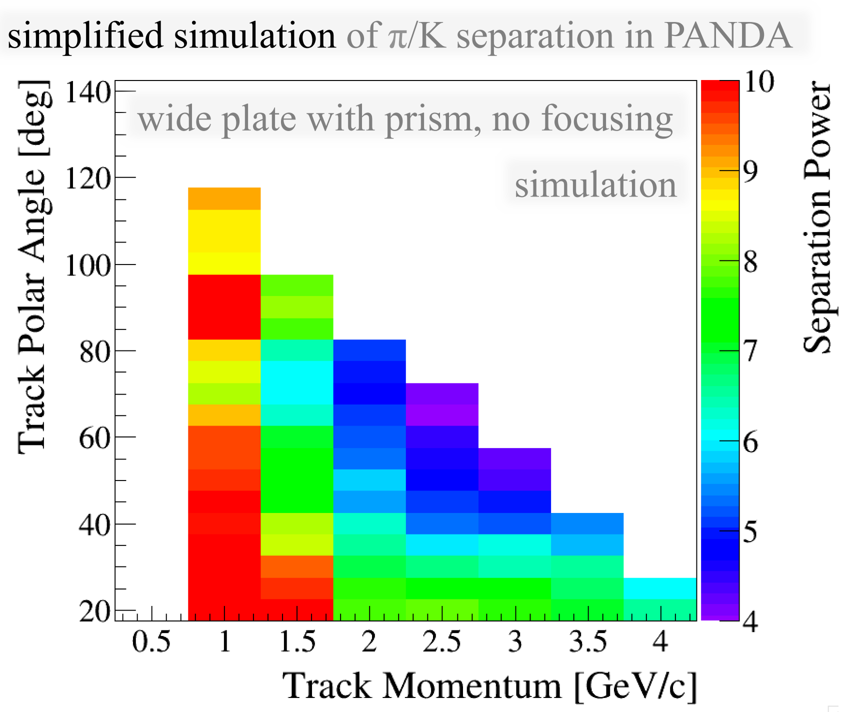
- ring image sharper with new lens
- photon yield consistent with MC
- Cherenkov angle resolution worse than MC but already acceptable
- validation of narrow bar/prism

2015 CERN Beam Test – Plate Data



Analysis of wide plate data needs detailed tuning of simulation – good agreement achieved.

Timing resolution and measurement of time-over-threshold worse than expected, not a showstopper.



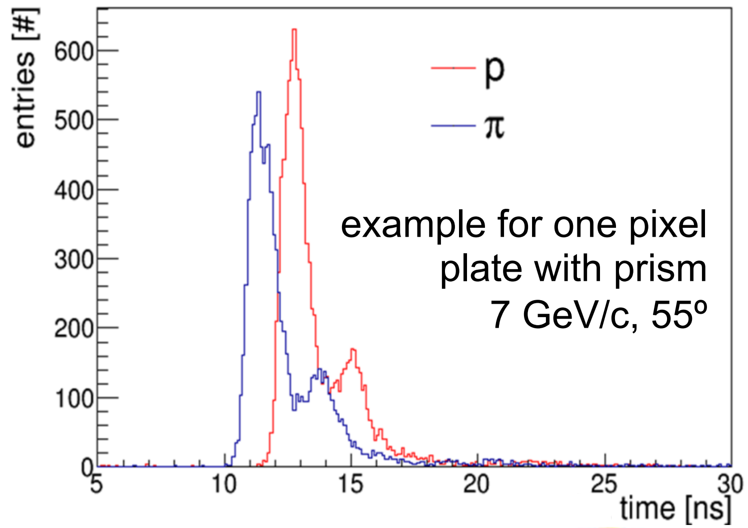
Simplified simulation suggests that design using wide plate and prism meets or exceeds PID requirement over entire kaon phase space.

Unclear is focusing system helps.

Hope to complete analysis and obtain validation with data by February.

Next step in analysis of wide plate data will be:

time-based likelihood analysis of π/p separation at 7GeV/c (≈ π/K @ 3.5GeV/c) in data and MC.



Summary From March 2014 (Part II)

Resource-loaded MS Project plan available (FAIR@GSI).

FTE coverage insufficient, currently at 70-80%, significant FTE issue developing in 2014/2015. Risk of delays. Need to react.

Other resources at Erlangen, GSI, Mainz in reasonably good shape.

If design improvements work and FTE issue solved:

- projected construction cost (3.5M€) would be covered by GSI PMA funds (in hand);
- project on time for installation in 2018.

Update Dec 2015

Collaboration partner institutes hit hard by BMBF funding problems.

We have not been able to improve the FTE situation, no new hires for Barrel DIRC at GSI or in university groups, FTE issue still present and urgent.

Holding off on update of detailed FTE list until BMBF funding situation becomes clear.

New schedule based on installation date in 2020.

Scrutiny Report – Barrel DIRC Summary:

The system is still in an R&D phase but well under control.

If the manpower problem can be solved by the help of other groups,
a completion of the DIRC by mid 2020 is possible.

The system is financed as a 100% in-kind contribution by GSI.

System keeps making steady progresss after delay due to poor test beam campaign in 2014.

- Preliminary results from 2015 beam test at CERN encouraging, analysis ongoing.
  - Narrow bar with prism validated; validation of wide plate/prism PID by February?
- Established contact with new player in the DIRC field, potentially more competition:
  - Nikon building prototype plate an no cost to us, delivery expected by January.

Draft of Barrel DIRC TDR in internal circulation; wide plate design, fallback narrow bars.
- Hope to present TDR to collaboration at Bochum CollabMeet in March.

Have applied for CERN beam time in the fall of 2016 if additional plate tests are needed.

Manpower problem even more severe now due to BMBF funding problem.

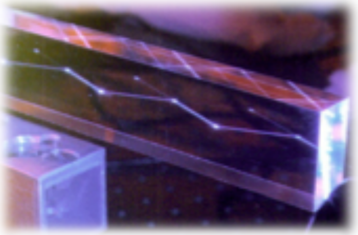
PANDA Barrel DIRC Schedule

2015: Finalize R&D, validate design in test beam, write TDR draft.

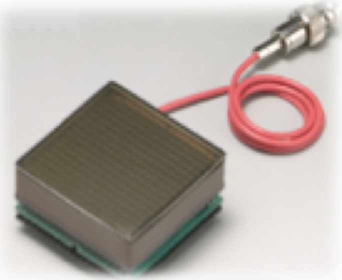
2016: Finalize TDR, present at CollabMeet and submit to FAIR.

2017-2020: Component Fabrication, Assembly, Installation.

- 2017: Finalize definition of production specs, intiate tender.
- 2017-2020: Industrial fabrication of fused silica bars and prisms.
  Industrial production of photon sensors.
- 2018-2019: Production and QA of readout electronics at GSI/Mainz.
- 2018-2020: Fabrication of bar containers and mechanical support frame,
  gluing of bars, construction of complete bar boxes.
  Detailed scans of all sensors in Erlangen.
  Assembly of readout modules in Mainz.
- 2020: Installation of mechanical support frame in PANDA
  insert bar boxes, mount readout modules.
  Ready as "Start Setup / Day One" detector.



DIRC bar with laser



Photon sensor

Thank you for your attention.

EXTRA MATERIAL

COST UPDATE 2013/14

Costbook 3.0: 3343k€ (2005 € – would be 4360k€ in 2015 €)
included 300k€ risk money (additional polishing)

PMA: 2690k€ (2005 Euro)
3509k€ (escalated) transferred from BMBF to GSI in 2012

baseline design: narrow bars from Zygo, oil tank			
	unit cost (k€)	units	total (k€)
Radiator support	10	2	20
Bar boxes	2	18	36
Radiators			
Bars	16	160	2560
Radiator spares			
Bars	16	16	256
Expansion volume			
Oil tank	100	1	100
EV support	100	1	100
MCP-PMTs	5.3	310	1643
DAQ	0.01	18000	180
HV/LV	10	18	180
Calibration system	50	1	50
Mechanical utilities	20	1	20
Integration/installation	30	1	30
total			**5175**

please note: approximate numbers, for PANDA internal use only

Costbook 3.0 basis:

800k for radiator bars
1200k for sensors

Main issue:
fabrication cost for bars (industry) has increased

2 PhD students and a PostDoc worked on cost/performance optimization in simulation starting in 2010.

First SSB meeting focused on identifying FTE tasks to estimate total FTE requirement, second meeting on cost.

Categories: Project Management, Software, Hardware, 3 project phases, quarterly estimates;

Best guess: sum total around 17 – 20 FTE at any time
(19-21 during final R&D and construction, 16-18 during commissioning).

WBS/FTE plan from early 2013, based on installation Q2/2017 – not updated yet due to unclear BMBF situation.

Part 1

PANDA Barrel DIRC Workpackages (version 1.1)

		Phases																			
		Design & R&D				Production & Construction									Installation & Commissioning						
	Task	2014				2015				2016				2017				2018			
	FTE	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Sum	17.8	20.3	20.8	18.8	19.6	19.1	18.6	18.6	17.1	17.4	17.9	17.9	17.9	17.0	17.0	17.0	16.3	16.3	16.3	16.3
Project Management																					
Project Control		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PANDA Sub-system Management		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Commissioner															1.0	1.0	1.0	1.0	1.0	1.0	1.0
Technical Design Report			0.5	1.0	1.0	1.0	0.5														
Safety		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Software																					
Online																					
FEE/DAQ		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Trigger		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Calibration		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0
Monitoring / Slow Control (DCS)		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Offline: Simulation																					
Full Simulation		1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Backgrounds		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.5	0.5	0.5
Standalone Simulation / DrcProp		0.5	0.5	0.5	0.5																
Design Studies		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5												
Offline: Reconstruction																					
BABAR-like/Fast Reco		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Reco Algorithm Updates		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PID Algorithm		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Chromatic Mitigation		0.3	0.3	0.3	0.3																
Offline Calibration/Alignment												0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

PANDA BARREL DIRC WBS (2014)

Part 2

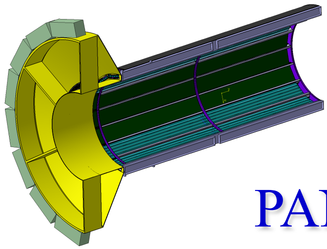
PANDA Barrel DIRC Workpackages (version 1.1)

		Phases																			
		Design & R&D				Production & Construction									Installation & Commissioning						
	Task	2014				2015				2016				2017				2018			
	FTE	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Sum	17.8	20.3	20.8	18.8	19.6	19.1	18.6	18.6	17.1	17.4	17.9	17.9	17.9	17.0	17.0	17.0	16.3	16.3	16.3	16.3
Hardware																					
Radiators																					
	Properties/Specifications	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3							
	QA	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0							
	Vendor Liaison	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2							
Sensors																					
	PMT Tests, QA	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0							
	PMT Ageing	0.5	0.5	0.5	0.5																
	Vendor Liaison	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3							
	SiPM Tests																				
	Installation & Commissioning														1.0	1.0	1.0	0.5	0.5	0.5	0.5
Electronics																					
	Sensor Readout/Front-end	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.5												
	DAQ/Data Collection	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.5												
	Calibration, QA	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Component Production (Liaison)					1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0							
	Installation & Commissioning														1.0	1.0	1.0	1.0	1.0	1.0	1.0
Optics																					
	Design	0.5	0.5	0.5	0.5																
	Vendor Liaison	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2							
	Tests, QA	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3							
	Installation & Commissioning														0.3	0.3	0.3	0.3	0.3	0.3	0.3
Mechanical Systems																					
	Radiator Box Design	0.2	0.2	0.2	0.2																
	Expansion Volume Design	0.2	0.2	0.2	0.2																
	Support Structure Design	0.2	0.2	0.2	0.2																
	FEA/Integrity	0.2	0.2	0.2	0.2																
	PANDA Integration	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Tooling	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5							
	Component Production					4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0							
	Installation & Commissioning														4.0	4.0	4.0	1.0	1.0	1.0	1.0
Infrastructure																					
	HV/LV	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Cabling	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Nitrogen	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Cooling	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Prototypes / System Tests																					
	Beam Test Campaign		2.0	2.0																	
	Data Analysis	1.0	1.0	1.0	1.0										1.0	1.0	1.0	3.0	3.0	3.0	3.0

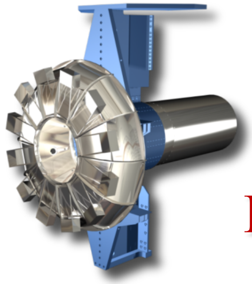
Expect work packages to be shared between U. Erlangen, GSI, HIM/U. Mainz.

(Details to be determined, other groups very welcome.)

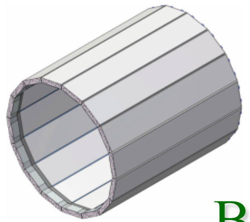
BARREL DIRC COUNTERS



PANDA
BARREL DIRC



BABAR
DIRC



BELLE II
TOP

Radiator geometry	Narrow bars *(32mm)*	Narrow bars *(35mm)*	Wide plates *(450mm)*
Barrel radius	48cm	85cm	115cm
Bar length	240cm *(2×120cm)*	490cm *(4×122.5cm)*	250cm *(2×125cm)*
Number of long bars	80 *(16×5 bars)*	144 *(12×12 bars)*	16 *(16×1 plates)*
Expansion volume	30cm, mineral oil	110cm, ultrapure water	10cm, fused silica
Focusing	Lens system	None (pinhole)	Mirror
Photodetector	~18k MCP-PMT pixels	~11k PMTs	~8k MCP-PMT pixels
Timing resolution	~0.1ns	~1.5ns	<0.1ns
Pixel size	6.5mm×6.5mm	25mm diameter	5.6mm×5.6mm
PID goal	3 s.d. π/K to 3.5 GeV/c	3 s.d. π/K to 4 GeV/c	3 s.d. π/K to 4 GeV/c
Timeline	Installation 2020	1999 - 2008	Installation 2016