STAR detector upgrades
in relation to
RHIC SPIN program

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Main Assumptions:

- The RHIC Spin Collaboration will write a report which:
  - Describes the full spin program,
  - provides context of beam and physics achievements and
  - lists needs for future detection capabilities and instrumentation.

- The 5 and 10 week scenario's will enter the document:
  - Near the end to indicate their impact,
  - i.e. not at as early constraints on the spin program!
Requirements on the STAR detector upgrade

- **Particle identification** (-1<|\(\eta\)|<1): Full acceptance TOF barrel system to extend particle identification capabilities

- **High rate TPC front-end electronics (FEE) readout and DAQ upgrade**: Allow for maximal utilization of high luminosity RHIC operation (AuAu/pp)

- **Inner tracker** (-1<|\(\eta\)|<1): Enhanced inner, high-rate tracking capabilities for heavy quark identification (charm/beauty) at mid-rapidity based on a precision micro-vertex detector

- **Endcap tracker** (1<|\(\eta\)|<2): Improved forward, high-rate tracking capability to enable reliable charge sign discrimination for W boson decays

- **Forward calorimetry upgrade** (2<|\(\eta\)|<4): Enhanced capabilities to measure forward produced mesons
STAR upgrade program

Overview

- Full Barrel Time-of-Flight system
- DAQ and TPC-FEE upgrade
- Forward Meson Detector
- Forward triple-GEM EEMC tracker
- Forward silicon tracker
- APS pixel detector
- Barrel silicon tracker
- Integrated Tracking Upgrade
Forward Meson Spectrometer
Conceptual Design

Physics Motivations:

• probe gluon saturation in p(d)+A collisions via…
  ➢ large rapidity particle production \((\pi^0, \eta, \omega, \eta', \gamma, K^0, \ldots)\) detected through all \(\gamma\) decays.
  ➢ forward di-jet surrogates \((\pi^0-\pi^0)\) probes gluons with smallest Bjorken-\(x\) in Au nucleus
  ➢ di-jets with large rapidity interval (Mueller-Navelet jets)

• disentangling dynamical origins of large \(x_F\) analyzing power in \(p\uparrow+p\) collisions.
• longitudinal spin asymmetries for \(\pi^0-\pi^0\) and \(\gamma-\pi^0\) rapidity correlations

FMS is a 2m×2m EM calorimeter built from existing lead-glass cells to replace the FPD west of STAR.
• built from existing lead glass cells from IHEP, Protvino and FNAL

• $0.8M proposal by Penn State University to FY05 NSF-MRI solicitation for high voltage, readout electronics and mechanical realization in January, 2005.

• planned implementation in STAR by October, 2006
Physics, status and timeline

- The study of heavy flavors and W production: Upgrade of the STAR inner/forward tracking system
- Simulation work and design of detector layout based on silicon and triple-GEM technology (On-going R&D and prototyping effort) started
- Integrated tracking design of a new inner and forward STAR tracking system mandatory
- Staging of tracking upgrade in accordance with readiness of detector technology and beam development:

Possible scenario:
- Stage 1: Installation of STAR Micro-Vertex Detector together with a minimal new barrel tracking detector based on silicon technology (-1 < \( \eta \) < 1) (Heavy Flavor Physics)
  - Proposal APS Heavy Flavor Tracker early CY05
  - Proposal Barrel after FY05 run
  - Installation of new inner tracking system by summer 2008 (FY09 run)
- Stage 2: Upgrade of the forward tracking system (1 < \( \eta \) < 2) (W physics)
  - Proposal after FY06 run
  - Installation of forward system by summer 2009 (FY10 run)

- Dedicated time for machine development with polarized protons to achieve high luminosity and high polarization is vital for the success of this novel program!
STAR tracking upgrade: Conceptual layout

- Solidworks design

- Forward silicon tracker
- APS pixel detector
- Barrel silicon tracker
- Triple-GEM tracker
Comments on STAR tracking upgrade

- STAR tracking upgrade in RHIC SPIN document:
  - Not yet a full DOE proposal!
  - Plans and work in progress!

- Relation to other DOE proposals:
  - ToF
  - APS Heavy Flavor Tracker
  - DAQ upgrade

- Communication to DOE Nuclear Physics:

- Funding profile and sources:
**STAR tracking upgrade - Heavy flavor production**

**STAR RHIC-SPIN program**

- Comprehensive study of the spin structure and dynamics of the proton, in particular the nature of the proton sea, using polarized protons: "RHIC SPIN Baseline program" (DOE review, June 2004)
  - Gluon contribution to the proton spin using various probes involving:
    - Final-state jets such as inclusive jet production and di-jet production (Short-term)
    - Inclusive $\pi^0$ production (Short-term)
    - Prompt photon production (Long-term)
    - Heavy-Flavor production (Long-term)
  - Flavor decomposition of quark and anti-quark polarization in $W$ production (Long-term)

**Heavy flavor production**

- Unique test of partonic $a_{LL}$
- Sensitive to gluon helicity with low background from quark helicities
- NLO formalism available (Bojak and Stratmann)

$$A_{LL} = \frac{(\sigma_{++} + \sigma_{--}) - (\sigma_{+-} + \sigma_{-+})}{(\sigma_{++} + \sigma_{--}) + (\sigma_{+-} + \sigma_{-+})}$$
**STAR tracking upgrade - W production**

- **Flavor decomposition of quark and anti-quark polarization**
  - Semi-inclusive DIS - sensitivity reduced by fragmentation functions and $e_q^2$ weighting

- **W± production in pp collisions forms the best means to probe the flavor structure of the proton sea**

  \[ \Delta d + \bar{u} \rightarrow W^- \]
  \[ \Delta \bar{u} + d \rightarrow W^- \]
  \[ \Delta \bar{d} + u \rightarrow W^+ \]
  \[ \Delta u + \bar{d} \rightarrow W^+ \]

- **Parity violating single-spin asymmetries at RHIC provide access to the quark flavor structure of the proton spin:**

  \[ A_{L}^{PV(W^+)}(\bar{p}p) \rightarrow \Delta u/u \]
  \[ A_{L}^{PV(W^-)}(p\bar{p}) \rightarrow \Delta \bar{d}/\bar{d} \]

  \[ A_{L}^{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} \]

  \[ A_{L}^{PV(W^+)}(\bar{p}p) \rightarrow \Delta u/u \]
  \[ A_{L}^{PV(W^-)}(p\bar{p}) \rightarrow \Delta \bar{d}/\bar{d} \]
STAR tracking upgrade - Forward tracking

- Simulated forward $p_T$ resolution ($1 < \eta < 2$)
- Forward $p_T$ reconstruction: $\pi^-$
  - True $p_T = 30$ GeV
  - Range in $\eta$: $1 < \eta < 2$

- Reconstructed $p_T$ for various detector configurations:

- Simulated fast tracking configuration:
  - Inner (fast) configuration: 3 silicon layers
  - Outer (fast) configuration: 2 triple GEM layers

N. Smirnov (Yale)

Integrated tracking approach of pixel upgrade and inner silicon upgrade in combination with forward GEM tracker!
Goal of STAR tracking upgrade working group:

- Work out the case for a proposal towards an upgrade of the STAR inner (-1<\(\eta\)<1) and forward (1<\(\eta\)<2) tracking system which is required for the study of heavy flavor (AuAu/pp) and W production (pp)
  - W physics case: Flavor decomposition of quark/anti-quark polarization
  - Heavy flavor spin case (Strong dependence of partonic asymmetry on heavy quark mass- study of heavy flavor tagged jets): STAR Heavy flavor program driven by STAR's relativistic heavy-ion program
  - Integrated tracking design of a new inner and forward STAR tracking system is mandatory
  - Staging of tracking upgrade in accordance with readiness of detector technology and beam development

- Set-up of simulation tools, physics simulation studies and R&D work on triple-GEM technology has been started

- Participation so far from: ANL, BNL, IUCF, LBL, MIT, Yale, Zagreb,...
  - Graduate students/Postdocs: 3
  - Staff physicists/faculty: 15
  - Engineers/technicians: 2

- Convenors: Ernst Sichtermann (LBL) and B.S. (MIT)

- Steering committee: G. v. Nieuwenhuizen (MIT), N. Smirnov (Yale), S. Vigdor (IUCF), H. Wieman (LBL)
Remarks on the physics case (1)

- AuAu heavy-flavor physics drives the STAR inner tracking upgrade
  - Pixel detector proposal which requires a new pointing device (STAR SVT review)
  - Potential heavy flavor spin physics case (gluon polarization) in polarized pp collisions
  - Requirements:
    - Secondary vertex reconstruction capabilities for central region (-1 < \( \eta \) < 1) in combination with the APS Heavy Flavor Tracker
    - Intrinsically fast detector / readout system
    - To be defined: Number of silicon barrel layers at what radius? Resolution? Readout speed? Occupancy?
Remarks on the physics case (2)

- Study of flavor decomposition drives an upgrade of the STAR forward tracking system
  - Endcap calorimeter in combination with a new proposal towards a forward tracking system
  - Complication in STAR with TPC: Tracking/Charge discrimination for high energy leptons break down in the forward direction
  - Welcome ideas for use in Heavy Ion running,
  - Requirements:
    - $e^-/e^+$ charge sign discrimination in forward direction ($1 < \eta < 2$) (Sagitta $\sim$2.5mm for high $p_T$ $\sim$30GeV tracks)
    - Intrinsically fast detector / readout system
    - To be defined: Number of silicon disks and location? Resolution? Impact of dead material in front of EEMC

- For both upgrades: Integrated mechanical design: **Integrated Tracking Upgrade**
General considerations

- Start from the beginning with an integrated tracking design approach which is based on:
  - Integrated mechanical design for the APS Heavy Flavor Tracker, barrel layers and forward disks
  - Design which is reflected by many silicon based inner tracking systems at collider detectors such as: CDF/DO (Tevatron), ZEUS/H1 (HERA) and ATLAS/CMS (LHC)
  - First setup: APS Heavy Flavor Tracker and minimal barrel system
  - Flexibility to upgrade inner-forward system and inner-barrel system at a later stage
  - Assumption: TPC stays as such, FTPC is phased out and DAQ/FEE upgrade is completed

- Rely as much as possible on existing well established technology:
  - Detector technology (Conservative choice: Conventional silicon strip and triple-GEM technology)
  - Readout systems (APV25-S1)

- Report towards a full proposal to document the conceptual layout of an integrated tracker for STAR under preparation:
  - Physics motivation
  - Conceptual layout and technical realization
  - Timeline and Manpower
  - Infrastructure
  - Cost estimate

- Profit from potential resources at existing STAR institutions in terms of man-power and infra-structure
STAR tracking upgrade: Simulation status

- **Overall status of simulation**

  - **Fast simulation**
    - PYTHIA input
    - Poor man’s “geant”
    - Study detector number, placement, resolution, etc.

  - **Develop basic track reconstruction tools:**
    - “standard” helix fit
    - First application of standard helix fit to W decay electrons
    - Full simulations (W+background)
    - Heavy flavor

  - **Import design in GSTAR, ITTF:**
    - Full GEANT3 model (barrel/forward disks)
    - Strip simulator
    - Detector geometry in ITTF (New STAR track reconstruction)
    - ITTF tracking in barrel region (Au-Au simulations)
    - GEM tracker in GSTAR
    - Forward ITTF tracking
STAR tracking upgrade: Simulation status

- Fast simulator setup (Y-Z view)
Status of triple GEM R&D effort

- Design of at least three triple-GEM chambers to be installed and tested at STAR under beam conditions:
  - Profit from experience by COMPASS with triple-GEM technology (fast, precise)
  - Establish collaboration to a US company to develop and manufacture GEM foils
  - Manufacture 2D-readout structures
  - Design of readout system using existing chip: APV25-S1

- R&D team:
  - Collaboration between STAR/PHENIX: ANL, BNL, MIT, Yale

- Tech-Etch Inc. (Plymouth, MA):
  - TechEtch is capable of producing GEM foils
  - First results are encouraging in terms of overall gain values achieved
  - SBIR proposal to DOE from TechEtch in collaboration with R&D team: Submitted December 10, 2004

APV25-S1 chip
STAR tracking upgrade: R&D status

- Triple-GEM prototype chamber

- 2D-readoutboard: Under preparation at Compunetics Inc.
- Hybrid: Available
- DAQ system: Under preparation
- Chamber mechanics: Under preparation
Cost estimate for STAR Barrel and Endcap Trackers

- Preliminary cost breakdown (Stage 1: barrel / Stage 2: endcap tracker)

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